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Combustion synthesis: Towards novel nanomaterials

Andrzej Huczko1,3, Agnieszka Dąbrowska1, Michał Bystrzejewski1, Łukasz Dobrzycki1, Michał Fronczak2, Anar Mukhametzhanova3, Santosh Tiwari1, Manoj Pandey1, Rabisharan Bogati2, Bhim Kafle1, Deepak Prasad Subedi5

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Abstract: The combustion synthesis (CS) is an autogenous and strongly exothermic chemical reaction in a powdered mixture of a strong reducer and oxidizer. Such processes, due to short duration and fast quench, can be a source of novel nanomaterials. Here we present (i) the CS synthesis of SiCN nanowires (SiCNWs) and (ii) the magnesiothermic reduction of the asbestos waste. The resulting raw and purified products were analyzed with different chemical and physicochemical techniques (XRD, SEM, TGA and Raman spectroscopy) to verify its composition and morphology.

Keywords: COMBUSTION SYNTHESIS, MAGNESIOTHERMIC REDUCTION, SiC NANOWIRES, GRAPHENE, NANOSTRUCTURES, WASTE

1. Introduction

The bottom-up approach of the synthesis of nanomaterials involves the generation of building blocks (ions, atoms, radicals, molecules) via the thermal or plasma activation of starting reactants. Here we propose the combustion synthesis (CS) which is an autogenous and strongly exothermic redox reaction between oxidizer and reducing agents and has been well known and explored for many years now [1]. For example, the thermite reaction has been widely used for connecting rails, in military applications and for many years now [1]. For example, the thermite reaction has been widely used for connecting rails, in military applications and for many years now [1]. The CS is here an adaptation of a simple and easier synthesis option that negative electrode used in asbestos waste can produce fine silica with some specific surface properties this due to the high temperature and fast quench of the combustion synthesis. The resulting raw and purified products were analyzed with XRD, SEM, EDS, TGA and Raman spectroscopy to verify its composition and morphology.

2. Experimental

Table 1 presents the operational parameters of all runs. The silicon reduction of fluorinated graphite was aimed not only at the production of SiCNWs but it was also expected that the defluorination of CF$_2$ can lead towards the formation of graphene-like carbon nanostructures. The magnesiothermic reduction of asbestos waste can produce fine silica with some specific surface properties this due to the high temperature and fast quench of the combustion products. The resulting raw and purified products were analyzed with XRD, SEM, EDS, TGA and Raman spectroscopy to verify its composition and morphology.

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Starting reactants</th>
<th>Mass of starting reactants, g</th>
<th>Combustion atmosphere</th>
<th>Starting pressure, MPa</th>
<th>Peak pressure, MPa</th>
<th>Mass of raw products, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1</td>
<td>Si + CF$_2$</td>
<td>4.71</td>
<td>Air</td>
<td>0.1</td>
<td>2.8</td>
<td>3.26</td>
</tr>
<tr>
<td>I-2</td>
<td>Si + CF$_2$</td>
<td>6.63</td>
<td>Air</td>
<td>1.0</td>
<td>7.0</td>
<td>4.53</td>
</tr>
<tr>
<td>II-1</td>
<td>Mg + asbestos waste</td>
<td>6.70</td>
<td>Argon</td>
<td>0.1</td>
<td>0.4</td>
<td>6.34</td>
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<tr>
<td>II-2</td>
<td>Mg + asbestos waste</td>
<td>5.48</td>
<td>Argon</td>
<td>1.0</td>
<td>1.4</td>
<td>5.28</td>
</tr>
<tr>
<td>II-3</td>
<td>Mg + asbestos waste</td>
<td>5.35</td>
<td>Argon</td>
<td>0.1</td>
<td>1.2</td>
<td>5.32</td>
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<tr>
<td>II-4</td>
<td>Mg + asbestos waste</td>
<td>5.46</td>
<td>Argon</td>
<td>1.0</td>
<td>1.8</td>
<td>5.42</td>
</tr>
</tbody>
</table>
3. Results and Discussion

The exothermal combustion is accompanied by the strong emission of heat and light. The latter one can be a useful source of information about the nature of the reaction and its time. Thus, the Light Signal Diagnostics (LSD) protocol was developed, which enabled the on-line measurement of the reaction duration and characteristics, especially the detailed monitoring of the propagation of the combustion wave and its front. Fig. 1 presents few examples of such results for the selected combustions which confirm the short reaction duration (within ca 1 second) and its susceptibility to even the minor changes in initial operational parameters (such as the pressure and type of gaseous atmosphere). One may also follow the complex time signal trajectory with its oscillations and local combustion wave maxima. They correspond to the kinetics of the process. The light characteristics is reproducible within the same operational conditions. Thus, it can be treated as a reactions fingerprint.

Fig. 1. The in situ mapping of combustion synthesis for different run; A: run II-4; B: run II-3; C: run I-2; D: run II-1

As one can see, the combustion in the Si/CF$_x$ is much more vigorous regarding the emission of a light and heat. Different mixtures of reactants may lead to the designed nanomaterials (Fig. 2). The versatility is a crucial advantage of the combustion synthesis. On the other hand, LSD enables its precise diagnostics and facilitates the optimization.

The morphology of raw products is quite different comparing to the starting mixture (Fig. 2). The raw product from combustions in the Si/CF$_x$ systems is amazingly voluminous this due to the high amount of 1D SiC nanostructures.

Fig. 2. Reactants before combustion (left) and raw reaction products (right) from runs; a: run II-4; b: run I-2

3.1. Synthesis of silicon carbide nanowires (SiCNWs)

The silicon reduction of the fluorinatated graphite CF$_x$ (x = 0.89) in air atmosphere follows the general equation

$$\text{Si} + \text{CF}_x = \text{SiC} + \text{C} + \text{SiO}_2 + \uparrow\text{SiF}_4 + \uparrow\text{C}_x\text{F}_y$$

We showed earlier [12] that the reaction of silicon with halogenated carbons (like TEFLON®) proceeds more efficiently under the presence of oxygen this due to vigorous gas phase mass transport of silicon via gaseous SiO molecules. It was expected that the application of the fluorinatated graphite as an oxidizer could enable not only the growth of SiCNWs but also the formation of layered graphene-like carbon nanostructures resulting from the silicon extraction of fluorine from layered graphite matrix. To isolate the SiCNWs, the un-reacted Si and silica were leached with boiled 30% KOH why the residual carbon was removed via air oxidation at 600 °C in the following step. The combustion was accompanied by a strong pressure increase (Table 1) due to the high temperature and formation of gaseous side products (SiF$_4$ + C$_x$F$_y$). The latter one is confirmed by a substantial mass decrease of solid reactants (Table 1). The content of un-reacted Si in a raw product (from wet chemistry analyses) for runs I-1 and I-2 was equal to 5.4 and 3.6 wt%, respectively. Thus, the total conversion of starting silicon was very high, 93.0 % and 95.6 % for runs I-1 and I-2, respectively.

Fig. 3 presents the SEM images of the starting mixture (runs I-1 and I-2) composed of several micron-sized Si crystallites (Fig. 3A) and layered CF$_x$ (Fig. 3B).

Fig. 3. SEM images of starting mixture (runs I-1 and I-2)

The morphology of the raw product (Fig. 4) does not depend on the starting pressure. The raw product is a non-homogeneous mixture of different nanosized species including SiCNWs, nanoballs (200-400 nm) of SiO$_2$, spherical (well below 100 nm) soot particles and microcrystallites of SiC.

Fig. 4. SEM images of raw product

The purified product (Fig. 5) is composed essentially of SiC nanowires (well below 100 nm) with some SiC cubic microcrystallites.

Fig. 5. SEM images of purified product
To confirm the purity of the product the EDS analysis was carried out (Fig. 6) which confirmed the stoichiometry of the formed SiC. The results (Table 2) confirm the content of SiC in a purified product above 90 at.%.

Table 3. EDS analysis of the purified product

<table>
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<tr>
<td></td>
<td>[wt.%]</td>
</tr>
<tr>
<td>Carbon</td>
<td>K-series</td>
</tr>
<tr>
<td>Oxygen</td>
<td>K-series</td>
</tr>
<tr>
<td>Silicon</td>
<td>K-series</td>
</tr>
<tr>
<td>Fluorine</td>
<td>K-series</td>
</tr>
<tr>
<td>Magnesium</td>
<td>K-series</td>
</tr>
<tr>
<td>Iron</td>
<td>K-series</td>
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</table>

Total: 94.12  100.00  100.00

TGA analysis (Fig. 7) confirmed that conclusion. The purified SiCNWs contain less that 5 wt% of carbon which removal from the final product occurs between 500 and 600 °C.

Fig. 8 presents XRD spectra of the reactants. The starting mixture (Fig. 8a) is composed of crystalline Si elemental (with some residual Ge presence)) while the CF$_x$ phase seems to be amorphous. The raw product (run I-2, Fig. 8b) contains mostly SiC with some un-reacted silicon while the carbon is evidently in an amorphous form. The purified product (Fig. 8c) is dominated by SiC reflexes.

The results showed that pure SiC nanowires can be efficiently produced via the silicon reduction of the fluorininated graphite. The observations of the product did not reveal, however, the presence of layered carbon nanostructures. Thus, it seems that the extremely strong thermal effect of combustion totally atomizes the carbon (forming the hexagonal network in starting CF$_x$) which later condenses as amorphous soot.

3.2. Magnesiothermic reduction of asbestos waste

The magnesiothermic processing of asbestos waste [13] with Mg as a reducing agent follows here the general scheme

\[
\text{Mg} + \text{MgO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O} = \text{MgO} + \text{Mg} + \text{Si} + \text{SiO}_2 + \text{H}_2\text{O}
\]

Ma et al. [14] earlier produced porous silicon by magnesiothermic reduction of serpentine mineral. It was expected here that the final product, after chemical purification (acid leaching), would contain mostly fine silica (along with Si elemental) with some specific surface properties. As a matter of fact, silica-based amine-grafted sorbents exercised high amine efficiency for CO$_2$ capture, leading to a record-high CO$_2$ capacity of ~12 mmol g$^{-1}$ under simulated flue gas conditions [15].

Fig. 9 presents the micrograph of starting asbestos waste which reveals its particle size well below 5 µm and heterogeneous morphology.
Fig. 9. Micrograph of asbestos waste

The combustions were carried out with a two-fold excess of Mg (runs II-1 and II-2) and with a stoichiometric amount of a reducer (runs II-3 and II-4) – Table 1. The mass of the collected raw product did not differ substantially from the starting mass and the pressure increase was quite moderate this all showing that we dealt entirely with the solid-phase reaction. Fig. 10 presents the SEM images of the starting reactants (runs II-3 and II-4), composed of heterogeneous mixture of Mg particles and waste microcrystallites with some residual asbestos fibers.

Fig. 10. SEM images of starting mixture (runs II-3 and II-4)

The raw product (Fig. 11) has a quite different morphology. There are only very few of asbestos fibers and the material is dominated by cubic nanocrystallites of MgO.

Fig. 11. SEM images of raw product (runs II-3 and II-4)

The porous material (in a purified product) is mostly composed of the elemental Si with some residual silica – Table 3.

To identify its identity the EDS analysis was carried out (Fig. 13).

Table 3. EDS analysis of the purified product

<table>
<thead>
<tr>
<th>Element</th>
<th>Series</th>
<th>unn. C</th>
<th>norm. C</th>
<th>Atom. C</th>
<th>Error (1 Sigma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>K-series</td>
<td>16.59</td>
<td>17.84</td>
<td>27.83</td>
<td>2.43</td>
</tr>
<tr>
<td>Silicon</td>
<td>K-series</td>
<td>74.18</td>
<td>79.74</td>
<td>70.89</td>
<td>3.11</td>
</tr>
<tr>
<td>Iron</td>
<td>K-series</td>
<td>1.87</td>
<td>2.01</td>
<td>0.90</td>
<td>0.13</td>
</tr>
<tr>
<td>Aluminium</td>
<td>K-series</td>
<td>0.38</td>
<td>0.41</td>
<td>0.38</td>
<td>0.05</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>93.03</td>
<td>100.00</td>
<td>100.00</td>
<td>0.00</td>
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The XRD spectra of reactants are shown in Fig. 14. The starting mixture (run II-4, Fig. 14a) is dominated by Mg elemental with the waste mineral phase (here denoted as a serpentine). The raw product (run II-4, Fig. 14b) contains mostly MgO with some unreacted magnesium and serpentine, along with other side products. Surprisingly, the purified product (Fig. 14c) is dominated by the elemental silicon (instead of the expected silica) with some iron silicide and silicon carbide (formed from a residual carbon). That result proves that the sought reaction proceeded much deeply and resulted in a magnesiothermic reduction of silica.

Fig. 12. SEM images of purified product (run II-3 and II-4)

Fig. 13. EDS analysis of purified product (run II-4)
The adsorption performance of both raw and purified products was analyzed in the process of 4-chlorophenol removal from aqueous solution. The adsorption of raw product (runs II-3 and II-4) was negligible due to the basicity of the surface. However, the surface of the purified products (after leaching with HCl) does not exhibit basic properties. In these cases the adsorption of 4-chlorophenol was detectable and measurable. However, the highest obtained values of the adsorption capacity were not high, namely 12 mg/g and 18 mg/g for run II-3 and II-4, respectively. The obtained adsorption isotherms (Fig. 15) are typical for S1 isotherms in Giles’ classification [16] or for the III type in the IUPAC classification [17]. Both correspond to the weak attraction between solute molecules and the surface of the adsorbent.

4. Conclusions

Combustion synthesis was used to produce SiC nanowires and to reduce the asbestos waste. The silicon defluorination of fluorinated graphite yields 95% pure SiCNWs. However, the residual carbon did not form 2D nanostructures, as expected, but condensed as a soot. The asbestos waste, containing mostly silicon-related compounds, was deeply reduced with Mg elemental, but contrary to expectations, the purified product contained almost 50% of elemental Si along with some residual fine silica.

5. References

Improving the Linearized stresses resistance by Nano-Coating, Part-2

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Abstract: The part-2 research is a continuation of part-1 of using a simulation of Nano coating effect on linearized stresses resistance using Finite Element Analysis (FEA) software was carried out. The prime focus here was on exposing a thin Aluminum (Al7075-T6) walled spherical vessel to internal pressure before and after coating, this spherical vessel was coated by Nano-layer using two different materials such as Titanium (Ti) and Nickel (Ni) with thicknesses ranging (100 nm, 500 nm, and 900 nm). Then a comparison of the obtained results was made before and after coating. The results showed that the aluminum Al7075-T6 thin walled spherical vessel successfully coated with Titanium and Nickel separately using ANSYS software. In addition, the results have shown that 100,500 and 900 nm thickness Nickel coated aluminum 7075-T6 thin walled spherical vessel has a better improvement in linearized stresses resistance. These improvements in linearized stresses resistance were equal to 42% with Nickel coating in comparison with Titanium coating of thickness (100, 500 Ind 900 nm). The improvement of the linearized stress highest resistance is about 2.5% and 5% for Ti and Ni, respectively.

KEYWORDS: MECHANICAL PROPERTIES, NANO, COATING, Ti, Ni, AND AL 70705-T6

Background:

Nanotechnology is a nascent, vibrant, and burgeoning scientific discipline that is predicted to have important implications for an extraordinarily broad array of applications encompassing almost every industrial sector. It is surmised that virtually no facet of the industry will be left uninfluenced by its seemingly ubiquitous reach. Nanotechnology is defined as the capacity for the controllable manipulation of matter at the molecular and atomic levels, typically from 1 nm to 100 nm. It allows for and encompasses the fundamental ability to synthesize novel materials and to create devices that exhibit extraordinary properties with enhanced functionality. One compelling driver of this technology lies in the premise that matter behaves in radically different ways for nano scale materials in contrast to their bulk material counterparts. Nano scale materials can possess innumerable components that are endowed with exponentially greater surface areas, which are critical in many industrial processes. Nano materials or Nano scale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. A nanometer is one millionth of a millimeter - approximately 100,000 times smaller than the diameter of a human hair as shown in figure-1. Nano materials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields. (A. Alagarasi, 2011). Nano coatings have the potential for enhancing the performance and durability of an extensive array of manufacturing processes, in addition to improving the items that they produce. They may thus enable significant energy savings to be realized across just about every market sector. Nano coating imparts multifunctional attributes to many everyday consumer and industrial products.

Figure 1: Nano-material (National Center for Electron Microscopy, Lawrence Berkeley Lab./ U.S. Department of Energy)

Nanotechnology: Richard Feynman gave flight to the concept of nanotechnology via his 1959 introductory lecture “There’s Plenty of Room at the Bottom.” Stied in 1986 K. Eric Drexler’s book Engines of Creation articulated the promise of this new science in the diverse range of future scenarios. An important development that transitioned many “Nano visions” into tangible reality was the development of Scanning Tunneling Microscopy (1981) and Atomic Force Microscopy (1986). These instruments enabled imaging at a Nano metric resolution and the manipulation of individual atoms. (Boehm, Frank. 2010) Nanotechnology is a newly emerging branch of technology, which incur high expectations of its possibility to change the world fundamentally. Some policymakers and technology developers even speak about “the Next Industrial Revolution”, which advancing nanotechnology is supposed to bring along (Schummer, 2004). Others argue that nanotechnology is just a new label put on research projects in conventional fields of science – such as chemistry, physics, biomedical engineering, materials science and electrical engineering to gain more research funding. However, there have been also efforts to define various terms in the field of nanotechnology, and thus build a common understanding about the issue.

Research objectives: The main objective of this work is: The main objective in prat-2 is to study and analyze the linearized stresses improvement when using a Nano coating of Al 7075-T6 by Titanium and Nickel Nano-particles separately of thickness of 100, 500 and 900 nm.

Research methodology:

In this work, a simulation of the Nano coating effect on mechanical properties for optimizing its performance using FEA software carried out. The prime focus here was on exposing a thin walled spherical vessel made of Aluminum (Al7075-T6) under internal pressure before and after coating with Nano coated materials such as Titanium (Ti) and Nickel (Ni) with different thicknesses. A comparison of the results before and after coating will be made. In the same fashion prepared electro-deposition of composite coatings containing Nano particles in a metal matrix. It was showed that the inclusion of Nano sized particles can give rise to increased micro hardness and corrosion resistance and modified growth to form a Nano crystalline metal deposit and shifted reduction potential of a metal ion. (Low et al, 2006). The above observations motivated the present investigation, where an attempt will be made to develop and characterize the mechanical, chemical properties, micro structural and compositional features of the coating in present work.
Materials:
Materials are probably more deep-seated in our culture than most of us realize. Transportation, housing, clothing, communication, recreation, and food production virtually every segment of our everyday lives is influenced to one degree or another by materials. Historically, the development and advancement of societies have been intimately tied to the members’ ability to produce and manipulate materials to fill their needs. In fact, early civilizations have been designated by the level of their materials development (Stone Age, Bronze Age, and Iron Age). (William D. Callister, Jr, 2006)

Aluminum:
The excellent combination of lightweight, high strength, high corrosion resistance, and the acceptable cost has made aluminum and its alloys one of the most commonly used metal groups (Kaufman, J. Gilbert, 2000). In many of automobile and aerospace industries applications, aluminum and its alloys are widely used in these applications (Dileep, B.P., Kumar, V.R., Prashanth, M. and Phanibhushana, M.V., 2014). Al 7075-T6 aluminum alloy (tables-1 and 2) is an aluminum alloy, 7xxx: series alloys have zinc as their main alloying element, 5.6 – aluminum alloy (tables-1 and 2) is an aluminum alloy, 7xxx: series alloys have zinc as their main alloying element, 5.6 –

Titanium:
Titanium is one of the most commonly used metal groups. (Kaufman, J. Gilbert, 2000). T: thermally treated to make stable tempers. T6: solution treated, and then artificially aged (Kaufman, J. Gilbert, 2000). It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability. (Lütjering, G. and Williams, J.C., 2007.)

Table-3: Some important characteristics of Titanium and Titanium based alloys as compared to other structural metallic materials based on Fe, Ni, and Al. (Lütjering. G. and Williams, J.C., 2007).

<table>
<thead>
<tr>
<th>Component</th>
<th>Ti</th>
<th>Fe</th>
<th>Ni</th>
<th>Al</th>
</tr>
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<tbody>
<tr>
<td>Melting Temperature (°C)</td>
<td>1670</td>
<td>1538</td>
<td>1455</td>
<td>660</td>
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<tr>
<td>Room Temperature E (GPa)</td>
<td>115</td>
<td>215</td>
<td>200</td>
<td>72</td>
</tr>
<tr>
<td>Yield Stress Level (MPa)</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Density (g/cm3)</td>
<td>4.5</td>
<td>7.9</td>
<td>8.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Comparative Corrosion Resistance</td>
<td>Very High</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Comparative Reactivity with Oxygen</td>
<td>Very High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Comparative Price of Metal</td>
<td>Very High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Nickel: Nickel is probably the most versatile of the metallic elements. Among alloys containing Nickel are some having high corrosion resistance and others that retain excellent strength and ductility from temperatures approaching absolute zero to those near 2000 F. Some Nickel alloys are strongly magnetic, others are virtually nonmagnetic; some have low rates of thermal expansion, others have high rates; some have high electrical resistivity; some have practically constant module of elasticity; one has an “elastic” memory. In addition, Nickel is Magnetostriuctive. (Everhart, J. ed., 2012). The element Nickel is a member of the transition group in the fourth series of the periodic table, which include iron, Nickel, and cobalt. It has the atomic number 28. (Everhart, J. ed., 2012).

Table-4: Physical Properties of Nickel. (Everhart, J. ed., 2012)

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<tr>
<th>Data points</th>
<th>Physical Properties</th>
<th>Commercial Nickel (99.5% nom)</th>
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</thead>
<tbody>
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<td></td>
<td>High purity&quot; Nickel (99.97% min)</td>
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<tr>
<td>Density</td>
<td>2.81 g/cc</td>
<td>Commercial Nickel (99.5%)</td>
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<td>Boiling point, °C</td>
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<td>Vapor pressure (at Melting point), bar</td>
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<td>----</td>
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<td>Specific heat (294.3 K), J/(kg K)</td>
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<td>456.3612</td>
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<td>Thermal conductivity (298.15 K) W/(m K)</td>
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<td>45.7</td>
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<td>Coefficient of thermal expansion (10-6/m K)</td>
<td>13 x 10-6</td>
<td>12.3 X 10-6</td>
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<tr>
<td>Electrical resistivity, Micro-ohm-cm</td>
<td>7.16</td>
<td>9.5</td>
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<tr>
<td>Temperature coefficient of resistance (68-212 F), Micro-ohm-cm/F</td>
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<td>Modulus of rigidity, GPa</td>
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<td>Density, g/cm3</td>
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Pressure Vessel:
Pressure vessel is a tank contains pressures, either internal or external. This pressure may be obtained from an external source, or by the application of heat from a direct or indirect source, or any combination thereof. (Boiler, ASME and Code, P.V.1989).
Spherical shells as structural parts are used extensively in many applications, like nuclear, offshore, fossil oil and transport, because they can be subjected to variable loading conditions like external pressures or internal or both (V. Prasad and B. Praveen Kumar, 2017) for the following advantages:

1. The stress resistance considered to be uniform
2. The distribution of pressure is uniform upon the tank storage.
3. Sphere contains more volume for the surface area.
4. Also metal thickness is sometimes about half as much as a cylinder of the same diameter for the same pressure rating.
5. The stresses and strains are spreading more uniformly.
6. The cost of the wall thickness of a spherical shell will be about half the wall thickness needed for a cylindrical shell for holding in the same pressure. So, in a spherical container use a thinner shell which means lesser cost and weight.
7. Area to volume ratio is the area that a sphere occupies will be lesser compared to a cylindrical container of the same volume.

But in spite of the above advantages spherical pressure vessels are more expensive than cylindrical pressure vessels to fabricate, and this higher price is only justifiable for large vessels.

**Theoretical Background:**

The proposed work as a comparison of the performance analysis of mechanical properties of Nano coated and uncoated for the Al7075-T6 alloy. The work will be intend to enhance the mechanical properties, life time, ability of carrying high stress and the resistance to deformation of aluminum alloy AL 7075-T6. The finite element analysis (FEA) will perform on thin walled spherical pressure vessels geometry under internal pressure compared with the uncoated and coated with Nano thicknesses of Titanium and Nickel separately by using surface coating function in ANSYS software (Products Release 19.0).

**Geometric modeling of the case study:**

One finite element model is created, it is a thin walled spherical pressure vessel coated with different Nano thickness of Titanium and Nickel separately. As seen in figures (2 to 5).

Stress analysis in the thin-walled spherical pressure vessel:

Theoretically, spherical shape it is the ideal shape for a vessel that resists internal pressure. To derive the stresses in a spherical vessel, a cut through the sphere on a vertical diametric plane as in Fig. 6a and isolate half of the shell and its fluid contents as a single free body (Fig. 6b), was made acting on this free body is the tensile stresses σ in the wall of the vessel and the fluid pressure $p$. This pressure acts horizontally against the plane circular area of fluid remaining inside the hemisphere. Since the pressure is uniform, the resultant pressure force $P$ as in Fig. 6b (Gere and Goodno, 2008)

$$P = p \pi r^2$$

Where, $r$: is the inner radius of the sphere, $p$: net internal pressure, or the gage pressure. Because of the symmetry of the vessel and its loading (Fig. 6b), the tensile stress $\sigma$ is uniform around the circumference. Moreover, since the wall is thin, an assumption with good accuracy may be used in which the stress is uniformly distributed across the thickness $t$. The accuracy of this approximation rise as the shell becomes thinner and lowers as it becomes thicker. The resultant of the tensile stresses $\sigma$ in the wall is a horizontal force equal to the stress $\sigma$ times the area over which it acts, or

$$\sigma (2\pi r t)$$

Where: $H8 = 0.03 \text{ m}$, $H9 = 0.039 \text{ m}$, $Ri = 0.18 \text{ m}$, $Ro= 0.189 \text{ m}$, $V7= 0.07 \text{ m}$
From Hooke's law (equations: 8-13) with \( z \) the radial direction, with \( \sigma = 0 \):

\[
\begin{bmatrix}
\varepsilon_r \\
\varepsilon_z \\
\varepsilon_{rr} \\
\varepsilon_{zz}
\end{bmatrix} = \begin{bmatrix}
1/E & -\nu/E & -\nu/E & \sigma_r \\
-\nu/E & 1/E & -\nu/E & \sigma_z \\
-\nu/E & -\nu/E & 1/E & \sigma_{rr} \\
\sigma_r & \sigma_z & \sigma_{rr} & 1 - \nu
\end{bmatrix} \begin{bmatrix}
\sigma_r \\
\sigma_z \\
\sigma_{rr} \\
1 - \nu
\end{bmatrix} = \frac{1}{E} \begin{bmatrix}
1 - \nu & 0 & 0 & 0 \\
0 & 1 - \nu & 0 & 0 \\
0 & 0 & 1 - \nu & 0
\end{bmatrix} \begin{bmatrix}
\sigma_r \\
\sigma_z \\
\sigma_{rr} \\
1 - \nu
\end{bmatrix}
\]

Equations (7 to 14) are from (Kelly, P., 2013). To calculate the amount by which the vessel expands, consider a circumference at average radius \( r \) which moves out with a displacement \( \delta_r \), Fig. 8.

From the definition of normal strain:

\[
\varepsilon_r = \frac{(r + \delta_r) \Delta \theta - r \Delta \theta}{r \Delta \theta} = \frac{\delta_r}{r} \tag{15}
\]

This is the circumferential strain for points on the mid-radius. The strain at other points in the vessel can be approximated by this value.

The expansion of the sphere is thus

\[
\delta_c = r \varepsilon_c = \frac{1 - \nu}{E} \frac{r^2}{2t} \tag{16}
\]

Figure 8: Deformation in the thin-walled sphere as it expands (Kelly, P., 2013).

To determine the amount by which the circumference increases in size, consider Fig. 9, which shows the original circumference at radius \( r \) of length \( c \) increase in size by an amount \( \delta_c \). One has

\[
\delta_c = c \varepsilon_c = 2 \pi r \varepsilon_c = 2 \pi \frac{1 - \nu}{E} \frac{r^2}{2t} \tag{17}
\]

It follows from equations (16 and 17) that the circumference and radius increases are related through. (Kelly, P., 2013).

\[
\delta_c = 2 \pi \delta_r \tag{18}
\]

Figure 9: Increase in circumference length as the vessel expands (Kelly, P., 2013).

Linearized Normal Stress:

This section is a guide to how the stress linearization tool works to separate stresses into membrane and bending. Stress linearization was developed in the pressure vessel industry by Kroenke and Gordon in the 1970s. What is happening under the hood when your stress linearization utility presents results? The Linearized Stress results calculate membrane, bending, peak, and total stress along a straight line path in the Mechanical application.
Membrane stress:
Membrane stress calculates the stresses along the thickness of the shell in the longitudinal direction, in the transverse direction, and in plane shear. The result is available only for shell bodies and solids that are meshed using the thin-solid meshing option. Each element of the body can display individual stress values and give a check board appearance to the result contours. The membrane stress is usually equal to the code allowable stress for global areas and 1.5 as much for local areas. The membrane + bending stresses are required. A 5° slice of the model will represent the whole head. The slice has a split line near the weld to ensure that when meshed, the nodes at this location line up straight – the Stress Classification Line. Through-thickness elastic stress field into equivalent membrane, bending, and peak stresses for comparison with appropriate allowable limits.

- Membrane stress is the average stress through the thickness (P/A)
- Bending stress is the linearly varying stress through the thickness (Mc/I)
- Peak stress is the total stress minus the membrane plus bending

Peak stress:
A peak stress is a highly localized stress that exists at a discontinuity in the load path. An example of a peak stress is the high localized stress at the root of a thread in a bolt. (API SPEC 16R, 1997).

Results:
Figures (10-25) and tables (6-13) show the main values and improvements of the Linearized Normal Stress in X-axis.

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Figure-11: Linearized Normal Stress (X-axis) without coating

Table-5: Sample of data for Linearized Normal Stress values without coating

Figure-10: Linearized Normal Stress (X-axis) without coating

Figures (4.66, 4.68, 4.70, 4.72, 4.74, 4.76, and 4.78) show in more details and view the Linearized Normal Stress along a straight line path in a thin-walled spherical vessel.
**Figure-12:** Membrane [Pa], Membrane + Bending [Pa], total stress [Pa] without coating.

**Figure-13:** Linearized Normal Stress (X-axis) coated with 100 Nanometers of Titanium.

**Table-6:** Sample of data for Linearized Normal Stress values, coated with 100 Nanometers of Titanium.

<table>
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**Figure-14:** Membrane [Pa], Membrane + Bending [Pa], total stress [Pa], coated with 100 Nanometers of Titanium.

**Figure-15:** Linearized Normal Stress (X-axis) coated with 100 Nanometers of Nickel.

**Table-7:** Sample of data for Linearized Normal Stress values, coated with 100 Nanometers of Nickel.

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Table-8: Sample of data for Linearized Normal Stress values, coated with 500 Nanometers of Titanium.

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</table>

Figure 16: Membrane [Pa], Membrane +Bending [Pa], total stress [Pa], coated with 100 Nanometers of Nickel.

Figure 17: Linearized Normal Stress (X-axis) coated with 500 Nanometers of Titanium.

Figure 18: Membrane [Pa], Membrane +Bending [Pa], total stress [Pa], coated with 500 Nanometers of Titanium.
Figure-19: Linearized Normal Stress (X-axis) coated with 500 Nanometers of Nickel.

Table-9: Sample of data for Linearized Normal Stress values, coated with 500 Nanometers of Nickel.

<table>
<thead>
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<tbody>
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</tr>
<tr>
<td>1.875e-004</td>
<td>26066</td>
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<td>1881.2</td>
<td>9.7578e+00</td>
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<td>3.75e-004</td>
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<td>23800</td>
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<td>9.603e+005</td>
<td>-164.5</td>
<td>9.6014e+00</td>
<td>5</td>
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</tbody>
</table>

Figure-20: Membrane [Pa], Membrane +Bending [Pa], total stress [Pa], coated with 500 Nanometers of Nickel.

Table-10: Sample of data for Linearized Normal Stress values, coated with 900 Nanometers of Titanium.

<table>
<thead>
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</tr>
</thead>
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</tr>
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<td>3.75e-004</td>
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<td>23783</td>
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</tbody>
</table>
**Figure-22:** Membrane [Pa], Membrane +Bending [Pa], total stress [Pa], coated with 900 Nanometers of Titanium.

**Figure-23:** Linearized Normal Stress (X-axis) coated with 900 Nanometers of Nickel.

**Figure-24:** Membrane [Pa], Membrane +Bending [Pa], total stress [Pa], coated with 900 Nanometers of Nickel.
Table-12: Decreasing percentage in Maximum Linearized Normal Stress (X-axis).

<table>
<thead>
<tr>
<th>Titanium (Ti)</th>
<th>Nickel (Ni)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>value</td>
<td>Improvemnt %</td>
</tr>
<tr>
<td>0.0nm</td>
<td>1.00149206e6</td>
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<tr>
<td>100nm</td>
<td>9.98575125e5</td>
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<td>500nm</td>
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<td>900nm</td>
<td>9.75806737e5</td>
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</table>

Table-13: Summary of improvement percentage in different directions and planes

<table>
<thead>
<tr>
<th>Types of action</th>
<th>Improvement of Titanium (Ti) %</th>
<th>Improvement of Nickel(Ni) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 nm</td>
<td>500 nm</td>
</tr>
<tr>
<td>Total Deformati on</td>
<td>0.400</td>
<td>1.965</td>
</tr>
<tr>
<td>Normal Elastic Strain X axis</td>
<td>0.461</td>
<td>5</td>
</tr>
<tr>
<td>Normal Elastic Strain Y axis</td>
<td>0.365</td>
<td>5</td>
</tr>
<tr>
<td>Normal Stress X axis</td>
<td>0.468</td>
<td>8</td>
</tr>
<tr>
<td>Normal Stress Y axis</td>
<td>0.373</td>
<td>9</td>
</tr>
<tr>
<td>Equivalen t Stress</td>
<td>0.453</td>
<td>9</td>
</tr>
<tr>
<td>Shear</td>
<td>0.354</td>
<td>1.772</td>
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</table>

Table (4.17) show a summary for all types of stresses which calculated and their improvement percentage on this stresses after coating with Nano thicknesses of Titanium and Nickel.

Results Discussion:

Figure (25) shows the value of improvement on thin-walled spherical vessel for increasing the resistance of Linearized Normal Stress (X-axis) after coating the surface of thin-walled spherical vessel which produced from (Al 7075-T6) by different Nano thicknesses of Titanium and Nickel separately, starting coating from 100 Nanometers of (Titanium and Nickel) thicknesses, then increasing the thicknesses of coating to 500 and 900 Nanometers. The lowest value of improvement in decreasing the Linearized Normal Stress (X-axis) is (2.5%) for Titanium and the highest improvement in decreasing for Nickel (5%), between these two values the larger improvement is found in Nickel coating, improvements is about (58.3%) higher than Titanium. The improvement in linearized stress resistance done on aluminum alloy (Al 7075-T6) as a thin-walled spherical vessel, coated with different Nano thicknesses of Titanium (Ti) and Nickel (Ni) using surface coating technique in ANSYS Software, Product Release 19.0. This work began by applying internal pressure (1 bar) to a thin-walled spherical vessel made from (Al 7075-T6) without coating and finding the effects on linearized stress resistance. After which the internal pressure value was kept at (1 bar) and surfaces coating was applied in the range of (100 nm, 500 nm and 900 nm) thicknesses of a Titanium and Nickel separately. The comparison between Ni and Ti results are shown in table 13.

Conclusions:

From the results of this work, the following conclusions can draw.
- The aluminum 7075-T6 thin walled spherical vessel successfully coated theoretically by modeling with Titanium and Nickel by using ANSYS software with different Nano thicknesses of 100nm, 500nm, and 900nm respectively.
- The 900 nm Nickel coated aluminum 7075-T6 thin walled spherical vessel showed a maximum improvement in linearized stress resistance in comparison with Titanium, the percentage of these improvements were 2.5% for Titanium and 5% for Nickel as shown in figure 25.
- The highest percentage of the coated thin-walled spherical vessel by thickness 100, 500 and 900 nm of Nickel Nano-particles is equal 42% greater than Titanium coating of the thin-walled spherical vessel by 100, 500 and 900 nm of Titanium and in some cases equal about 58.3% as in table 13.
- Nickel and Titanium can help protect against corrosion and improve wear resistance, as well as increase the thickness of a surface.
- Nickel and Titanium can enhance the appearance of the spherical vessel by adding brightness.
- Against all other coating of different thicknesses. The Spherical vessel with Nickel coated exhibited the highest percentage of improvement.
References:


Chen, B. H., Hong, L., Ma, Y., & Ko, T. M. (2002). Effects of surfactants in an electro less nickel-plating bath on the properties of Ni– P alloy deposits, Industrial & engineering chemistry research, 41(11), 2668-2678


Schummer, J. (2006). ‘Societal and Ethical Implications of Nanotechnology’: Meanings, Interest Groups, and Social Dynamics. In Nanotechnology Challenges: Implications for Philosophy, Ethics and Society (pp. 413-449)


Abstract: Phenols are widely distributed in various plants and plant-derived foods. Currently, there is an increasing interest in their application as food supplements. In this study, we performed a virtual screening to identify potential molecular targets of phenolic compounds derived from medicinal plants known for their antioxidant and anticancer effects. A dataset of 75 phenols, reported in the literature and a virtual library of 7770 unique drug compounds, extracted from the DrugBank database (https://www.drugbank.ca/) were used. Multi-conformer structure databases were created using OpenEye OMEGA, shape- and chemical-based overlays of the conformers were performed in OpenEye ROCS (https://www.eyesopen.com/). As a result of the virtual screening, followed by data filtration and analysis, two bacterial enzymes, responsible for DNA replication, were suggested as potential novel targets of a plant-derived hydroxyanthraquinone. This research allows outlining the potential receptor-mediated pharmacological mechanisms of phenolic compounds and aims to be a first step in the development of in silico protocol for their prioritisation as healthy dietary supplements.

Keywords: PHENOLS, DRUGS, VIRTUAL SCREENING, TARGET IDENTIFICATION, FOOD/FEED SUPPLEMENTS

1. Introduction

Recently, the therapeutic applications of phenolic compounds found in traditional medicinal plants, foods, nutraceuticals and species have gained an increased scientific interest [1-4]. The generally accepted concept for their antioxidant activity as a mechanism driving their beneficial actions has been enriched with increasing evidence for modulation of variety of molecular targets resulted in therapeutic effects on cancer, diabetes, cardiovascular and neurological diseases [5].

In silico screening approaches have proved their efficiency at early stage identification of putative targets of phenols [6-8]. DrugBank database [9] represents a useful source of structural and experimental data in virtual screening projects. The latter includes discovery of new retinoid X receptor alpha modulators [10], as well as identification of novel inhibitors of putrescine uptake in Trypanosoma cruzi [11] and of the breast cancer resistance protein [12].

In the current study, an application of a virtual protocol for target-fishing is reported. It involves estimating the shape and chemical similarity between the structures of 75 naturally-derived phenols, reported in the literature [13] and known drugs, deposited in the DrugBank database [9].

2. Data and methods

Two datasets were used in the study, including: (i) 75 phenols and (ii) 7770 drug molecules. The first dataset is comprised of structurally diverse antioxidant compounds used in the traditional Chinese medicine for anticancer therapy [13]. It includes flavonoids, stilbenes, coumarins, curcuminoinds, lignans, quinones and phenolic acids. The information about drug structures and related molecular targets and actions were extracted from the DrugBank database, along with data on the status of the deposited medicines [9].

Preparation of the three-dimensional (3D) structures and the virtual screening were performed using programs of the OpenEye Scientific Software (https://www.eyesopen.com/). Multi-conformer structural databases were created using OMEGA v.3.1.1.2. [14], and the shape- and chemical-based overlays of the representative conformers were performed in ROCS v.3.3.1.2 [15].

3. Results and discussion

Here we present the application of a protocol for target identification in three main steps: (1) similarity-based searching of chemical structures; (2) ranking and filtration of the output data based on the obtained shape and chemical similarity scores; and (3) data curation by visual analysis of the overlays of phenols and DrugBank hits.

Step 1: At this step the flexibility of the molecules was taken into account by conformer generation in OMEGA, while the conformers’ alignment was performed and ranked using the ROCS TanimotoCombo score (ranging from 0 to 2). The latter includes a cumulative estimation of both the shape overlap of the conformers in the space plus the spatial alignment of chemically similar functional groups (e.g. hydrogen bond donor, hydrogen bond acceptor, cationic, anionic, hydrophobic and ring). As a result, 75 databases, one per each query phenolic structure, were generated. Each database was comprised of 500 top-scored paired overlays of phenolic and drug conformer, the latter designated as a hit.

Step 2: The highly scored hits were further filtered based on the drug status reported in the DrugBank database. Drug hits with status “withdrawn” were not included in the final set. By excluding drugs with status “investigational” or “experimental” the focus was placed only on hits with full documentation regarding the mechanism of action and the molecular target. Thus, only approved drugs with indication for oral administration were selected.

At this stage, a major problem arose, stemming from the significant number of plant phenolic derivatives among the known therapeutics. These drugs were identical or very similar in structure with many of our query phenols, therefore an exclusion of such “hits” was necessary to enrich the output with drugs which could potentially outline some new molecular targets. This dataset filtering procedure was performed by ranking based on the aforementioned overlay estimates. In particular, only matches with TanimotoCombo scores equal to or lower than 1.5 were considered with sub-optimal estimations of shape and chemical overlaps ranging between 50 and 80%. Duplicates of phenolic compounds or drugs were cleared up in the final compound library of query-hit pairs by preserving the lower scored matches for each phenolic query and the lower scored matches for each DrugBank hit.
allowed for further data curation. Alignments based on matching of carbohydrate moieties only without alignment of aglycone substructures were considered irrelevant. Additionally, we considered a structural diversity in the query-drug pairs as a suggested prerequisite for discovery of new pharmacological targets. Thus, we selected combinations of 8 drugs with 8 phenolic compounds (Table 1), with TanimotoCombo scores ranging between 1.0 and 1.3.

The DrugBank records for the selected query-hit pairs were analysed in details. By filtering out matches with incomplete records, only pairs with full data regarding molecular actions were summarised in Table 2. The outlined drug hits have agonistic action on the human estrogen receptors, alpha-2B adrenergic receptor, gamma-aminobutyric acid receptor; antagonistic and/or inhibitory action on human sodium/glucose cotransporter 2; bacterial DNA replication inhibitory effect; positive allosteric regulatory role regarding human gamma-aminobutyric acid receptor and capacity of binding the human estrogen-related receptor gamma.

The related pathological conditions vary depending on the targets. Modulation of the estrogen receptors and the estrogen-related receptor were relevant to cancer, osteoporosis, genital disorders, and hypoestrogenism. By the similarity-based virtual screening we predicted putative relation to the discussed pathological conditions of the following phenols: naringenin, daidzin, and resveratrol-3-glucoside. A group of drugs, used in adjunction to itexin, daidzin, and resveratrol. We outlined the sodium/glucose cotransporter 2, associated with type 2 diabetes treatment, as possible target of phenolic compounds like vitexin, daidzin, and resveratrol-3-glucoside. A group of drugs, used in adjunction to general anaesthesia, were paired with 5-methoxyfurancoumarin thus linking this compound to the putative modulation of the alpha-2B adrenergic and the gamma-aminobutyric acid receptors. While the aforementioned conditions were related to human molecular targets, the estimated similarity between one natural hydroxyanthraquinon and synthetic suppressor of bacterial DNA replication was related to molecular targets in a pathogenic organism.

The established phenol-target relationships were evaluated by searching experimental evidence in the literature. In our analysis, predicted targets with supportive experimental data linking them to the corresponding phenol were out of the focus, since the priority was outlining novel targets. Therefore, the estrogen receptor-related activities of naringenin [16, 17], resveratrol and daidzin [18, 19] were excluded. Furancoumairns have been discussed in the literature as modulators of the alpha-adrenergic [20] and the gamma-aminobutyric acid receptors [21], as well. Evidence [23], daidzin [24], and esculin [25] to the sodium/glucose cotransporter 2 were also found. Two bacterial enzymes (Table 2, No 5), however, were outlined as putative new targets of a hydroxyanthraquinon from Rubia cordifolia L. [13]. The alignment of this phenolic compound and the corresponding DrugBank hit (ID: DB01044) received a TanimotoCombo score = 1.3, with 80% shape similarity between the structures and 50% matching between their characteristic functional groups. The good alignment of the novel phenol-drug pair is presented in Fig. 1.

Table 1: Estimations of shape and chemical similarity between the DrugBank hits and phenolic queries

<table>
<thead>
<tr>
<th>No</th>
<th>DrugBank ID</th>
<th>Drug name</th>
<th>Phenol name</th>
<th>TanimotoCombo score</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>DB00292</td>
<td>Etomidate</td>
<td>5-methoxyfurancoumarin</td>
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<td>2</td>
<td>DB00890</td>
<td>Dienestrol</td>
<td>Daidzin</td>
<td>1.3</td>
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<td>3</td>
<td>DB06292</td>
<td>Dapagliflozin</td>
<td>Daidzin</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>DB00655</td>
<td>Estrone</td>
<td>Naringenin</td>
<td>1.3</td>
</tr>
<tr>
<td>5</td>
<td>DB01044</td>
<td>Gatifloxacin</td>
<td>Pseudopurpurin</td>
<td>1.3</td>
</tr>
<tr>
<td>6</td>
<td>DB00783</td>
<td>Estradiol</td>
<td>Resveratrol</td>
<td>1.3</td>
</tr>
<tr>
<td>7</td>
<td>DB09038</td>
<td>Empagliflozin</td>
<td>Resveratrol-3-glucoside</td>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
<td>DB08907</td>
<td>Canagliflozin</td>
<td>Vitexin</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Step 3: Analysis of the 3D representations of the overlays

No. 5), however, were outlined as putative new targets of a hydroxyanthraquinon from Rubia cordifolia L. [13]. The alignment of this phenolic compound and the corresponding DrugBank hit (ID: DB01044) received a TanimotoCombo score = 1.3, with 80% shape similarity between the structures and 50% matching between their characteristic functional groups. The good alignment of the novel phenol-drug pair is presented in Fig. 1.

Fig. 1 Overlay of hit (magenta) over query (cyan) structure.

The outlined drug hit represents a synthetic broad-spectrum antibiotic agent. The related pharmacological mechanism of prevention/treatment of bacterial infections in the respiratory tract involve suppression of DNA replication in Gram-positive and Gram-negative bacteria. Importantly, the phytochemicals from the chemical class of the anthraquinones have been known for their anti-bacterial effects [26]. In particular, biological activities against S. aureus and B. subtilis have been reported for the water extract of the medicinal plant R. cordifolia [27]. However, in our searches, no data was found for investigations on activity of R. cordifolia or the studied phenol against this Gram-positive bacteria.

The design of a food or feed supplement based on molecular scaffolds derived from medicinal plants requires comprehensive experimental analyses. Therefore, more studies are necessary to estimate the ability of the outlined phytochemical to bind and modulate the activity of the predicted bacterial targets without being harmful for the host organism, as well as to assess its bioavailability in mammals.
Table 2: Related molecular targets based on estimated similarity within phenolic compound-drug pairs.

<table>
<thead>
<tr>
<th>No</th>
<th>Target</th>
<th>Phenol name</th>
<th>Drug name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alpha-2B adrenergic receptor and Gamma-</td>
<td>5-methoxyfuranocoumarin</td>
<td>Etomidate</td>
</tr>
<tr>
<td></td>
<td>aminobutyric acid receptor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Estrogen receptor alpha</td>
<td>Daidzein</td>
<td>Dienestrol</td>
</tr>
<tr>
<td>3</td>
<td>Sodium/glucose cotransporter 2</td>
<td>Daidzin</td>
<td>Dapagliflozin</td>
</tr>
<tr>
<td>4</td>
<td>Estrogen receptor alpha</td>
<td>Naringenin</td>
<td>Estrone</td>
</tr>
<tr>
<td>5</td>
<td>DNA gyrase and DNA topoisomerase IV</td>
<td>Pseudopurpurin</td>
<td>Gatifloxacin</td>
</tr>
<tr>
<td>6</td>
<td>Estrogen receptors (alpha, beta) and</td>
<td>Resveratrol</td>
<td>Estradiol</td>
</tr>
<tr>
<td></td>
<td>Estrogen-related receptor gamma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sodium/glucose cotransporter 2</td>
<td>Resveratrol-3-glucoside</td>
<td>Empagliflozin</td>
</tr>
<tr>
<td>8</td>
<td>Sodium/glucose cotransporter 2</td>
<td>Vitexin</td>
<td>Canagliflozin</td>
</tr>
</tbody>
</table>

By searching the predicted novel molecular targets among the Protein Data Bank (http://www.rcsb.org/) resources we found significant number of relevant crystallographic 3D structures of the proteins bound to their chemical ligands. Thus, our results present opportunity for further in silico studies of protein-ligand interactions. As a next step, virtual screening based on estimation of structural similarity and data mining techniques are foreseen to support the identification of the studied hydroxyanthraquinon among local ethnopharmacological sources or food ingredients.

4. Conclusion

In summary, our investigation underlined the combination of similarity-based virtual screening with data processing techniques as a promising multi-staged protocol for identification of novel targets even for well-studied molecules possessing wide range of biological activities and related molecular targets.

We predicted potential anti-bacterial molecular mechanism of a hydroxyanthraquinon from natural origin particularly leading to suppression of bacterial DNA replication. The proposed novel phenolic compound-molecular target pairs could direct the scientific efforts to development of healthy food or feed supplements with possible preventative/therapeutic action on bacterial infections.

Overall, our study led to the estimation of potential receptor-mediated modes of action and presents a first step in the design of an in silico screening workflow for the discovery of lead structures bearing phenolic molecular scaffolds.

5. Acknowledgements

This work was supported by the Bulgarian Ministry of Education and Science under the National Research Programme “Healthy Foods for a Strong Bio-Economy and Quality of Life” approved by DCM # 577 / 17.08.2018”. The authors thank the OpenEye Free Academic Licensing Program for providing a free academic license for molecular modelling and chemoinformatics software.

6. References


Neural network approaches for a facility location problem

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Abstract: This paper examines the possibility to use neural networks for approximately solving the MiniSum problem, a classic facility location problem. For this we first create a set of realistic MiniSum instances, based on the Bulgarian road network. Two standard neural network approaches – Hopfield networks and Boltzmann machines, are then applied to the instances. Since the quality of solutions is not satisfactory, the reasons for the poor performance are discussed. An improved neural network approach is then proposed. This approach has excellent performance on the MiniSum instances. It always finds solutions just several percent worse than the optimum, and is often able to find the exact optimum.

Keywords: FACILITY LOCATION, NEURAL NETWORKS, COMBINATORIAL OPTIMIZATION

1. Introduction

Facility location problems are a large class of optimization problems, often occurring in practice. In this paper we are interested in the MiniSum problem, a classic facility location problem. MiniSum models the search for optimal placement of a set of warehouses with goal to minimize transportation costs. We give a formal definition of the problem in the next section.

The interest in using neural networks for approximately solving optimization problems started from the seminal paper of Hopfield and Tank [3]. They propose a certain type of network, which is able to find solutions to the Travelling salesman problem. This network can be generalized to many combinatorial optimization problems. It is also implementable in hardware and is naturally massively-parallel, which makes the whole approach interesting for solving large instances. Sadly, the Hopfield-Tank (HT) approach has problems. As noted in [8] and in many other places, the approach does not scale to large instances and the quality of the solutions it produces is bad. There were many efforts to improve the HT approach. One promising direction are Boltzmann machines (further denoted BM), which add randomness to the network operation.

Neural networks for combinatorial optimization may be interesting from theoretical perspective, but if such approaches produce low-quality solutions, they will have no practical value. We start by generating a set of realistic MiniSum instances, based on the Bulgarian road network. We then apply the HT approach and BM to the instances and confirm that the quality of the solutions they give is not satisfactory. After analyzing the reasons for the poor performance, we propose an improved approach, which has excellent performance on the MiniSum instances. On average it finds solutions just 0.3% worse than the optimum and in 88% of the cases it finds the exact optimum. This confirms that asynchronous massively-parallel systems of “neurons” can be used to produce high-quality solutions to combinatorial optimization problems. The reasons for the poor performance on HT and BM are in their specifics, not in the idea of using such systems of “neurons”.

2. The MiniSum problem

Intuitively, we are given a directed, weighted graph. Nodes represent populated places and edges represent roads. We need to choose k nodes from the graph where to locate warehouses. The goal is to minimize the sum of distances from each populated place to the closest warehouse.

2.1 Formal definition

The k-MiniSum problem is defined over a directed, weighted and strongly connected graph \( G(V,E) \) with vertex set \( V \) and edge set \( E \). The shortest distance in \( G \) between two vertices \( U \) and \( W \) is denoted as \( \text{dist}(U,W) \). Integer \( k \) is a parameter of the problem and is usually much less than the number of vertices.

Definition (k-MiniSum problem)

Find a list of \( k \) vertices \( V_1, V_2, ..., V_k \) from \( V \) which minimize

\[
\sum_{V \in V_1, V \in V_2, ..., V \in V_k} \text{dist}(U,V)
\]

The k-MiniSum problem in general graphs is well-known to be NP-hard (by reduction, for example, from the Set cover problem [4]).

2.2 Test instances

The Bulgarian road network is used to generate realistic MiniSum instances. For each instance a rectangular area is selected. All populated places and roads in this area are extracted and used as underlying graph. We choose the areas so that there are between 20 and 90 populated places and set the number of facilities to a value between 2 and 6. The instances are small enough to be able to exactly compute the optimal solution in reasonable time. As source of geographic data OpenStreetMaps [6] is used (data is extracted using SPARQL queries). For computing the exact solution each instance is modelled as integer programming problem and solved using the Cbc mixed integer programming solver [1]. In total we have selected 50 different rectangular areas, which gives 250 MiniSum instances. The image below shows one of them.

Fig. 1 Example MiniSum instance with 4 warehouses. The dots represent populated placed and the 4 selected locations are marked with additional circular outline.

3. Existing neural network approaches

Good description of combinatorial optimization using Hopfield networks can be found in [7], and using Boltzmann machines – in [5]. The two approaches have a lot in common. In fact, Boltzmann machines can be thought of as stochastic version of Hopfield networks. Both approaches assume a binary problem is given. There is a set of \( n \) binary variables \( V_1, V_2, ..., V_n \), an \( n \times n \) weight matrix \( W \) and a weight vector \( D \). The approaches find a local minimum of the function \( \sum W_{ij} V_i V_j - \sum D_i V_i \) (called the energy function). To approximately solve a combinatorial optimization problem we need to choose a weight matrix and weight vector such that local minima of the energy function correspond to good solutions of the problem. We call this step encoding. It should be noted that there are requirements, which matrix \( W \) should meet (described in [7]). Usually, when encoding a problem, the requirements are naturally met.
Clearly, there are many ways to encode the MiniSum problem. Next, one possible way, inspired by the encoding of other problems in [7] and [8], is described. We believe that the encoding is reasonable, but there is a possibility for another encoding, giving better results, to exist.

Let \( n \) be the number of vertices in \( G \) and \( k \) be the number of warehouses we need to place. The neural network encoding has \( 2 \cdot n \cdot k \) binary variables. We call one group of \( n \cdot k \) variables the client – facility variables and denote them as \( CF[i,j] \). \( CF[i,j] \) is 1 iff the client in vertex \( i \) is serviced by facility (warehouse) number \( j \). Similarly, another group of \( n \cdot k \) variables corresponds to the facility – location relation. We denote them as \( FL[i,s,j] \) and \( FL[i,j,s] \) is 1 iff facility \( j \) is located in vertex \( s \). The transportation cost can now be expressed as \( \sum_{i,j} CF[i,j] \cdot FL[i,j,s] \cdot dist(V_i,V_s) \), which is in a form, compatible with the energy function notation. Fig. 2 illustrates the encoding.

![MiniSum encoding.

For a solution to be valid, each client should be serviced by only one facility, and each facility should be located in only one vertex. The typical approach to achieve this 1–of–many constraint with neural networks is to add penalty terms to the energy function. Similarly to [7] and [8] we add to the energy function a group of penalty terms of the form \( A \cdot (1 - \sum_j CF[i,j])^2 \) for each client \( i \). When \( A \) is large enough, these terms force the network to choose exactly one facility for each client. We analogously add term of the form \( B \cdot (1 - \sum_j FL[i,j,s])^2 \) for each facility \( j \) to enforce the other 1–of–many constraint. Note that, when the brackets are open, the expressions are in a form, compatible with the notion of energy function. Choosing the values \( A \) and \( B \) is not straightforward and it affects the quality of the produced solution. The need to choose weights for the penalty terms is considered to be a major problem of the HT approach. Later in this section we will describe our approach for choosing the weights.

The problem encoding tells us how to construct, given a MiniSum instance, the set of binary variables, the weight matrix and weight vector. Variables are then mapped to simple computing units (neurons). Each unit corresponds to a variable. It has an output value equal to the value of the variable. The units are also connected to each other, matrix \( W \) gives the weights of the connections. Each unit has a procedure for updating its output, the procedure is different between HT and BM. The whole system of units starts from a random state (random output for each unit) and repeatedly chooses a unit and executes its update procedure. After enough time has passed, we read the output values of the neurons and this is the final solution. Again, the encoding tells us how to translate from the values of the binary variables \( V_i \) to the objects of the initial problem. In the case of the described encoding, the variables with value 1 tell which facility services each client and where each facility is located.

### 3.1 Hopfield network updates

Assume unit \( S \) wants to perform an update. It computes the value \( \text{inp}[S] = \sum_j W[S,j] \cdot \text{output}[j] \). If \( \text{inp}[S] < B[S] \) the unit sets its output to 1, otherwise it sets the output to 0. This computation is equivalent to checking the sign of the gradient of the energy function with respect to \( \text{output}[S] \). The unit chooses the value of its output so that the energy function does not increase.

### 3.2 Boltzmann machine updates

In BM there is a notion of temperature. The temperature \( T \) controls the probability of accepting a change of the unit's output. Assume unit \( S \) wants to perform an update. It computes \( D \), the difference in the energy function if we flip the output of \( S \). If \( D < 0 \), \( S \) flips its output. Otherwise it flips its output with probability \( (1 + e^{D/T})^{-1} \).

It can be noticed that, when the temperature \( T \) is high, almost any change is accepted with high probability. When \( T \) is low, only changes which decrease the energy function are accepted. In this sense, when \( T \) is low, BM operates very similarly to a HT network. Temperature \( T \) gradually decreases with time. It starts from a value high enough to allow almost any change to be accepted (with high probability). Then every \( M \) steps it is multiplied by a constant a little less than 1 (where \( M \) is chosen to be proportional to the number of units).

### 3.3 Choosing penalty weights

Penalty terms were introduced to guarantee the validity of the solution. When their weight is too small, the system can arrive at a local minimum, in which a client is not connected to any facility, or no location is chosen for a facility. If the penalty weights are too high, they will dominate the energy function and will drive the system into a state representing a valid, but low-quality solution. Our approach to choosing the weights is to try to make them as small as possible. For this we first start from small values. We then repeatedly double the weights and run the network optimization procedure, until the network finds a valid solution. After this we repeatedly try to decrease the weights by a small fraction (10% - 5%) until the system still finds valid solutions. Actually, since in our encoding there are two separate weights (denoted \( A \) and \( B \)), we alternate between them in the decreasing steps.

### 3.4 Discussion on the performance

Here by performance we mean the quality of the solution. Since in both HT and BM there is some randomness, multiple runs were performed. More specifically, the described procedure for choosing penalty weights by itself performs multiple runs with different weights. Also, multiple runs were performed with the best weights found. In total this gives several hundred runs of the optimization procedure for each instance. The best solution found during the runs is selected.

The results of both HT and BM are very discouraging. While they are always able to find valid configurations, on average they find solutions more than two times more expensive than the optimum. The results of BM are slightly better than HT, but the runtime is significantly longer. Also, the cost of the found solutions just slightly decreases when increasing the number of facilities. And the quality of the solutions is not much better than a random solution. This points that both HT and BM put emphasis on finding valid solutions and almost do not optimize for solution quality.

It can be noticed that both HT and BM are variations of local search. They operate on a set of \( M \) binary variables and find local minimum in a solution space of size \( 2^M \) by starting from a random state and iteratively improving it. Local search is a well-researched area and is the base of many of the best-performing general approaches for (approximately) solving combinatorial optimization problems. Good overview of local search methods and their performance is [2]. We can borrow ideas from the analysis of local search methods to understand the problems with HT and BM, and improve their performance.

#### Neighbourhood

To choose the next state, local search performs small modifications of the current. The states, reachable from the current state in one modification step, are called its neighbours. The performance of local search highly depends on the neighbourhood definition, at least because local minimum is defined with respect to
a neighbourhood. For HT and BM the neighbourhood is formed by flipping one binary variable. This seems to be not flexible enough. Flipping one variable changes the validity of the current solution, which makes the penalty term a major factor for deciding whether to accept a solution. Once a facility is connected to a location, for example, it becomes hard to change the location. The neighbourhood puts more emphasis on finding a valid solution than on finding a good solution. This may be a problem of our encoding of MiniSum. Yet, the mechanics of HT and BM seem to not be able to represent better neighbourhoods without excessive redundancy in the encoding.

**Solution space**

Since MiniSum is a hard problem, it is expected that the solution space is complex. But the penalty terms in the energy function create additional problems. It was already noted that choosing weights for the penalty terms is not straightforward. With respect to the solution space, the penalty terms create many (possibly poor) local minima from which it is hard to escape.

**Randomization**

Randomization often improves the quality of the solutions, found by local search. One common way to add randomization is to allow the search to occasionally accept modifications, which decrease the quality of the solution. This is done in an effort to escape from poor local minima. Since HT always decreases the value of the energy function, in this sense the method is completely deterministic. There is a historic explanation for this – Hopfield networks were developed as associative memory, not as machinery for optimization. Because of their determinism, we can expect HT to perform worse than stochastic local search.

BM allows transitions, increasing the value of the energy function. In this sense, they are better than HT. In fact, there is a theoretical result that, given enough time, BM will find the optimal solution (in probabilistic sense). But the time necessary for this is larger than the time for iterating through the whole solution space, so the result has little practical value.

**Summary**

As summary, the poor performance of HT and BM seems to follow from a combination of the penalty terms as mechanism for enforcing solution validity and the inflexible neighbourhood definition. For the HT approach there is the additional drawback of complete determinism (in the sense of the previous paragraph).

### 4. Proposed neural network approach

The proposed model uses the same binary variables CF and FL as in the already described MiniSum encoding. It minimizes the function \( \sum_{i,j} CF[i,j] \cdot FL[i,j] \cdot dist(V_i,V_j) \). Note that there are no penalty terms in this function, another mechanism will be used to guarantee the validity of the solution. The binary variables are again mapped to units which have outputs, equal to the value of the corresponding variable. The whole system repeatedly updates the outputs of the units, same as the HT and BM approaches.

The units in the proposed approach have two more properties. Let's say that units \( X \) corresponds to the variable \( V_k \). Then:

- \( group[X] \) is a list of units which, intuitively, compete with \( X \) for activation. Eventually only one of the units in the group will have output equal to 1 (will be on). This is the mechanism for enforcing solution validity.

- \( con[x] \) is a list of pairs of unit and weight (real number). This list represents the units to which \( X \) is connected (similarly to the \( W \) matrix in section 3).

The groups in the encoding naturally correspond to the 1-of-

many constraints. Each client needs to be connected to exactly one facility, so for a \( CF[i,j] \) (client - facility) unit its group is \( \{ CF[i,t] | t \in 1...k \} \). Here \( k \) is the number of facilities. Similarly, for a \( FL[j,s] \) (facility – location) unit its group is \( \{ FL[j,t] | V_i \in V \} \). This is because each facility needs to be located in exactly one vertex of the graph.

Connections in the encoding are only between CF[i,j] and FL[j,s] units. More specifically, CF[i,j] is connected to FL[j,s] with weight \( dist(V_i,V_j) \). Similarly, FL[j,s] is connected to CF[i,j] with the same weight. Here i, j and s iterate through all valid values. This also has very natural interpretation – if client i is serviced by facility j (\( CF[i,j] \)) which is located in vertex s (\( FL[j,s] \)) then we pay \( dist(V_i,V_j) \) for transportation.

As in Boltzmann machines, there is a notion of temperature \( T \), which controls the probability of accepting transitions. This temperature decreases exponentially and can be either local for each unit, or global for the whole system.

If unit \( X \) wants to update its output, it first finds the set of units which have value 1 and are connected to \( X \). Lets call this set \( ON \). If \( ON \) is empty, \( X \) sets its output to 1. Otherwise, \( X \) computes \( value[X] = (\sum_{e \in ON} weight[e]) / |ON| \). Here weight is the weight of the connection to the corresponding unit. \( X \) also computes \( BEST = \min \{ value[s] | s \in group[X] \} \). The unit sets its output to 1 if \( value[X] < BEST \), else it sets it to 0. After this \( X \) flips its output with probability \( 1 + e^{\frac{tmp - value[x]}{T}} \).

The operation of the system consists of a sequence of updates of unit outputs (starting form a random state). Assume there are \( M \) units in total. The sequence of updates is of size \( 5M^2 \) and is separated into \( M \) groups. After each group the temperature \( T \) is multiplied by a constant \( C \), which is chosen so that after the \( M \) groups \( T \) becomes 0.001 (the initial temperature is chosen as the maximum energy delta of a variable flip according to the initial random state). Each group of updates consists of \( 5M \) individual ones, in each of which we randomly choose a unit and update its output, as we already described.

Note that, when the temperature is low, the way we process groups guarantees the validity of the solution and the arrival at a local minimum of the energy function. Additionally, on higher temperatures there is a large probability to be in states, in which a facility is connected to multiple locations, or a client is connected to multiple facilities. Taking average in the value computation is done to increase exploration by allowing cheap “drifting” of the chosen location to neighbouring ones.

Since there is randomness in the system’s operation, it makes sense to perform multiple runs. In our experiments we performed 4 independent runs for each instance and took the best solution found. Actually, most of the time one run was enough to find the optimal solution.

On the test MiniSum instances the described approach is able to find the exact optimal solution in 88% of the cases and achieves average error of 0.3%. By error we mean the difference between the returned solution and the optimal solution. The maximum error on an instance is 8%, the next largest is 2%. We haven't tuned the parameters of the described model, so probably it is possible to achieve slightly better results. Also, it is worth noting that, even on our small-sized MiniSum instances, the proposed approach is much faster than both the integer programming approach and BM.

### 5. Conclusion

We created a set of realistic MiniSum instances and proposed a general neural network approach for facility location, which has excellent performance on the instances. This shows that massively parallel systems of “neurons” can find good quality solutions to combinatorial optimization problems. Apart from being theoretically interesting, such systems allow for efficient distributed implementation. There are also developments in special hardware for neural networks, which can significantly decrease the time of
the computation. As future work it is left to analyze the convergence properties of the proposed approach and to evaluate it on other facility location problems and combinatorial optimization problems with 1-of-many constraints.

References

[1] "Cbc (Coin-or branch and cut) mixed integer linear programming solver", https://github.com/coin-or/Cbc


Energy (isentropic) analysis of three-cylinder steam turbine with re-heating

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Abstract: In this paper is presented energy (isentropic) analysis of high power, three-cylinder steam turbine with steam re-heating. A comparison of real (polytropic) and ideal (isentropic) steam expansion processes at nominal load show that observed turbine develops real power of 655.35 MW, while in ideal situation it can develop 716.18 MW. The highest energy loss and the lowest energy efficiency occur in the high pressure turbine cylinder (25.67 MW and 89.14%), while intermediate pressure cylinder has the highest energy efficiency and the lowest energy loss. The energy efficiency of the whole observed turbine is 91.51%, what is in the expected range for such high power steam turbines at nominal load. Further optimization of this steam turbine will be primarily based on the high pressure cylinder.

KEYWORDS: ENERGY (ISENTROPIC) ANALYSIS, STEAM TURBINE, ENERGY EFFICIENCY, ENERGY LOSS

1. Introduction

Steam turbines are the dominant power producers which drive electric generators for the electricity production worldwide [1]. Steam turbines can operate in conventional power plants [2], combined power plants (where steam is produced from flue gases of gas turbine) [3], marine power plants [4] and many others.

Steam turbines are complex power producers which consist of many stages, elements and sub-systems. In various power plants can be found steam turbines which consist of several cylinders (single-flow or dual-flow) as well as steam re-heater due to many benefits which it brings in entire power plant operation [5]. However, many low power steam turbines usually consist of only one single-flow cylinder (in some situations it can also be only one Curtis stage) for the drive of auxiliary components (pumps, compressors, etc.) [6].

In this paper is performed energy (isentropic) analysis of high power steam turbine, which consists of three cylinders and has a re-heater between high pressure and intermediate pressure cylinders. The analysis is performed for each turbine cylinder as well as for the whole steam turbine. Calculated power distribution, energy efficiencies and losses for the whole turbine and each of its cylinders at nominal load present interesting overview of turbine operation, while the obtained conclusions can be used as a guideline in future research and improvements.

2. Description and operating process of the analyzed three-cylinder steam turbine with re-heating

Analyzed steam turbine consists of three cylinders: High Pressure Cylinder (HPC), Intermediate Pressure Cylinder (IPC) and Low Pressure Cylinder (LPC). All the cylinders are connected to the same shaft which drives an electric generator, as presented in Fig. 1.

Steam produced in steam generator [7] is delivered to HPC which has two steam extractions - both of them lead steam to high pressure feed water heaters [8]. After expansion in HPC, remaining steam mass flow rate is lead to steam re-heater, which increases steam temperature (along with pressure drop due to losses which occurs in re-heater). After re-heater steam enters into IPC which also has two steam extractions - first extraction leads steam to high pressure heater while second extraction leads steam to the deaerator. Remaining steam mass flow rate which exits IPC enters in LPC. LPC has three steam extractions - all of them lead steam to low pressure feed water heaters [9]. After expansion in LPC, remaining steam mass flow rate is lead to steam condenser for condensation [10].

It should be noted that steam mass flow rates leaked through the front and rear gland seals of each cylinder [11] are neglected in this analysis due to lack of such data. However, in real operation, steam mass flow rate leaked through both gland seals of each turbine cylinder will be led to gland steam condenser [12].

Fig. 1 also presents operating points required for the observed turbine and all of its cylinders energy (isentropic) analysis.

3. Energy analysis equations

3.1. Overall energy analysis equations

Energy analysis is defined by the first law of thermodynamics [13] and is independent of the ambient conditions in which control volume or a system operates. Mass and energy balance equations for a control volume or a system in steady state, disregarding potential and kinetic energy, can be expressed according to [14] as:

$$\Sigma \dot{m}_IN = \Sigma \dot{m}_OUT \quad (1)$$

Steam expansion processes of each analyzed turbine cylinder (real and ideal) in $h$-$s$ diagram are presented in Fig. 2. Real (polytropic) expansion processes are: for the HPC - 1-2-3; for the IPC - 5-6-7 and for the LPC - 8-9-10-11-12, while ideal (isentropic) expansion processes are: for the HPC - 1-2is-3is; for the IPC - 5-6is-7is and for the LPC - 8-9is-10is-11is-12is. According to those operating points for both expansion processes in each turbine cylinder, presented in Fig. 2, will be shown operating parameters obtained during the turbine exploitation (real process at nominal turbine load), as well as operating parameters of ideal expansion (obtained by retaining constant steam specific entropy in each turbine cylinder).

Fig. 1. General scheme of steam turbine along with operating points required for the analysis

Fig. 2. $h$-$s$ diagram of the real (polytropic) and ideal (isentropic) expansion processes inside each cylinder of the analyzed steam turbine
\[ QIN + PIN + \sum (m_{IN} \cdot h_{IN}) = \\
= QOUT + POUT + \sum (m_{OUT} \cdot h_{OUT}), \]

(2)

where \( m \) is mass flow rate (kg/s), \( Q \) is heat transfer (kW), \( P \) is power (kW), \( h \) is operating medium specific enthalpy (kJ/kg), \( IN \) denotes input (inlet) and \( OUT \) denotes output (outlet).

Operating medium energy flow [15] is calculated as:

\[ \dot{E} = m \cdot h, \]

(3)

where \( \dot{E} \) is energy flow of operating medium (kW).

General definition of control volume or system energy efficiency is [16]:

\[ \eta = \frac{\text{energy output}}{\text{energy input}} \]

(4)

where \( \eta \) is energy efficiency (%).

Mentioned overall equations are used in the energy (isentropic) analysis of observed steam turbine and each of its cylinders.

3.2. Energy (isentropic) analysis of the observed steam turbine

Energy (isentropic) analysis of entire observed steam turbine and each of its cylinders is based on the comparison of real (polytropic) and ideal (isentropic) steam expansion processes.

Equations for the calculation of all required variables in energy (isentropic) analysis of the observed turbine and its cylinders are presented in Table 1 and Table 2. In Table 1 are presented equations for HPC and IPC, while in Table 2 are presented equations for LPC and whole turbine. Markings in all the equations from Table 1 and Table 2 are defined in accordance to Fig. 2.

**Table 1. Equations for the energy (isentropic) analysis of steady turbine HPC and IPC**

<table>
<thead>
<tr>
<th>HPC</th>
<th>Eq.</th>
<th>IPC</th>
<th>Eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{HPCr} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(5)</td>
<td>( P_{IPC} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(10)</td>
</tr>
<tr>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
</tr>
<tr>
<td>( P_{LPC} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(6)</td>
<td>( P_{IPC} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(11)</td>
</tr>
<tr>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Equations for the energy (isentropic) analysis of LPC and whole steam turbine**

<table>
<thead>
<tr>
<th>LPC</th>
<th>Eq.</th>
<th>WHOLE TURBINE</th>
<th>Eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{LPC} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(15)</td>
<td>( P_{WT} = \sum P_{cylinders} )</td>
<td>(20)</td>
</tr>
<tr>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( P_{LPC} = m_{1} \cdot (h_{1} - h_{2}) )</td>
<td>(16)</td>
<td>( P_{WT} = \sum P_{cylinders} )</td>
<td>(21)</td>
</tr>
<tr>
<td>( + (m_{1} - m_{2}) \cdot (h_{2} - h_{3}) )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \frac{P_{WT}}{P_{WT, is}} = \frac{\sum P_{cylinders}}{P_{WT}} \]

(22)

**Table 3. Steam parameters in each operating point for real (polytropic) expansion (nominal turbine load)**

<table>
<thead>
<tr>
<th>O.P.</th>
<th>Pressure (MPa)</th>
<th>Temperature (°C)</th>
<th>Mass flow rate (kg/s)</th>
<th>Steam specific enthalpy (kJ/kg)</th>
<th>Steam specific entropy (kJ/kg·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.72</td>
<td>564.3</td>
<td>536.88</td>
<td>3398.6</td>
<td>6.2737</td>
</tr>
<tr>
<td>2</td>
<td>7.28</td>
<td>381.8</td>
<td>38.14</td>
<td>3103.4</td>
<td>6.3500</td>
</tr>
<tr>
<td>3</td>
<td>4.77</td>
<td>321.9</td>
<td>43.97</td>
<td>2998.7</td>
<td>6.3551</td>
</tr>
<tr>
<td>4</td>
<td>4.77</td>
<td>321.9</td>
<td>454.77</td>
<td>2998.7</td>
<td>6.3551</td>
</tr>
<tr>
<td>5</td>
<td>4.2</td>
<td>565.7</td>
<td>454.77</td>
<td>3594.5</td>
<td>7.2545</td>
</tr>
<tr>
<td>6</td>
<td>2.36</td>
<td>473.6</td>
<td>26.39</td>
<td>3405.7</td>
<td>7.2764</td>
</tr>
<tr>
<td>7</td>
<td>1.22</td>
<td>376.8</td>
<td>30.91</td>
<td>3211.2</td>
<td>7.2961</td>
</tr>
<tr>
<td>8</td>
<td>1.22</td>
<td>376.8</td>
<td>397.48</td>
<td>3211.2</td>
<td>7.2961</td>
</tr>
<tr>
<td>9</td>
<td>0.44</td>
<td>255.4</td>
<td>14.19</td>
<td>2974.2</td>
<td>7.3556</td>
</tr>
<tr>
<td>10</td>
<td>0.24</td>
<td>191.3</td>
<td>14.48</td>
<td>2851.1</td>
<td>7.3831</td>
</tr>
<tr>
<td>11</td>
<td>0.12</td>
<td>123.5</td>
<td>29.05</td>
<td>2721.7</td>
<td>7.3975</td>
</tr>
<tr>
<td>12</td>
<td>0.02</td>
<td>60.1</td>
<td>339.75</td>
<td>2467.5</td>
<td>7.4827</td>
</tr>
</tbody>
</table>

* Operating points (O.P.) are defined according to Fig. 1 and Fig. 2.

Ideal (isentropic) steam expansion process is a process between the same pressures and with identical mass flow rates as in the real (polytropic) one, but while retaining the same steam specific entropy [19]. As presented in Fig. 2, ideal (isentropic) steam expansion process for each turbine cylinder is defined from the cylinder inlet until the outlet, without any change in steam specific entropy during the expansion.

According to such ideal expansion process, each turbine cylinder will develop higher power (in comparison to real process), because this process did not take into account losses during steam expansion. Steam parameters in each operating point of each observed turbine cylinder, Fig. 2, during ideal (isentropic) steam expansion process are summarized and presented in Table 4.

**Table 4. Steam parameters in each operating point for ideal (isentropic) expansion (nominal turbine load)**

<table>
<thead>
<tr>
<th>O.P.*</th>
<th>Pressure (MPa)</th>
<th>Temperature (°C)</th>
<th>Steam specific enthalpy (kJ/kg)</th>
<th>Steam specific entropy (kJ/kg·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.72</td>
<td>564.3</td>
<td>6.2737</td>
<td>3398.6</td>
</tr>
<tr>
<td>2</td>
<td>7.28</td>
<td>381.8</td>
<td>6.3500</td>
<td>3054.0</td>
</tr>
<tr>
<td>3</td>
<td>4.77</td>
<td>321.9</td>
<td>6.3551</td>
<td>2951.0</td>
</tr>
<tr>
<td>4</td>
<td>4.77</td>
<td>321.9</td>
<td>7.2545</td>
<td>3594.5</td>
</tr>
<tr>
<td>5</td>
<td>4.2</td>
<td>565.7</td>
<td>7.2961</td>
<td>3389.4</td>
</tr>
<tr>
<td>6</td>
<td>2.36</td>
<td>473.6</td>
<td>7.3831</td>
<td>3112.2</td>
</tr>
<tr>
<td>7</td>
<td>1.22</td>
<td>376.8</td>
<td>7.3975</td>
<td>2943.2</td>
</tr>
<tr>
<td>8</td>
<td>1.22</td>
<td>376.8</td>
<td>3112.2</td>
<td>2943.2</td>
</tr>
<tr>
<td>9</td>
<td>0.44</td>
<td>240.4</td>
<td>2943.2</td>
<td>2943.2</td>
</tr>
<tr>
<td>10</td>
<td>0.24</td>
<td>172.0</td>
<td>2811.6</td>
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<tr>
<td>11</td>
<td>0.12</td>
<td>104.8</td>
<td>2862.3</td>
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<tr>
<td>12</td>
<td>0.02</td>
<td>60.1</td>
<td>2405.3</td>
<td>2405.3</td>
</tr>
</tbody>
</table>

* Operating points (O.P.) are defined according to Fig. 2.
5. Results and discussion

A comparison of real and ideal developed power for the whole observed steam turbine and each of its cylinders is presented in Fig. 3. The whole turbine develops real power equal to 655.35 MW; while in the ideal conditions, it could develop 716.18 MW (if in all turbine cylinders isentropic steam expansion occurs).

While observing turbine cylinders, the highest power (both real and ideal) develops LPC, while the lowest power (again, both real and ideal) will be developed in IPC. For the LPC, which is a dominant power producer, should be noted that its operating conditions are worst in comparison to other cylinders (high steam volume flow rate, occurrence of water droplets in steam for the last few stages - under the saturation line, long curved turbine blades - high centrifugal forces, etc.), therefore this cylinder should be carefully designed and maintained.

Steam re-heat process applied for the observed turbine, Fig. 1 and Fig. 2, ensures operation of the majority of LPC turbine stages in the superheated area (an area in which water droplets did not occur), therefore it surely improves turbine operation and have a positive influence on the entire power plant efficiency.

Energy loss of the entire analyzed steam turbine and all of its cylinders are calculated as a difference between real (polytropic) and ideal (isentropic) power. The whole turbine energy loss equals to 60.82 MW, while when observing turbine cylinders the highest energy loss occurs in HPC (25.67 MW) and the lowest energy loss can be seen in IPC (11.87 MW), Fig. 4.

Specific energy loss of the whole turbine and all of its cylinders is obtained by dividing the energy loss with real (polytropic) developed power. This variable is similar to specific fuel consumption, which is a commonly used for defining operating conditions of internal combustion engines [20, 21]. In the case of the analyzed steam turbine and all of its cylinders, it can be concluded that the dominant value of specific energy loss occurs in HPC (12.18%), which means that HPC has the highest energy loss in regards to real developed power (significantly higher when compared to other cylinders and to the whole turbine). The lowest specific energy loss is observed for IPC (7.01%), while the whole observed steam turbine has specific energy loss equal to 9.28%.

Comparison of Fig. 4 and Fig. 5 leads to the important conclusion that for the whole observed turbine and each of its cylinders specific energy loss and energy efficiency are reverse proportional.

5. Conclusions

The paper present energy (isentropic) analysis of three-cylinder high power steam turbine in which operation process is included steam re-heater. Comparison of steam expansion processes (ideal and real) through each turbine cylinder at nominal load leads to several notable conclusions:
- While observing turbine cylinders, the highest power (both real and ideal) develops low pressure cylinder, while the lowest power is developed in the intermediate pressure cylinder. A whole turbine at nominal load develop real power equal to 655.35 MW, while ideal (isentropic) power which can be obtained in ideal situation is 716.18 MW.
- Due to the highest steam pressures and temperatures, high pressure turbine cylinder has the highest energy loss, while the lowest energy loss occurs in the intermediate pressure cylinder. The same conclusion is valid if observing specific energy loss. The energy loss in the whole observed turbine is 60.82 MW and specific energy loss for the whole turbine is 9.28%.
- Specific energy loss of any turbine cylinder and of the whole turbine is reverse proportional to energy efficiency.
- High pressure cylinder has the lowest, while intermediate pressure cylinder has the highest energy efficiency (89.14% in comparison to 93.44%). The energy efficiency of the whole observed turbine is 91.51%, what is in the expected range for such high power steam turbines at nominal load.
- Further research and possible improvements will be firstly based on high pressure turbine cylinder and the aim will be to decrease its losses and increase its efficiency.

6. Acknowledgment

This research has been supported by the Croatian Science Foundation under the project IP-2018-01-3739, CEEPUS network CIII-HR-0108, European Regional Development Fund under the grant KK.01.1.1.01.0009 (DATA CROSS), University of Rijeka scientific grant uniri-tehnic-18-275-1447 and University of Rijeka scientific grant uniri-tehnic-18-18-1146.

8. References


Concept of parametric design and fast 3D printing of individual shoes

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Abstract. A personalized approach to printing individual shoes is possible due to the availability of laser scanning of the feet and professional interpretation of the results. Based on preliminary diagnostics of the condition of the musculoskeletal system in areas of high pressure in the feet, it is possible to identify problems associated with pain in the joints of the lower extremities and lumbosacral, abnormalities and asymmetries of their structure. It is also possible to timely relieve ankle, knee, femoral joints, lumbosacral spine, correct posture and gait, reduce joint pain, prevent surgery on joints of the lower extremities and lumbosacral spine, monitor the dynamics of changes in the rehabilitation period.

The task of effective prevention and early diagnosis of problems of the musculoskeletal system can be solved with the targeted popularization of individual shoes and orthopedic insoles among the population, as well as its accessibility thanks to additive technologies, databases of parametric digital models, an established production and technological cycle and a flexible client-oriented service, including protocols for remote and virtual interaction between production and the end user.

However, shoes printed on a 3-D printer, so far, are not attractive to consumers or manufacturers. Mass production of shoes is still much faster and cheaper, although initially it was assumed that the introduction of additive technologies will significantly reduce the cost and time costs, but so far this has not happened for several reasons. In our country, there is a shortage of specialists in digital technologies, 3D-modeling and printing. In addition, as elsewhere in the world, equipment for fast 3D printing has a very high cost and only giants such as Adidas or Nike can create real production of printed products. However, it is a matter of time. The area of additive technologies is attracting more and more medium and small firms, individual designers, because 3D printing allows you to achieve unexpected and revolutionary results, as well as provide customized solutions at an affordable price.

KEYWORDS: DIGITAL TECHNOLOGIES, PARAMETRIC DESIGN, 3D-PRINTING, INDIVIDUAL SHOES.

1. Introduction

1.1. An increase in the number of people with pathologies of the musculoskeletal system.

A more in-depth and personalized approach to printing individual shoes is possible due to the availability of laser scanning of the feet and professional interpretation of the results. Based on preliminary diagnostics of the condition of the musculoskeletal system in areas of high pressure in the feet, it is possible to identify problems associated with pain in the joints of the lower extremities and lumbosacral, abnormalities and asymmetries of their structure. It is also possible to timely unload the joints of the lower extremities and the lumbosacral spine, reduce pain in these areas, prevent operations on the joints of the lower extremities and the lumbosacral region of the spine, identify the dynamics of changes in the rehabilitation period, and adjust posture and gait [1].

1.2. The high cost of printed shoes due to monopolies in this market segment.

Shoes printed or connected on a 3D printer in our country are gaining popularity rather slowly and in a limited segment - for sports (Nike, Adidas, New balance, etc.). Initially, it was assumed that additive technologies would make the cost of such shoes low and affordability high. However, this has not yet happened (the cost of a pair of 3D sneakers of the above brands can reach from 300 - 600 dollars in retail). As a result, a third problem arises.

1.3. The growing inaccessibility of high-quality individual and orthopedic shoes.

According to Rosstat's research on the living conditions of Russians dated April 5, 2019, more than 35% of Russian families cannot afford to buy one pair of shoes for each season. It is only about everyday shoes, excluding categories of the population with orthopedic problems.

2. Background and means to solve the problem

2.1. The situation in the segment.

Despite the fact that such giants of the shoe industry as Adidas, Nick, Under armor, New balance, Reebok have long and successfully used technology for fast and economical 3D printing to produce individual parts of the upper and lower shoes. For example, layer-by-layer photopolymerization of resins in a bath (or stereolithography) - SLA, DLS, etc. However, mass production of shoes is still much faster and cheaper.

This situation occurs for several reasons:
• In our country, there is a shortage of specialists in digital technologies, 3D-modeling and printing.
• We, as well as around the world, have equipment for fast 3D printing at a very high cost, and only giant companies such as, for example, the American concern Carbon can create real mass production of printed products.

However, it is a matter of time. The area of additive technologies is attracting more and more medium and small companies, individual designers, because 3D printing allows you to achieve unexpected and revolutionary results, as well as provide customized solutions at an affordable price.

In addition, engineering thinking is evolving, leading to the introduction of new design methods, such as parametric design.

2.2. Fashion tech.

The beginning of the XXI century is characterized by a large number of scientific studies and discoveries. The technological breakthrough did not pass by the world of fashion. The development of the Fashion Tech trend in the variety of its manifestations is associated with the enormous opportunities that modern digital technologies provide the industry with. The origins of these phenomena are the 20th century, which has overturned the generally accepted notions of life on our planet, its forms and development. Such theories, for example, as chaos theory, complexity theory, quantum field theory, etc., have formed a new synergistic picture of the world. Researchers have identified such qualitative changes in the paradigm of public consciousness as the transition: from a picture of the sustainable development of society to a vision of its metastability; from order to chaos; from evolution to co-evolution of complex systems; from independence to dependence; from dimensionality to proportionality or fractal replication by the world of itself. Parametric design, which came into practical use at the beginning of the XXI century, basically reflects the entire spectrum of emerging ideas about the world as a complex system of interdependent elements, changes in one of the parameters of which leads to a change in the whole system, as well as the basic algorithms that lie in basis of this system.

2.3. Parametric design.

In the process of designing a new product, or customizing an existing one, many tasks arise for combining data of different generation and characteristics that are dependent and independent from each other. Thus, the process of designing a complex product can be delayed, and making changes to an existing project can give rise to a series of self-replicating errors, significantly complicating
the process of further work. Especially, in a situation with a predominance of "manual" operations in the project.

The undoubted advantage of automation of technological processes is a significant reduction in time spent on product development. However, specialized CAD systems require the involvement of experienced technical professionals, who, unfortunately, are not enough to meet the needs of the industry. Thus, specialized CAD systems are ineffective or inaccessible to small enterprises or private practitioners. At the same time, the active expansion of additive technologies in all branches of industry allows us to implement the most ambitious ideas in the material, which, of course, attracts the attention of specialists from various fields (designers, marketers, etc.).

Against this background, parametric design seems to be attractive, allowing you to create algorithms for objects or processes of any complexity based on the analysis of data arrays, as well as their interaction in real time, which serves as a universal mechanism for creating both individual objects and entire systems. The scalability of projects is the most important property of this approach, which enables the specialist to manage the complexity of the project, to build any hierarchical structure [2, 4-7].

One of the most important properties of the parametric approach is its adaptability to environmental factors. Using the method allows you to create objects consisting of groups of autonomous elements. Some of these groups respond to the influence of external factors by changing the properties of the groups associated with them and, as a consequence, the system as a whole. For example, in response to a change in pressure force, the texture density and surface pattern of the material change.

2.4. "Rhinoceros & Grasshopper."

Universal parametric design tools such as Rhinoceros and Grasshopper allow a creative specialist to realize ideas that are difficult to understand, easily translating them into an algorithm language and expressing them in a visual modeling environment. It is the creator of the concept that can choose from a variety of design parameters that are most important for the full implementation of his plan. Also, any number of changes are made quickly and clearly, without requiring the replication of repeated operating cycles.

For example, the motive of the collection is a cellular fractal structure, in which each element, having its own set of parameters, is part of another cellular fractal structure, being one of the parameters for its element. Generally speaking, this is a kind of grid located inside another grid that is inside the third grid, etc. And, thanks to additive technologies, such as 3D printing on fabric, collections of this kind, including scalable parametric motifs, are now not uncommon (Atlantis Plato, Alexander McQueen).

The synergy of the designer’s creative intent and capabilities of digital design technologies allows us to take a fresh look at the growing role of form and its embodiment in the modern fashion industry. The development of the natural sciences shows us the evolution of complex objects of animate and inanimate nature, as, kind of, derived from the processes of fusion, division and transformation, fueling the interest of scientists and designers in biomorphic and topomorphic objects. Complex objects of living nature undergo significant transformations under the influence of many laws throughout the life cycle, providing a vivid example of the parametric principles of shaping in the environment.

2.5. "Wearable technologies."

Such project logic implies reaching a fundamentally different level of creating clothes and shoes - the level of formation of the vital membranes of the human body, its "small infrastructure". According to some scientists, in the near future it will be possible to design complex objects and systems in those areas of life where shells created or built according to the principles of molecular synthesis will arise directly at the object of application of their functions, and shape and design correction will occur by changing the software code. Outdated or faulty elements of such an infrastructure will be able to be updated or self-repaired according to the same algorithmic principles. Futurologists believe that clothing and the environment, united by a unity of functions, will have their own ecosystem, harmoniously integrated into the surrounding nature.

Modern materials containing natural fibers, such as silk, as well as nanoparticles of an electrical conductor, flexible sensors, etc., make smart fabrics a reality. Sports and physical activity are not always equivalent to “health” and “safety”. Therefore, intelligent sportswear for diagnosis and prevention is included in everyday life. However, the inclusion of technological components in clothing requires a change in the thinking of both manufacturers and consumers. Therefore, for integration into our everyday life, “smart clothes” is becoming more and more like everyday clothes.

The increase in the density and concentration of the urban environment, the acceleration of social processes, the need to provide protection and comfort at various standards of consumption, forces engineers and designers to use new adaptive parametric technologies and materials.

3. The solution to the problem

We see that the problems of increasing the availability of individual shoes, as well as effective prevention and early diagnosis of disorders of the musculoskeletal system, can be solved by:

- targeted popularization among the population of individual printed shoes and orthopedic insoles;
- the advent of inexpensive domestic equipment for 3d printing;
- established production and technological cycle;
- flexible client-oriented service, including protocols for remote and virtual interaction between production and the end user.

3.1. Hypothesis - the production of affordable individual shoes printed on a 3D printer is possible due to the availability of available equipment, supplies and software, as well as:

- a well-developed base of parametric models;
- algorithmic design in real time for customization of models from this base;
- mobile client service and VR / AR technologies (mobile offices, virtual fitting and mobile application).

3.2. Goal

The purpose of the work is to increase the efficiency of technological processes in the domestic shoe industry and the quality of manufactured products.

3.3. Tasks of work:

- create an algorithm for converting graphic data of foot pressure force to the surface obtained as a result of scanning into a digital model of upper and lower parts of shoes made of 3D-printed material with a reconfigurable relief structure, the density and height of which depend on the pressure force;
- analyze the properties and behavior of the digital model of the upper and lower parts of the shoe;
- create prototypes and samples of a digital model;
- analyze the change in their elastic properties depending on the materials used;
- implement the results in the form of a working module of the technological complex of parametric design and quick 3d printing of individual shoes in the format of a mobile salon.
4. What is planned to be achieved:

1. Create an effective algorithm for converting the data of scanning the pressure force of the foot onto the supporting surface, into a digital model of the upper and lower parts of the shoe with a reconfigurable relief structure for quick printing of individual shoes in the format of mobile salons;
2. Create a database of digital models of upper and lower shoe parts;
3. Create a work module for the technological complex of parametric design and fast 3d printing of individual shoes in the format of a mobile salon.

5. Methods and tools for implementation:

Methods of data collection and analysis:
- This work analyzes sources on the topic, the results of laser foot scans, conducts experimental studies to create digital models of materials with a reconfigurable structure and simulate their behavior, as well as studies of real materials (sheets and filaments).
- Prototypes are created, and their elastic behavior is analyzed taking into account the properties of real materials and boundary conditions.

Tools and equipment:
- BY,
- 3d printers,
- results of 3D scans,
- sheet materials,
- filaments.


6.1. The optimal network structure of the 3D shoe printing mobile showrooms, in our opinion, should include:
1. One head office, in which there is one designer, one technologist, one orthopedist, as well as a base of models, blocks, soles, materials.
2. N-number of mobile salons equipped with all necessary equipment, in which there is one operator who controls a 3D scanner, a 3D printer, communicates with customers, courier service and head office, receives and issues orders.
3. Logistics department-warehouse, connecting the network with the supply center, delivering orders to customers involved in transportation.
4. The client communicates with the designer and orthopedist remotely. Mobility allows you not to get attached to the location and move the salon to the points of maximum concentration of the target audience (various social centers, events, etc.)

6.2. The basic technological cycle will consist of the following steps:
1. The only appeal: the client comes to the mobile salon, where he selects a model from the catalog or develops an individual one together with a specialist who conducts a topological analysis of the distribution of foot pressure on the supporting surface and interprets the results of the study. The client receives a digital scan model of their feet on digital media; if necessary, additionally consults with the designer and orthopedist.
2. After receiving the order, the specialist conducts a more detailed morpho-functional analysis of scan results.
3. Next, the selection of materials for printing is carried out depending on the configuration of the three-dimensional structure and the number of its layers, the pressure value.
4. The algorithm of the interdependence between the pressure zones and the density of the relief pattern is established.

5. Relief modeling is carried out, the vector model is converted to a solid model to be sent to the preparation program for 3d printing.
6. A new design for the details of future shoes is being created. If necessary, customization of the finished design solution from the catalog is performed.
7. Directly in the salon or in the central office (depending on the complexity of the project), 3D printing of the upper and lower parts of the shoes is performed, their connection.

All clarifications with the client are carried out remotely through instant messengers or the company's information portal in 24/7 mode. It is also possible to develop a virtual application for trying on a product before delivery or during production / alteration.
Shoes are delivered to the client by courier or mail, (pickup possible).

6.3. Expansion Technology Cycle:
1. Products can be equipped with additional tools, for example, nanospray-preventive disposable socks, for gentle and comfortable use of shoes and protect the foot from scuffs and calluses.
2. Depending on the polymers used, micro-offices may provide services for collecting used 3D shoes for further processing.
3. As a marketing move, as well as a scaling element, you can offer customers a kind of “designer” of individual elements (soles, upper parts, individual pads, 3D models of feet), 3D handles and the corresponding polymers for independent amateur customization of individual shoes at home.
4. In addition, it is possible to integrate systems of elastic sensors into shoes for timely diagnosis and prevention of diseases according to the position of the body in space and the difference in pressure of the foot sections to the surface. And with the help of its own mobile application, “smart shoes” will instantly inform its owner about an error in the distribution of load on the joints during training or in ordinary life.

7. The expected result and directions of its practical use.

It is planned to create an effective algorithm for converting graphic data of the pressure force of the foot to the surface, obtained as a result of scanning, into a digital model of the upper and lower parts of shoes with a reconfigurable relief structure, the density and height of which depend on the pressure force, in order to quickly print individual shoes in the format of mobile salons.

The final product, in essence, is a complex consisting of prompt customer service, affordable technology, environmentally friendly materials and high-quality individual shoes for all categories of the population at an affordable price.

8. A wide target audience.

Accessibility, efficiency, the possibility of cheapening by ordering standard models from the catalog, unlimited possibilities of customization, as well as providing quality service to customers with special needs and orthopedic problems make the product suitable for all categories of the population.


- The modular structure with reduced labor costs enables both remote service and business scaling to the regions, regardless of their economic and environmental conditions, as well as the sale of franchises.
- In addition, the development of hardware, software, mobile applications, integrable “smart” blocks, materials, both for business and for the end user, provides an opportunity to develop in these areas.

Separately, it is necessary to mention the target audience with special needs.
The estimated competitive advantages of the methodology for the target audience with problems of the musculoskeletal system:
• unloading of the ankle, knee and femoral joints, lumbosacral spine, and, as a result, reduction of pain in them;
• posture and gait correction;
• the ability to track the dynamics of changes;
• prevention of surgical interventions on the joints of the lower extremities and lumbosacral region [3].

10. Explanatory Note

11.1. Purpose and scope:
- for a wide consumer of affordable individual shoes;
- for the target audience with problems of the musculoskeletal system.

11.2. Specifications.
Algorithm for translating graphic data obtained by scanning the foot into digital models of the upper and lower parts of shoes with a reconfigurable relief structure, the density and number of layers of which depend on the foot pressure on the surface.

11.3. TEP.
Based on assessments of the results of the practical implementation of parametric design tools in related fields, we can assume a significant reduction in the following indicators:
- 12-15% reduction in the cost of paying for production downtime, as well as energy consumption by reducing downtime in the technological cycle, its acceleration and simplification;
- the residual carbon footprint from shoe production will be reduced by 30-35%;
- the development and customization of the product will be reduced by 50-60% due to the base of parametric digital models.

11. Conclusion

Currently, the work is at the stage of developing an algorithm for converting graphic data obtained as a result of scanning into digital models of upper and lower parts of shoes with a reconfigurable relief structure, the density and height of which depend on the force of the foot pressure on the surface. But it is already possible to draw a preliminary conclusion that the unification of this process, with the receipt of a library of such samples, will several times reduce the time spent on the development of prototypes and their customization.

Directions for further research:
• Parametric programming algorithms;
• Latest software and algorithmic design technologies;
• 3D printing technology;
• 3D scanning technology;
• Consumables, filaments.

12. Literature

1. Li and Tanaka. Feasibility study applying a parametric model as the design generator for 3D-printed orthosis for fracture immobilization. 3D Printing in Medicine (2018) №4.
Automated design of proposal for new construction knitting unit consisting of a needle bed, needles and CAM systems for flat knitting automatic machine

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Abstract: The work proposes a new design of a new kind of knitting unit consisting of a needle bed, needles and cam systems that allow selection in operation only with the needles on the needle bed without any other additional details, such as springing or stopping jack. The proposed construction is designed in accordance with the requirements of modern flat knitting machines with the possibility of individual needle selection. Because the structures are interdependent, the braiding systems are designed to work only with the new proposed needles and needle bed construction. The three new construction for needle, needle bed and cam systems are aligned with one another and allow the introduction of a new principle for electromechanical needle selection with a special electromechanical selector operating with negative selection, i.e. turns the needle off when is on. The choice is made by working with needles with three types of butts, short and long, one-sidedly rounded, and long two-sidedly rounded, as well as with cam systems divided into two parts. This makes it possible to remove the additional details used in existing methods. Which would lead to a reduction in the depreciation of the machine and, consequently, to a lower maintenance cost. The designs are designed in Solid works environments, providing excellent exploration and dynamic visualization capabilities.

Keywords: FLAT KNITTING MACHINES, KNITWEAR, CAM SYSTEMS, KNITTING

1. Introduction

In today’s knitwear production, the main trends that are developing are increasing the capacity of the machine’s sample, reducing the time for knitting the parts and the possibilities for a quick transition from one model to another. This inseparably adds to the complexity of the basic structures by adding additional elements, which subsequently results in more depreciation and consequently higher maintenance costs for the machines. [1,6,7]

These trends also lead to a wide variety of flat knitting machines, which also leads to a huge diversity in the basic mechanisms involved in the contour formation process. Such mechanisms are: cam systems, pull mechanism, thread control mechanism and more. These mechanisms for each machine model are differentiated for the specific type of machine, with the individual details aligned with the location and construction of the others to accomplished the knitting process. This leads not only to the specificity of the mechanisms used in machines manufactured by different companies, but even from different models of the same company. This naturally affects the actuators because of their direct relationship to the location, position, and trajectory of the knitting needles performed by the knitting mechanism to create the individual knitting structures, but also respectively of the structure and knitting needle. For this reason, the location, profile and drive of the cam systems must be consistent with the trajectory of the knitting needles and the restrictive metal strip located on the needle bed. [1,6]

2. Implementation

As already mentioned, the designs of the needle bed, the needles and cam systems, as well as their propulsion, respectively, are interconnected, and accordingly changes in the structure of one mechanism would automatically lead to changes in the others. [2,3,4]

The uniqueness of the proposed mechanism is that its cam systems are made of two parts and not one. The upper knitting loop and the lower knitting tuck, this in itself also leads to adjustments in the design of the needle bed and the construction of the knitting needle, which is driven by three types of butts, upper systems working for stitch loop formation, and lower for tuck loop formation or miss loop, and ultimate butt in knitting field selection.

Fig.1 Knitting carriage with the complete design of the cam systems.
Figure 1 shows an image of a knitting carriage showing the complete structure of the cam systems, each mechanism being assigned a corresponding position number. Position number 1 shows the knitting mechanism of the knitting carriage, which, as can be seen, is divided into two parts upper and lower. The upper as mentioned above determines the trajectory of the knitting needle by means of its short butt located at the upper end of the needle for knitting or transmitting needle upon transferring, and the lower forms the trajectory of the tuck loop or receiving needle by its long butt located in the middle of the needle. [4,5]

The designations of positions 2 and 9 represent selector mechanisms for the direct selection of needles determining the working and non-working needles for determining the respective knitting structure. The two selector mechanisms operate independently and sequentially depending on the direction of moving of the knitting carriage. When moving from right to left, the left one, shown in the figure 2, will work, since the lower part of the knitting carriage is represented, and the one with position number 9 will be included in the opposite direction. As shown in the figure, the two mechanisms are located. This is necessary due to the fact that the selectors select the needles in the immediate vicinity of the knitting mechanism. The selector mechanisms are again divided into two parts, the upper working with the short butts and the lower working with the long needle butts. In addition to having two sets of selectors, the main original part of the selector mechanism is the principle of needle selection, which is a combination of the applied selector mechanisms in modern flat-knitting machines allowing individual needle selection and older models allowing only group choice of needles.

The presented construction allows for the individual choice of needles, through an electromechanical approach, whereby by means of a selector with a special form forming a pushing canal and performing a reciprocating motion to the needle bed and driven by an electromagnet, it changes the trajectory of the knitting needle by pressing the canal is in the butt of the needle, which has a rounded portion on the side of the canal, and pushes it towards the bottom of the needle bed, thereby leading it out of its knitting trajectory. [3,4]

The numbers 5 and 6 of the figure show the selector mechanisms determining the knitting field and involved in the inclusion and exclusion of knitting needles in the manufacture of fully fashion garment.

As with the needle selector mechanisms, here again we have two sets of left and right, which are mirrored relative to the knitting mechanism. Both sets are equipped with the same type of selectors that operate independently of one another. When the knitting needles are switched on, the inner selectors work, with the two selectors on the left 5 or right 6 sets sequentially engaged in two different loop rows when the knitting carriage moves toward the knitting field, depending on the direction of its movement. To exclude knitting needles, with the same rule being excluded in two consecutive rows, but in this case when leaving the knitting field. As can be seen with the selectors determining the knitting field, the on and off selectors are mirror-mounted and therefore the knitting needles have a rounded end of the heel on both sides. From this we can see the mentioned interconnectedness of the different mechanisms involved in the knitting knot. [3,4,5]

In the same figure, positions 4 and 7 show permanent magnets used to collect small particles or broken needle heels in order to prevent the broken butt from being hit or wedged in the wedges of the cam systems.

Position numbers 3 and 8 in Figure 1 indicate brushes mounted on the knitting carriage plate represented by position number 10. The brushes are positioned for both cleaning the accumulated moss and for assisting the opening of the tabs of the latch needles. The plate is practically the basic detail of the knitting carriage, ensuring the positioning of all other details.

Figure 2 shows a realistic three-dimensional view of the knot needle bed assembly, a needle knitting mechanism in a 2x2 spacer trajectory. In the image, some of the details are represented by translucent images, such as the plate, for example, to make the details below them visible. The presented figure also gives an opportunity to get an idea of the drive of the individual modules from the cam systems.

Figures 3 and 4 represent respectively a two-dimensional and three-dimensional section view of the knitting carriage, needles and needle bed in the molding process, which makes it possible to see the arrangement of the needle butts with respect to the lifting and removing wedges, and the selectors of the cam systems.

3. Conclusion
The proposed construction is designed in accordance with the requirements of modern flat knitting machines with the possibility of individual needle selection. The three new proposals for needle, needle bed and cam systems are aligned with one another and allow the introduction of a new principle for electromechanical needle selection with a special electromechanical selector operating with negative selection, i.e. turns the needle off and on. The choice is made by working with needles with three types of butts, short and long, one-sidedly rounded, and long two-sidedly rounded, as well as with cam systems divided into two parts. This makes it possible to remove the additional details used in existing methods. Which would lead to a reduction in the depreciation of the machine and, consequently, to a lower maintenance cost.

Fig. 3 Two-dimensional section of the knitting carriage, needles and needle bed.

Fig. 4 Three-dimensional section of the knitting carriage, needles and needle bed.

References

5. Manolova R. “Automated design of proposal for new construction cam systems for flat knitting automatic machine. Part 2- construction of a drive for knitting mechanism, providing raising and take down cams that modeling of trajectory of knitting needles.” BJED, issue 33/2017 71-76.
Parametric modeling - review of the methodology and a few softwares, used in the civil engineering

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Abstract: This review is aimed to present a group of OOP and OOM languages that support CAD systems and their concept – abstraction, polymorphism, inheritance, encapsulation, object, class, cohesion and coupling. It is given a list with programming languages who take part in OOP and calculation of complex mathematical and physical computations. The problem of communication between different disciplines in the construction process and the challenges of solving more complex and global solutions is addressed. The parametric modeling is represented as a powerful tool and way to solve compound graphical, geometrical and mathematical tasks by using visual programming.

Keywords: BIM, SOFTWARES, OOP, REVIEW, PROGRAMMING LANGUAGES, THEORY, PARAMETRIC DESIGN, CAD.

1. Увод

Строително-информационното моделиране е първа стъпка към фундаменталните промени в методиката на архитектурно-строителното проектиране, вкл. виртуалните и инженерни симуляции. Създаването на тримерни обекти, съъставяни от данни и атрибути, стои в основата на един иновативен съвременен подход в проектирането на инженерно-строителните проблеми. Изследването на функционалността на строителните съоръжения, конструкции и материали се свежда към изследване на влиянието на различни отдели параметри или групи параметри върху поведението на отделни елементи на дадена система, в последствие на цялата разглеждания система. По този начин се създава йерархия на изследваните технически и/или последствие на цялата разглеждания система. По този начин се създава йерархия на изследваните технически и/или последствие на цялата разглеждания система. По този начин се създава йерархия на изследваните технически и/или последствие на цялата разглеждания система. 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Капсулиране – способността да бъде скрита детайлна информация, с която да се улесни работния процес. Основен принцип при капсулирането е върху группирането на сродни информация, при което не се разрешава на поведението на класа по нов начин, който не е програмиран първоначално в него [4].

Полиморфизм – възможността да се работи по един и същ начин с обекти и/или класове като се дефинира различна имплементация на зададено абстрактно поведение. Този метод на работата с обектите дава различни резултати спрямо първоначално заложените им характеристики [4].

Наследяване – това е основен принцип в ООП. Позволява да бъдат дефинирани нови характеристики през задаване на параметри и/или разширяване на първоначално заложените такива на съществуващи обекти. Използването на класове е най-популярният метод за наследяване [4].

Свързаност на отговорности и функционалност – принципи, които са неделима част от ООП, защито допълват и изграждат базовите принципи и методи. Свързаността показва степента на взаимодействие в рамките на една програма или съответен компонент за решаването на една единствена задача. Свързаността се класифицира в две групи: I) сила, при която елементът изпълнява една единствена задача и дава добри резултати; II) слаба, при която се изпълняват няколко задачи с елементът изпълнява една единствена задача и дава добри резултати; II) слаба, при която се изпълняват няколко задачи с различен фокус. При втория подход резултатите често не са достатъчно изчерпателни [4].

В табл. 1 е приложен кратък списък на програмни езици, които се използват в различни области на инженерната и индустриалната автоматизация, математически изследвания, приложими и в областта на изкуствения интелект. Индустриална автоматизация, математически изследвания, които се използват в различни области на инженерната и достатъчно изчерпателни различен фокус.

Свързаност; II) слаба, при която се изпълняват няколко задачи с различен фокус. При втория подход резултатите често не са достатъчно изчерпателни [4].

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Таблица 1: Класификация на програмните езици по популярност, употреба и степен на трудност на изучаване [5.6. 7].

<table>
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<tr>
<th>№</th>
<th>Наименование:</th>
<th>Популярност:</th>
<th>Употреба:</th>
<th>Сложност на изучаване</th>
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<td>Python</td>
<td>Много висока</td>
<td>ООП, Изкуствен интелект, Машинно самообучение</td>
<td>Ниска до средна сложност</td>
</tr>
<tr>
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<td>Специализирано и общо предназначение</td>
<td>Средна до висока сложност</td>
</tr>
<tr>
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<td>Висока</td>
<td>ООП</td>
<td>Труден</td>
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<tr>
<td>4</td>
<td>Objective-C</td>
<td>Висока</td>
<td>ООП</td>
<td>Висока сложност</td>
</tr>
<tr>
<td>5</td>
<td>Ruby</td>
<td>Висока</td>
<td>ООП, Общо предназначение</td>
<td>Ниска до средна сложност</td>
</tr>
<tr>
<td>6</td>
<td>Matlab</td>
<td>Средна</td>
<td>Специализирано предназначение, Математически изследвания</td>
<td>Средна до висока сложност</td>
</tr>
<tr>
<td>7</td>
<td>F#</td>
<td>Нишов език</td>
<td>Не е език за ООП, Има общо и специализирано предназначение, Математически изследвания и</td>
<td>Средна до висока сложност</td>
</tr>
</tbody>
</table>

3. Анализ на функционалните възможности на някои софтуери за архитектурно-инженерното проектиране и програмните езици за взаимодействие между тези софтуери.

Аutomатизираното архитектурно-инженерно проектиране е енергоемък процес. С въвеждането и прилагането на хармонизираните европейски стандарти, изискванията към строителния процес се увеличават на национално и европейско ниво. Тези проблеми са предмети на много дискусии и публикации. В един анализ на тема устойчиво строителство, публикуван във вестник „Строител“ [8, 9], са засегнати множество проблеми: „На строителната индустрия се разглежда въпроса за социални, климатични и енергийни представяваща и да играе основна роля в извънствие на много важни политически за устойчиво развитие, тъй като в своите дейности може да използва технология, която са отговорни за охлаждане на околната среда и за ефективно оползотворяване на ресурсите през целия жизнен цикъл на сградата – от избора на строежа през проектирането, изграждането, експлоатацията, поддръжката, обновяването до разрушаването.” За решаването на тези казуси, CAD и BIM-системите дават добри решения по отношение на изграждането, експлоатацията и поддръжката на сградния фонд.

Строително-информационното моделиране дава информация за всеки елемент от обекта, технически данни и местоположението му в тримерното пространство и създава възможности за оптимизация на времето и средствата по изграждане и поддръжка на строителните съоръжения и стради.

Фиг. 2. Принцип на обектно-ориентираното моделиране.

На фиг. 2 е показана принципната схема на обектно-ориентираното моделиране. Аналогията между фиг.1 и фиг.2 показва еквивалентната концепция работи при ООП и ООМ [12]. Параметричното моделиране [2, 10] е процес, при който дизайнът на обектите при архитектурно-инженерното се задава чрез програмен код. Кодът се осъществя чрез скрит или
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FreeCAD</td>
<td>FreeCAD is a powerful open-source 3D modeling software. It integrates design and visualization tools for 3D modeling. It supports various design workflows, allowing for interactive object manipulation and design features.</td>
</tr>
<tr>
<td>2</td>
<td>Rhinoceros</td>
<td>Rhino is a powerful software tool for 3D modeling and design, suitable for industrial and architectural projects. It supports wide range of design features, such as parametric modeling and surface design.</td>
</tr>
<tr>
<td>3</td>
<td>Fusion 360</td>
<td>Fusion 360 is a versatile cloud-supported design software that allows for collaboration and sharing of design ideas. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
<tr>
<td>4</td>
<td>Solidworks</td>
<td>Solidworks is a powerful design software suitable for industrial projects. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIA</td>
<td>A powerful software for parametric design and engineering. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
<tr>
<td>OpenSCAD</td>
<td>OpenSCAD is a powerful open-source software for 3D design and visualization. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
<tr>
<td>Vectorworks</td>
<td>Vectorworks is a powerful software for 2D and 3D design and visualization. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
<tr>
<td>Revit</td>
<td>Revit is a powerful software for architectural design and construction. It supports various design workflows, such as parametric modeling and surface design.</td>
</tr>
</tbody>
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### Table 2: Software with functionalities and requirements

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>CATIA</td>
<td>Profesional license - Requires a paid license.</td>
</tr>
<tr>
<td>OpenSCAD</td>
<td>Profesional license - Requires a paid license.</td>
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<tr>
<td>Vectorworks</td>
<td>Profesional license - Requires a paid license.</td>
</tr>
<tr>
<td>Revit</td>
<td>Profesional license - Requires a paid license.</td>
</tr>
</tbody>
</table>

### Table 3: Comparison of software features

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<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIA</td>
<td>Supports parametric design and modeling.</td>
</tr>
<tr>
<td>OpenSCAD</td>
<td>Supports parametric design and modeling.</td>
</tr>
<tr>
<td>Vectorworks</td>
<td>Supports parametric design and modeling.</td>
</tr>
<tr>
<td>Revit</td>
<td>Supports parametric design and modeling.</td>
</tr>
</tbody>
</table>

### Table 4: Comparison of software costs

<table>
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<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
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<tr>
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</tbody>
</table>

### Table 5: Comparison of software requirements

<table>
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<th>Name</th>
<th>Description</th>
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<tr>
<td>Revit</td>
<td>Requires a paid license.</td>
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</tbody>
</table>
Таблица 2 е представена с цел кратко систематизиране на по-добро познаване и насочване на вниманието на проектантите и изследователите от различните специалности, за да ги информира за съществуващи на пазара софтуерни решения, които повишават продуктивността чрез решаване сложни проблеми и получаване на детайлировани резултати. Лицензите на повече от тези програми са скъпи, но компанияте дават възможност на ученици, студенти и изследователи да се възползват от функционалността им възможности. По този начин бъдещите специалисти ще бъдат подготвени и отворени към предизвикателствата на професията за превръщане на идеите в реални продукти и системи, изграждащи едно устойчиво и новаторско общество, решаващи проблеми като тези споменати във вестник „Строител“ [8, 9].

4. Изводи

Направеният обзор на групи от програмните езици, софтуерите за проектиране и влизат в сила стандарти и норми, показва, че с развитието на високите технологии се променят и методите за решаване на проблемите на съвременното общество. Една индустрия като строителството, която по подразбиране е възприета като консервативна, с бързи темпове се развива чрез автоматизация на инженерния труд. Това е съществен резултат от динамиката на живота на съвремения човек и стремежа му към ефективност, безопасност, устойчивост в своето развитие. Програмирането и инженерното проектиране намират допирни точки с цел решаване на комплексни задачи от по-високо ниво. Обектно-ориентираното моделиране дава база за нова концепция на мисленето и развива по иновативен начин методите за анализ, изследване и взимане на решения. Параметричният дизайн [2] чрез неговата възможност да „програмираш“ обект повишава продуктивността на специалистите. Нормативната уредба и стандарти също включват критерии и изисквания към сградния фонд с цел покачването качествено на изпълнение в строителството. Обектите, моделирани в строително-информационното моделиране служат като виртуално досие на сградите и съоръженията. В него се създава подробната информация за местоположението и функционалността на всеки елемент от сградата, което позволява ефективна и дълготрайна експлоатация. Прегледът на световния опит показва, че това е пътят към създаване на нови и усъвършенствани технологии за проектиране и управление на самостоятелна сграда до цели мегаполиси.

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Abstract: Artificial neural network (ANN) is a computer model that was originally designed to simulate the properties and operation of the human brain. Unlike other computer systems, ANN is taught through examples, most often accumulated through observations. This technology has been developing for several decades and its applications are multiplying in all areas. This publication aims to present the possibilities of using the concept of ANN in architectural and construction applications. Basic concepts related to neural networks (neurons, layers, connections, weights, training, strategies, etc.) and various activation functions are discussed. The advantages and disadvantages of neural networks are analyzed, rules and useful guidelines are given for their use. In this context, an overview of many ANN solutions available by 2020 on various tasks related to the design and civil engineering is proposed.

Keywords: NEURAL NETWORKS, NEURAL LAYERS, BACK-PROPAGATION, ACTIVATION FUNCTIONS, REGRESSION ANALYSIS, CLASSIFICATION, IMAGE RECOGNITION

1. Увод

През 1958 г. Франк Розенблат за пръв път предложи концепцията за електронно устройство, наречен перцептрон [1], което би трябвало да може да имитира човешкото мислене. Тази разработка поставя началото на т.н. изкуствени невронни мрежи (ИНМ, ANN – Artificial neural networks), които се състоят от определен брой взаимосвързани елементи, наречени неврони (neurons). Те са организирани (фиг. 1) в 2, 3 и повече слоеве (layers), които взаимодействат помежду си с тежестни коефициенти (weights), които определят силата и влиянието на свързаните неврони. Всеки неврон е свързан с всички неврони в следващия слой. Задължително има input layer, който включва входните данни, които се подават на ИНМ. Има и слой за резултати (output layer), който показва реакцията на ИНМ на подадените входни данни. Има и междинни „скрити“ слоеве (hidden layers), които позволяват да се моделират сложни взаимовръзки между входа и изхода.

Въведен момент при разработването на ИНМ е определянето на броя скрити слоеве и техните неврони. Не съществуват твърдо установени правила или технология, най-често броят се определя с експериментиране, като се търсат най-малка грешка.

Процесът изисква натрупване на комплекти от входни параметри и сама разграничава влияещите от невлияещите входни променливи, които участват като входни параметри за ИНМ. Желателно е броят входни параметри да е много голям. Все пак трябва да се отбележи, че ако сред въведените параметри попадат такива, които не влияят на търсените резултати, след обучението на тях ще се съберат нулеви или почти нулеви стойности на тежестните коефициенти, т.е. невронната мрежа по време на обучението си сама разграничи влияещите от невлияещите входни параметри [3].
съответен на тях търсен резултат (или резултати). Обучението трябва да разполага с достатъчно голяма и представителна база данни. Препоръчва се за обучението да има от 5 до 10 записа за всеки тежестен коефициент [4]. Тъй като невронните мрежи се обучават на линейни взаимовръзки по-ефективно, една от целите при изготвянето на данните е да се намалят нелинейността. Ако данна данных X е решепчона на резултата, по-ефективно е вместо нея да се използва (1/X) [3].

Още една причина налага предварителната обработка на данните, преди използването им за обучение на ИНМ. Това е използването на лог-синомодална (или друга подобна) активационна функция. Тя води до стойности на изхода от всеки неврон в обхвата от 0 до 1. Това налага нормализация на резултатите. Ако данна данна нормализира минимална и максимална стойности, съответно \( V_{min} \) и \( V_{max} \), при стойност \( V \), нормализираната \( V \) стойност се определя чрез формула (6):

\[
A = \left( V - V_{min} \right) / \left( V_{max} - V_{min} \right)
\]

Така подготовените комплекси входни данни и резултати се делят на две групи: 1) за обучение на ИНМ, и 2) за тестове на обучената ИНМ, в съотношение 2 към 1. Обучението започва с случайни начини стойности на тежестните коэффicients на невронните. След това ИНМ се захранва с подготовените за обучение данни и с помощта на обратно разпространение на грешката постепенно настройва своите коэффicients. Обучението продължава, докато средната квадратна грешка за всички комплекси данни за обучение в една епока падне под определена, предварително зададена минимална стойност.

Няма твърди правила за определянето на броя неврони в скрития слой. Ако той е твърде малък, ИНМ може и да не успее да реши задачата и да намери правилното съответствие между входни данни и резултати. При тези възможни връзки между невроните, увеличава времето за обучение, а понякога води и до поява на грешка постепенно настройва своите коефициенти. Обучението продължава, докато средната квадратна грешка за всички комплекси данни за обучение в една епока падне под определена, предварително зададена минимална стойност.

След обучението, ИНМ се тества с предварително отделена част от данните, като целта е средната квадратна грешка да остане под предварително зададена стойност.

Тежестните коэффicients могат да бъдат положителни или негативни (отговарят на възбуждащи връзки между невроните) и подаваните входни данни да са в същия обхват, като входните данни. Този процес се повторя, докато средната квадратна грешка за всички комплекси данни за обучение в една епока падне под определена, предварително зададена минимална стойност.

Основните задачи, които се решават с методите на искусствения интелект, в частност с ИМ, са:

- функционално/ретрорецепционен анализ, включително предиктивни модели, апроксимиране и моделиране;
- класифициране, разпознаване на схеми (patterns) и образи, вземане на решения;
- обработка на данни, в това число къстърризироване, филтриране, разпределение и компресиране;
- разпознаване и генериране на реч, разпознаване на изображения;
- управление на трафик и маршрутизация;
- автоматизация на проектрането.

2. Приложения на невронните мрежи в архитектурно-строителните задачи

Тази технология се развива всечно няколко десетилетия и приложенията във всички области. Класификация на някои приложения на невронните мрежи в областта на архитектурно-строителните задачи са направени през 1995 г. от Goh [3], както следва: моделрениране на материали [5]; оценка на дефекти и повреди – чрез анализ на изображения (фотографии) [6,7]; структурен анализ и дизайн [8-11]; оценка на съвместно втягане [12] и др.


В областта на архитектурните проблеми решения с помощта на ИНМ са сравнително редки. В [18] е разгледан пример как архитектурни решения могат да бъдат оценявани с помощта на ИНМ, обучена с емпирични данни от 56 сгради.

За разлика от архитектурната проблематика, в областта на строителното инженерство се наблюдават много по-големи размери примери за използване на ИНМ. Например в [19] се разглеждат стоманобетонни греди, които се изследват за провисване в 3 сечения на 3 образца. Гредите са с правоъгълно сечение 100 x 200 mm и отвор 2,1 m. При наговарване с 1/7 от оразмерителния огъващ момент се поява пукнатина и следва превразпределение на напреженията. При оразмеряване по EC2 за представителни 3 греди са получени разлики от 21% спрямо експерименталните данни. В изследването е предложен алтернативен подход с обучаване на ИНМ с данните от 293 измерване на провисване на 3 греди. Използвана е ИНМ със скрит слой с обратно разпространение на грешката. Входа се подават 4 параметъра: модул на еластичност на бетона \( E_c \), модул на еластичност на стоманата \( E_s \), площ на стоманената армировка \( A_s \) и огъващ момент \( M \). Модулът на скрит слой се състои от 30 неврони. ИНМ се обучава за 200 епохи. Резултатите са получени при изследването показват 2,5% относителна грешка в 70% от случаите.
В [20] е представено изследване на стоманобетонна колона, подложена на нецентричен натиск при едностранино температурно въздействие. За решаване на представения проблем е разработен софтуерен продукт FIRE, който изчислява статическият натоварване по моделите със стоманобетонен материал на крайните елементи и температурното въздействие чрез интегриране с времева стъпка. С помощта на програмата са решени 398 примера. За всеки от тях се вземат на входа размерите на правъгълен сечението $b$ и $d$, дебелината на бетоновото покритие $a$, процент на армирова $\mu$, относителното $\eta$ и $\eta/M_{\text{max}}$, където $\eta$ е соавата сила преди пожара, $M_{\text{max}}$ е максималната нормална сила при нула е гравитационна сила. При тези параметри се изчислява времето в минути, което ще издръж козената колона, без да загуби носещата си способност. С тези данни е обучена ИНМ с обратно разпространение на грешката с 5 входни вектора, един скрит слой с променлив брой неврони и един неврон на изхода.

Обучението трае 1000000 епохи. ИМ се конструира 9 пъти със скрит слой от 2 до 10 неврона и се обучава с едни и същи параметри. Най-добри резултати се получават при вътрешен слой с 9 неврони.

Интересен пример със стоманен мост с метална ортотропна плоча, която се усилва с ребра от метални профили в двете посоки, получените от изчисленията по различни норми, които не надминават 0,92.

В [23] е разгледан проблем с управление на градското движение. В големите градове броят автомобилите непрекъснато нараства и това води до често задържания, които от своя страна водят до загуба на време – отсъствие на работното място на голям брой от хора. Проблемът би могъл да се реши чрез установяване на няколко кръстовища, но това води до ангажирането на голям брой служители. За тази цел се използва ИНМ, която да използва ИНМ, да разработи софтуерен продукт за управление на мостът, като на входа на невронната мрежа се включват данни за скоростта на движението, които се изчисляват от изчисленията по различни норми, които не надминават 0,92.

Изследването показва, че скоростта на невронната мрежа се контролира от скоростта на движението, което е абсолютно приемливо. След откриването на невронната мрежа, се установява, че Невронната мрежа е достатъчно устойчива, за да се прилага в даден случай. Входните параметри са: $b$ и $d$, дебелината на бетоновото покритие $a$, процент на армирова $\mu$, относителното $\eta$ и $\eta/M_{\text{max}}$. Входите на ИНМ се разделят на два във вида: 1) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа, и 2) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа.

Входните данни са нормализирани и се разделят на две граници: 1) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа, и 2) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа.

При много геотехнически проблеми липса точна анатомична теория или модел за техните решения. В [24] са показани приложения на ИНМ в земната механика. Показан е пример с изчисляване на носимоспособността на пилоти.

Интересен пример със стоманен мост с метална ортотропна плоча, която се усилва с ребра от метални профили в двете посоки, получените от изчисленията по различни норми, които не надминават 0,92.

В [23] е разгледан проблем с управление на градското движение. В големите градове броят автомобилите непрекъснато нараства и това води до често задържания, които от своя страна водят до загуба на време – отсъствие на работното място на голям брой от хора. Проблемът би могъл да се реши чрез установяване на няколко кръстовища, но това води до ангажирането на голям брой служители. За тази цел се използва ИНМ, която да използва ИНМ, да разработи софтуерен продукт за управление на мостът, като на входа на невронната мрежа се включват данни за скоростта на движението, което е абсолютно приемливо. След откриването на невронната мрежа, се установява, че Невронната мрежа е достатъчно устойчива, за да се прилага в даден случай. Входните параметри са: $b$ и $d$, дебелината на бетоновото покритие $a$, процент на армирова $\mu$, относителното $\eta$ и $\eta/M_{\text{max}}$. Входите на ИНМ се разделят на два във вида: 1) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа, и 2) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа.

Входните данни са нормализирани и се разделят на две граници: 1) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа, и 2) скоростта на движението, която се изчислява на базата на тренинга на невронната мрежа.
3. Изводи

Настоящата публикация разглежда изкуствените невронни мрежи и приложението им в архитектурно-строителни задачи. Разгледани са основните понятия в концепцията и различни активационни функции. Анализирани са преимуществата и недостатъците на ИНМ, посочени с насоки за тяхното използване. Направен е кратък обзор на наличието към 2020 година решения, реализирани с ИНМ, на разнообразни задачи, свързани с проектиране и автоматизация на инженерния труд в областта на строителството.

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Optimization of pneumatic vane motor based on mathematical modeling and computer simulation

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Abstract: Pneumatic vane motors are important actuators in industry, their optimization is difficult without a best mathematic model and computer simulation. In this article we present a mathematical model for pneumatic vane type motors, construction of a simulation program associated with constructive engine parameters, experimental confirmation, and pneumatic motor performance optimization based on this model. The article begins with the description of the working principle of the vane type pneumatic motors, the geometric parameters that characterize it. The set of mathematical model equations consists in: the equations of geometry, the equation that describe the rotating moment, and equations expressing the mass flow into the motor. For the construction of the simulation program we have used the programming language of the G type LabView. Matching the results obtained from the simulation with the measured ones experimentally indicate that the built mathematical model is accurate and can be used to optimize pneumatic motors.

KEYWORDS: PNEUMATICS, PNEUMATIC VANE MOTOR, AUTOMATIZATION, FLUID-POWER, LABVIEW, COMPUTER SIMULATION.

1. Introduction

The principle of the vane motor is that a rotor with a number of vanes is enclosed in a rotor cylinder. The motor is supplied with compressed air through one connection and air escapes from the other connection.

To give reliable starting, the air pressures press the vanes against the rotor cylinder. The air pressure always bears at right angles against a surface. This means that the torque of the motor is a result of the vane surfaces and the air pressure.

To study the performance of vane motor is difficult without a best mathematic model and computer simulation. In this article we present a mathematical model for pneumatic vane type motors and the way to optimize them.

2. Preconditions

To build a mathematic model, assuming a polytrophic process and an ideal gas.

2.1 Mathematic Model

To construct the mathematical model of the pneumatic vane motor we will refer to the set of equations consisting of: equations describing geometry, equations expressing the rotational momentum of the rotor, and equations describing the mass flow of fluid passing through the motor.

Equations describing geometry

\[
\gamma = \frac{2\pi}{z} \quad (2.1.1)
\]

Where \( z \) is the number of vanes which is usually between 3 and 8.

The eccentricity \( ex \) is the difference between the inner radius of the cylinder and the radius of the rotor:

\[
ex = R_s - R_R \quad (2.1.2)
\]

the rotor angle \( \beta \) is a function of the stator angle \( \alpha \).

\[
\beta = \alpha - \arcsin \left( \frac{ex \cdot \sin (\alpha)}{R_s} \right) \quad (2.1.3)
\]

Geometric volume \( V_w \) of work chamber, volume between two vanes is given by:

\[
V_w = \frac{L}{2} \left( R_s^2 \cdot \beta - R_R^2 \cdot \alpha - ex \cdot R_s \cdot \sin (\beta) \right) \quad (2.1.1)
\]

Geometric volume \( V_{\alpha} \) of filling volume and the expanded volume \( V_{\exp} \), if the geometric data is available, see Fig. 2.1.2 given by:

\[
V_{\alpha} = \begin{cases} 
V_\alpha & \text{for } 0 < \alpha \leq \gamma \\
V_\alpha - V_{\alpha-\gamma} & \text{for } \gamma < \alpha \leq 2\pi \\
V_{2\pi} - V_{\alpha-\gamma} & \text{for } 2\pi < \alpha \leq 2\pi + \gamma 
\end{cases} \quad (2.1.2)
\]

The filling volume \( V_{\fill} \) and the expanded volume \( V_{\exp} \) if the geometric data is available, see Fig. 2.1.1. The ratio between the expanded and filling volume determines to what extent the internal energy of the air is used and is called the expansion ratio \( \varepsilon \).

\[
\varepsilon = \frac{V_{\exp}}{V_{\fill}} \quad (2.1.3)
\]

If a high expansion ratio is used, the engine power increases, but it may be that the air temperature in the supply equipment drops so much that it results in freezing of the water in the air by blocking the engine.

The nominal displacement volume is given by:

\[
V_{\text{disp, nom}} = V_{\fill} \cdot z \quad (2.1.4)
\]

Ideal engine torque

To construct the mathematical model of the rotational moment, we studied the thermodynamic processes. They include the equations for calculating the work, whose derivatives with
respect to time will give us the model of engine power and torque.

Figure 2.1.1 shows the volume of one compartment as a function of the rotation angle, Fig. 2.1.4 the corresponding PV diagram (assuming clockwise rotation of the rotor). State \( a \) is the beginning of the rotation when the vane opens the compartment and air fills the dead volume. In state \( b \) the compartment is completely filled with air of pressure \( p_1 \). While the rotor turns to \( c \), the volume of the compartment increases. This process is assumed to be polytropic and the air pressure can be calculated by:

\[
P_{1-e} = p_1 \left( \frac{V_{\text{exp}}}{V_{\text{fill}}} \right)^n = p_1 e^n \tag{2.1.5}
\]

Where \( n \) polytropic index, \( 1 \leq n \leq \kappa \), \( \kappa = 1.4 \) for air.

Typically a value of \( n = 1.3 \) is used (Daser 1969; Sbahi 1992). When the vane opens, the air discharges and the pressure falls to the surrounding pressure \( p_e \). This is the pressure at state \( d \) after the vane has closed the compartment and a reduction of the compartment volume begins. The air is compressed until at \( e \) the vane opens and releases most of the air to the second working port. Some air remains, state \( f \). The compression from \( d \) to \( e \) is often neglected.

The work from the whole process is the sum of the expansion work, the displacement work and the compression work. Assuming a polytropic process and an ideal gas, the work is given by:

\[
W = W_{\text{exp}} + W_{\text{disp}} + W_{\text{comp}} \tag{2.1.6}
\]

The power \( P \) of the motor can be calculated by differentiating the work \( W \) with respect to time. For the simulation model the torque \( T \) at the motor shaft is needed which is given by:

\[
T = \frac{P}{\omega} = \frac{1}{\omega} \frac{dW}{dt} \tag{2.1.10}
\]

The working radius of the shovel referred to in figure 2.1.5 can be calculated from the relation:

\[
X_\alpha = e x \cdot \cos \phi + \sqrt{B^2 - e x^2 \cdot \sin^2 \phi} \tag{2.1.11}
\]

The area \( A_v \) between the two shovels shown in light purple in figure 2.1.6 is calculated by the following equation:

\[
A_v = \frac{1}{2} \int_{\phi_1}^{\phi_2} X_\alpha (\phi) d\phi \tag{2.1.12}
\]
Referring to figure 2.1.7, the rotational moment will be described by the relation:

$$M = (p_a - p_b) \cdot (X_a^2 - r^2) \frac{L}{2} \quad (2.1.13)$$

**Mass flow**

Before the air can enter a compartment, it has to flow through long and narrow ducts whose resistance cannot easily be calculated analytically. There is also considerable leakage between the ports and through the bearing at the front side of the rotor.

Referring to Figure 2.1.8, we will express the mass flow through the equation:

$$\dot{m} = -\dot{m}_{from,1} + \dot{m}_{to,vol,1} \quad (2.1.14)$$

And through the equation of the ideal gas state:

$$p_1 = \frac{m_1 \cdot R \cdot T_0}{Vol_1} \quad (2.1.15)$$

The mass flow rate $\dot{m}_{to,vol,1}$ depends on the pressure at port 1. The mass flow through the motor can be calculated from the compartment volume and the pressure $p_1$. Assuming clockwise rotation, $\omega > 0$, the mass flow rate from inlet 1 of the stator to inlet e, $\dot{m}_{from,1}$, is given by:

$$\dot{m}_{from,1} = \frac{p_1 \cdot \omega \cdot V_{disp,nom}}{2 \pi R \cdot T_0} \quad (2.1.16)$$

For the mass flow rate $\dot{m}_{to,2}$ it follows accordingly:

$$\dot{m}_{to,2} = \frac{p_2 \cdot \omega \cdot V_{disp,nom}}{2 \pi R \cdot T_0} \quad (2.1.17)$$

The mass flow $\dot{m}_{to,e}$ can be calculated from the equation:

$$\dot{m}_{to,2} + \dot{m}_{to,e} = \dot{m}_{from,1} \quad (2.1.18)$$

The mathematical model of the ideal engine does not take into account some important phenomena, such as the leakage flows between vanes and stator, system inertia and mechanical friction. Therefore, additional flow paths with nozzles, inertia and bearing friction have to be added to this ideal motor, see Fig. 2.1.9 for nozzles. To find parameter values for the nozzles and the friction model, a numerical estimation scheme can be used (Beater 2004).

Using the mathematical model described above and the LabVIEW G type programming language we have built simulation programs for the pneumatic vane motor.
3. Optimisation

The performance characteristic of the motor is shown in curves as below fig. 2, from which torque, power, and air consumption can be read off as a function of speed. Power is zero when the motor is stationary and also when running at free speed (100%) with no load. Maximum power (100%) is normally developed when the motor is driving a load at approximately half the free speed (50%).

Where:

- \( P \) = Power
- \( M \) = Torque
- \( Q \) = Air consumption
- \( N \) = Speed

Torque at free speed is zero, but increases as soon as a load is applied, rising linearly until the motor stalls. As the motor can then stop with the vanes in various positions, it is not possible to specify an exact torque. Air consumption is greatest at free speed, and decreases with decreasing speed, as shown in the above diagram.

The performance of an air motor is dependent on the inlet pressure. At a constant inlet pressure, air motors exhibit the characteristic linear output torque / speed relationship. However, by simply regulating the air supply, using the techniques of throttling or pressure regulation, the output of an air motor can easily be modified. The most economical operation of an air motor is reached by running close to nominal speed. By torque of \( M = 0 \), the maximum speed (idle speed) is reached. Shortly before standstill (\( n = 0 \)), the air motor reaches its maximum torque (\( M_{\text{max}} = 2 \times M_{o} \)). At nominal speed (\( n_{n} \)), for example in the middle of the speed range, air motor reaches its maximum power output (\( P_{\text{max}} \)).

**Energy Efficiency**

A pneumatic motor achieves its maximum power when it is operating as close as possible to its rated speed (50% of the rated idle speed). The energy balance is best in this area, because the compressed air is used efficiently.

**Optimization of speed and torque**

The speed and torque can also be regulated by installing a pressure regulator in the inlet pipe. This means that the motor is constantly supplied with air at lower pressure, which means that when the motor is braked, it develops a lower torque on the output shaft.

**Speed regulation, air flow reduction**

Every size reduction or restriction on the air line, whether of the supply hose itself or fittings, before the air motor affects the amount of the supplied air. By throttling you reduce the speed of the motor and simultaneously, the required torque. That means that you reduce the motor performance. The most common way to reduce the speed of a motor is to install a flow control valve in the air outlet, you can set the speed without loss of the torque. When the motor is used in applications where it must reverse and it is necessary to restrict the speed in both directions, flow control valves with by-pass should be used in both directions. If the inlet air is restricted, the air supply is restricted and the free speed of the motor falls, but there is full pressure on the vanes at low speeds. This means that we get full torque from the motor at low speeds despite the low air flow. Since the torque curve becomes "steeper", this also means that we get a lower torque at any given speed than would be developed at full air flow. The benefit of throttling the inlet is that air consumption is...
reduced, whereas throttling the exhaust air maintains a slightly higher starting torque.

[Diagram: Speed regulation, air flow reduction]

Reducing motor leakages and air consumption

Inside the motor in the starting moment is the air pressure that pushes the vanes to the surface of the stator to create the necessary seal. So in the starting moment the leakages and air consumption are too big versus next moments, because the in the first moment distance between vanes and stator is too big. If the vanes are adapted with special spring see the figure 3.4 below. The seal is in the necessary level at the starting moment.

[Diagram: Motor leakages and air consumption reduction way]

Optimization of torque

Are to way to optimize the torque of the motor, increase the pressure, and increasing the radius of the stator and rotor. Using the program built in LabView we have done the simulation for stator diameter increased 10%, 20% and 30%.

[Diagram: Three diameters of stator considered in simulation]

4. Conclusion

Using simulation software for the design and optimization of pneumatic actuators is the best and most economical way. Implementation of simulation programs requires a good and complete mathematical model as well as a programming language that can solve complex hydrostatic and mechanical equations in real time. The mathematical model presented above as well as the built-in simulation software can be used for optimization and precision (PID) command of the pneumatic vane motors.

5. References

An experimental study on energy generation from photovoltaic-thermal hybrid systems

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Abstract: Solar energy is one of the leading renewable energy sources because of its great potential, affordability of the individual system prices, zero emission and no noise emission. 21st century will be based on renewable energy sources, with strict environmental measures, primary energy use will mainly consist of a combination of (different) clean energy sources among which solar energy will play a leading role. Two technologies for harnessing the energy of the sun are photovoltaic cells (PV) and solar collectors. Photovoltaic cells (PV) exploit the visible part of the spectrum while solar collectors use the infrared part. Combining these two technologies into one provides a system that produces electricity and heat at the same time using all parts of the solar spectrum. These systems are known as photovoltaic thermal systems or PV/T. This paper presents the description of these systems and methods of application. Among this, this paper gives description of experimental PV/T installation at Faculty of Mechanical Engineering in Banja Luka.

KEYWORDS: PV PANELS, SOLAR COLLECTORS, PHOTOVOLTAIC- THERMAL SYSTEM, SOLAR ENERGY

1. Introduction

With population growth and the development of a global economy, the need for energy is steadily rising and fossil fuels are no longer as secure a source of supply as they were in the last century. From all of the above, renewable energy sources are the focus of both scientists and decision-makers with a view to ensuring the energy stability of states and protecting the environment. Solar energy is one of the leading renewable energy sources because of its great potential, affordability of the individual system prices, zero emission and no noise emission.

PV panels and solar collectors harness solar energy by covering a certain part of the spectrum of solar radiation. Photovoltaic cells (PV) exploit the visible part of the spectrum while solar collectors use the infrared part. Combining these two technologies into one provides a system that produces electricity and heat at the same time, utilizing all parts of the solar radiation spectrum. These systems are known as photovoltaic thermal systems or PV/T. PV/T systems can produce more energy per unit area compared to a single PV panel and solar collector [1]. This paper presents the description of these systems and methods of application. Among this, this paper gives description of experimental PV/T installation at Faculty of Mechanical Engineering in Banja Luka.

2. PV/T Systems: the working principle and classification

Only 15-20% of the solar radiation that falls on the PV module is converted to electricity while the rest heats the module [2]. In other words, more than 50% of the incident solar energy is converted as heat (after deducting the reflected portion). This may lead to extreme cell working temperature as much as 50°C above the ambient environment. The electrical efficiency of PV modules decreases as the operating temperature of the module rises. The electrical efficiency of the PV module depends on the material from which the module is made, as well as on the tilting angle of the panel [3], dust [4] [5], shadows [6] and the climate of a specific geographical area [7] [8] [9]. Significant impact on the reduction of PV module efficiency is the exposure to intense solar radiation and high temperatures for a long time [10].

The most critical periods for the electrical efficiency of PV modules are periods with high ambient air temperatures and low wind speeds [11]. Another problem that may occur due to the high temperature of the module is that photovoltaic cells can totally be burned [12]. From all of the above it is concluded that cooling the PV module is important and necessary. By cooling the solar cells with a fluid stream like air or water, the electricity yield can be improved. But conceptually the better design is to re-use the heat energy extracted by the coolant.

A hybrid system is a system that connects two or more energy conversion devices or one system to which multiple energy sources are integrated. The efficiency of a hybrid system is usually higher than that of single technologies. In a hybrid PV/T system, the thermal energy of the panel is absorbed by the working fluid (coolant) by the heat conduction process or by convection, the panel temperature is reduced, thereby significantly increasing the electrical efficiency of the hybrid system. The advantages of PV/T systems are:

1. photovoltaic and solar collectors use different parts of the spectrum of solar radiation. Combining the two systems into one results in a more efficient use of the entire solar spectrum;
2. PV/T system requires less space for installation than separate installation of PV panels and solar collectors;
3. when implementing the system, the PV/T system requires less material than two separate systems;
4. electrical efficiency is increased by heat dissipation from the PV module;
5. the working fluid has a higher temperature due to the heat it absorbs from the photovoltaic cells;
6. Greater overall efficiency than separate systems.

PV/T systems are divided according to: type of collector, type of coolant, material of which PV is made, mode of flow of coolant. Fig. 1 shows the main features of a flat-plate PVT collector.

Fig. 1. Main features of a flat-plate PV/T collector [13]

Fig. 2 shows the longitudinal cross-sections of some common air-type PV/T collector configurations whereas the cross-sectional views of some examples of the water-type designs are in Fig. 3.

Significant research has been carried out in recent years in the field of CPV/T systems (Concentration photovoltaic/thermal system) in order to achieve the highest efficiency of the system, i.e. higher electrical efficiency and higher output temperature from the system. However, when analyzing such systems, it must be borne in...
mind that CPV/T systems are significantly more complex than flat plate PV/T systems, and that such systems are accompanied by a mirror-rotating device depending on the position of the sun. Photovoltaic cells in which the concentration of solar radiation is made are more expensive because of the working environment and exposure to higher radiation and high temperatures. Fig.4 is a simplified representation of the CPV/T collector.

![Fig.2. Longitudinal cross-sections of some common PV/T air collector designs [13]](image)

![Fig.3. Cross-sections of some common PV/T water collector designs [13]](image)

![Fig.4. Schematic of CPV/T collector [14]](image)

The BIPV/T (Building Integrated Photovoltaic-Thermal) system is the structural, architectural and aesthetic integration of the PV/T system into the building structure of the facility [15]. BIPV/T systems use the building envelope to collect solar energy to produce electricity and heat, providing an efficient way to reduce energy consumption in the facility from other sources. Establishing a BIPV/T system as a standard in architecture but also as a functional component of a facility to replace conventional building materials for cladding would lead to a significant expansion of the use of the BIPV/T system. Given that 32% of the world's consumption is spent on buildings, this way of supplying the facility with heat and electricity is of interest for the development of NZEB buildings. The characteristics of the BIPV/T system are:

- the system is physically connected to the building;
- the system generates electricity;
- the system generates thermal energy that can be used directly in the building or through other technical systems.

Fig 5. Represents some implemented BIPV/T systems.

![Fig.5. BIPV/T water system integrated in the facade of the building [16], BIPV/T roof system [17]](image)

3. Experimental setup of PV/T system

Faculty of Mechanical Engineering in Banja Luka is implementing the research project ‘Thermodynamic Analysis and Mechatronic Synthesis of Solar Power Plants in Urban Areas’, which is co-financed by the Ministry of Science and Technology Development, Higher Education and Information Society of Republika Srpska, Bosnia and Herzegovina. One of the project activities is experimental research of PV/T system in urban area. During research, it will be analyzed the possibility of obtaining electricity by conversion from solar energy as well as the thermal effects that accompany this phenomenon. Generated heat from PV panel will be used for water heating. Monitoring the trajectory of the Sun in order to obtain the maximum possible power in given climatic and meteorological conditions is a mechatronic type of a problem that is approached from the mechanical, energy (thermal and electrical) and control aspects. The management mode is based on stored data that depends on geographical location, the use of light sensors or the methods of monitoring maximum output. The implementation of mechanical as well as control structures is different and is based on microcontrollers, programmable logic controllers, phase controllers and application of artificial intelligence. The idea of the project is to carry out scientific research that will answer the question of which solar monitoring system is the most energy efficient from the electrical and thermodynamic point of view, but also optimal in terms of the complexity of design, technical solution of mechanical part and price, and with innovative design acceptable for use in urban areas. During research it will be used monocrystal PV/T module and control monocrystal PV module (Solarfam Monocrystalline Solar Panels model SZ-100 - 36M). All measurement results (insolation, air temperature, precipitation, wind speed, data on different angles of positions of photovoltaic panels) will be used to analyze and simulate the process and find the optimal and most efficient positions of the panels in order to obtain the maximum amount of electricity and the most efficient thermodynamic characteristics of the system. Fig.6. and Fig.7. represents 3D model of the experimental setup of PV/T system. Experimental setup will be placed in front of the building of the Faculty of Mechanical Engineering Banja Luka. Whole setup will be set in spring 2020 when will start experimental research and all measurements.
A large number of factors affecting the operation and efficiency of the PV/T system as well as the amount of electricity and heat generated, require additional research and analysis. Due to that, scientific project "Thermodynamic Analysis and Mechatronic Synthesis of Solar Power Plants in Urban Areas" implemented by Faculty of Mechanical Engineering in Banja Luka will contribute to this goal.

3. References

Mechanical and hydraulic stability of the offshore composite structure

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Abstract: The aim of this research it was the installation of an intake sea water GRP (glass-reinforced plastic) structure in Vlore Bay. A detailed study about the extreme wave condition offshore was carried out by the SWAN (Simulating Waves Nearshore) model. Then the mechanical structure stability calculation was performed with AxisVM8, a finite element modeler & solver. Conservative hypothesis were taken, such as to use the max static pressure value as per energy balance calculation on the sea waves. The program Fluid Flow was used to model the pipe line end with pipe chimney connections. The scope of the calculation was primarily to balance fluid flows in each chimney in order to match the range of 0.2 – 0.25 m/s velocity at each chimney entrance.

The result of the mechanical and hydraulically stability verification for the sea water intake structure take in consideration it was positive and this structure was installed successfully.

KEYWORDS: COMPOSITE MATERIAL, SIGNIFICANT HEIGHT OF WAVE, WAVE ENERGY, VON MISE STRESS, STRESS INTENSIFICATION FACTOR.

1. Introduction

In worldwide practice nowadays the use of offshore installations with GRP composite material is in a continuous development. The main characteristics that the engineered solution was deemed to be inclusive, where:

From the construction point of view:
1. Easiness of construction
2. Easiness of installation
3. Easiness of handling
4. They are virtually non-corrosive to seawater
5. Relatively high solidity / specific weight ratio
6. Limited sensitivity to changing temperatures
7. Their production with relatively large diameters guarantees a low flow rate.

From engineering point of view:
1. Very shallow sea depth (around 2.5 m)
2. Turbulent area in case of windstorm (sea storm) with sea water waves breaking.
3. Possibility, during sea storm to suck-in sand.
4. Possibility, during sea storm to dry a part of the structure.

2. Prerequisites and means for solving the problem

2.1 Definition of wave parameters

2.1.1 Study of wave typology in Vlora bay

The aim of this study is:
1. Determination of the nature of waves in Vlora bay
2. Computer wave modeling resulting in wave distribution, given in a graph of Hs with respect to Tm and Tp for each sector, where:
   • Hs- significant wave height
   • Tm- wave period
   • Tp- peak wave period

2.1.2 Nearshore wave modeling

Wave propagation from offshore and wave growth due to winds in Vlore Bay were modelled using the SWAN (Simulating Waves Nearshore) wave model to predict wave condition in this area [1]. From the study was found that under extreme wave conditions for all directions and for 1, 10 and 100 year return periods, the largest significant wave height is for the 100 year period equal to 4.2m. It should be noted that the water intake structure will receive waves from all directions, which will be considered in its design.

Figure 1, show the results of the SWAN model for a 100 year return period offshore wave.

2.2 Prediction of extreme wave condition (Weibull).

There are several different methods of estimating extreme events from limited data. They are based upon the idea of fitting a standard probability distribution to the range of data which is available. The extreme wave heights are then obtained by substituting the corresponding extreme probability levels into the fitted equation [2].

Extreme value distribution:
\[ P(H_s) = 1 - \exp\left(\frac{-H_s - \alpha}{\beta}\right) \]

Where \( H_s \) is the significant wave height, \( P \) = probability less than \( H_s \), and \( \alpha \), \( \beta \) are parameters to be found.

Weibull scales:
\[ x = \log (H_s - \alpha) \]
\[ y = \log(1 - P(H_s)) \]
\[ x = \log (H_{max}) \]

\( x \) and \( y \) are plotted on linear scales. Waves of a given return period (N years) are determined graphically from the appropriate probability. The expected highest individual wave (\( H_{max} \)) in a sequence is related to \( H_s \) by the approximate formula:
\[
\frac{N_{\text{max}}}{N} = \left(\frac{1}{2} \ln N\right)^\frac{1}{2}
\]
Where \( N \) is the number of waves in the sequence.

### 2.3 The SWAN wave transformation model

SWAN is a computational spectral wave transformation model. It can be used to obtain realistic estimates of wave parameters in coastal areas, from given wind, seabed, and current conditions [3].

The SWAN models represent the waves in terms of the two dimensional wave action density spectrum \( N(\sigma, \theta) \), even when the nonlinear phenomena dominate. The action density is equal to the energy density divided by the relative frequency:

\[
N(\sigma, \theta) = \frac{E(\sigma, \theta)}{\sigma}
\]

Where \( \sigma \) is the relative frequency and \( \theta \) is the wave direction. In SWAN the two dimensional wave action density spectrum may vary in time and space. Its evolution is described by the spectral action balance equation, which for Cartesian coordinates is:

\[
\frac{\partial N}{\partial t} + \frac{\partial}{\partial x} C_x N + \frac{\partial}{\partial y} C_y N + \frac{\partial}{\partial \sigma} C_\sigma N + \frac{\partial}{\partial \theta} C_\theta N = \frac{E(\sigma, \theta)}{\sigma}
\]

### 3. Solution of the examined problem

#### 3.1 Design basis and basic assumptions

From the above study we found that the wave climate in Vlore Bay consist of waves generated offshore that propagate through the west and north entrance of the bay and those generated locally within the bay by winds from the south. The largest wave of 4.5m occur from the direction sector 195 to 225°N. These waves have an associated mean wave period of 7 to 8 seconds. The 100 year return period of significant wave height is 3.5m.

The significant wave height, by international definition, the average height – measured from wave top to bottom, of the highest 30% waves. This means that, according to probability scatter, the highest wave is normally 1.5 x significant wave. The energy of the wave, i.e. the actual height when measured from average sea water level is 1.5/2 x significant wave height. For this reason we can assume by calculation that the effective highest wave, measured from the average sea water level is 2.62m (return period on 4 hours during the highest 100 year storm).

Actually, absolute wave height as indicated is that measured in the Vlore Bay when the effect of shallow sea depth is disregarded. When the sea depth is less than half of the wavelength, the wave starts to “feel” the effect of the sea bottom: its velocity decrease and finally the wave break, losing part of its energy [4].

The energy of the wave is then lower that the correspondent maximum “static equivalent” height, according to Bernoulli equation (mass and energy conservation principle for fluids in motion). The pressure and the resultant force of the wave break than, associated to this wave height is that due to Stevino’s approximation.

The value resulting from Bernoulli-Stevino, was used for mechanical design calculation purposes.

#### 3.2 Geometry description of the structure

In order to limit the flow velocity to a value in the range of 0.2 – 0.25 m/s, seven GRF pipe “chimneys” diameter 1600 and 1800 mm (selected according to hydraulic calculation) shall be welded through lamination PN10 type on a 1800 mm diameter underground piping (the header). In order to limit weight and dimensions of the header two pieces (12m and 9m respectively) of 1800 mm ID pipe shall be connected through an 18000 mm metallic clamp. The connection of the existing pipe end, at 250 m from shoreline shall be executed via another metallic clamp.

The pipe shall be buried to -1.5 m from the sea bottom, while the pipe chimneys, 3 m long each, shall extend 1.5 m from the sea bottom, 1 m from average sea water level.

As per study carried out, it’s clear that actual wave height around 250 m from shore line shall be in the range of 1 m or less. Once the pipe connections are verified according to mechanical stability the most problematic phenomenon to be take in consideration is that, on a shallow sea depth, the effect of turbulence of wave break may be a cause of sand entrance in the pipeline. Thus 1.5 m elevation from sea bottom line is deemed suitable, in the range of velocity selected, to limit the risk sand entrance in the pipeline during normal sea condition but may not be suitable in case of severe sea storm, thus causing the CCPP to stop its operation. Further action may be taken afterward to limit this phenomenon, with small modification to the present design.

#### 3.3 Velocity and pressure drop calculation

The program Fluid Flow release 3 was used to model the pipe line end with pipe chimney connections. The scope of the calculation was primarily to balance fluid flows in each chimney in order to match the range of 0.2-0.25 m/s velocity at each chimney entrance, thus increasing the pressure drop where necessary, through pipe chimney orifice, that shall be performed on 1800 mm common header.

#### 3.4 Process calculation results

In the figure 2 is given the simplified geometry of the structure.

The data for the tables below are taken directly from the program.

### Table 1. Flow data in pipe stacks

<table>
<thead>
<tr>
<th>Unique name</th>
<th>Length (m)</th>
<th>ID (mm)</th>
<th>User number</th>
<th>Flow (m³/h)</th>
<th>Pressure loss (Pa)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe 4</td>
<td>3</td>
<td>1600</td>
<td>-14</td>
<td>1608</td>
<td>0.7</td>
<td>0.22</td>
</tr>
<tr>
<td>Pipe 7</td>
<td>3</td>
<td>1600</td>
<td>-13</td>
<td>1477</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Pipe 6</td>
<td>3</td>
<td>1600</td>
<td>-10</td>
<td>1695</td>
<td>0.7</td>
<td>0.23</td>
</tr>
<tr>
<td>Pipe 5</td>
<td>3</td>
<td>1600</td>
<td>-8</td>
<td>1813</td>
<td>0.8</td>
<td>0.25</td>
</tr>
<tr>
<td>Pipe 3</td>
<td>3</td>
<td>1800</td>
<td>-5</td>
<td>1871</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Pipe 2</td>
<td>3</td>
<td>1800</td>
<td>-4</td>
<td>1993</td>
<td>0.6</td>
<td>0.22</td>
</tr>
<tr>
<td>Pipe 1</td>
<td>3,1</td>
<td>1800</td>
<td>-3</td>
<td>1540</td>
<td>0.4</td>
<td>0.17</td>
</tr>
</tbody>
</table>

### Table 2. Flow data in orifice

<table>
<thead>
<tr>
<th>Unique name</th>
<th>Elevation (m)</th>
<th>Orifice size (mm)</th>
<th>User number</th>
<th>Flow (m³/h)</th>
<th>Pressure loss (Pa)</th>
<th>Corne tap loss (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe 2</td>
<td>3</td>
<td>1600</td>
<td>15</td>
<td>1993</td>
<td>6.4</td>
<td>0.22</td>
</tr>
<tr>
<td>Pipe 3</td>
<td>3</td>
<td>1200</td>
<td>16</td>
<td>1870</td>
<td>118.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Pipe 4</td>
<td>3</td>
<td>950</td>
<td>17</td>
<td>1608</td>
<td>287.9</td>
<td>0.23</td>
</tr>
<tr>
<td>Pipe 5</td>
<td>3</td>
<td>900</td>
<td>18</td>
<td>1813</td>
<td>497.8</td>
<td>0.25</td>
</tr>
<tr>
<td>Pipe 6</td>
<td>3</td>
<td>800</td>
<td>19</td>
<td>1695</td>
<td>807.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Pipe 7</td>
<td>3</td>
<td>700</td>
<td>21</td>
<td>1173</td>
<td>0.6</td>
<td>0.22</td>
</tr>
</tbody>
</table>

#### 3.5 Mechanical stability calculation

Based upon input data as settled in 3.1, a computational finite element model was established both for 1600 mm and for 1800 mm pipe stack. Conservative hypothesis were taken, such as to use the max static pressure value as per energy balance calculation on the sea waves [5]. The pipe stack has been modeled as if rigidly connected to a fixed header (the underground pipe header) capable to withstand all transmitted forces. This approach is considered suitable for the purpose of mechanical verification, since...
appropriate SIF shall be applied to allowable pipe stresses to take into account the “Tee” branch connection geometry, also based upon the fact that the mechanical characteristics of the pipe stack and pipe header are homogeneous.

Pipes material features
Elastic modulus in longitudinal direction: 22000 N/mm²
Elastic modulus in transversal direction: 11000 N/mm²
Thick of the pipe: 27 mm
Density: 1850 kg/m³
Poisson coefficient: 0.2
Lowest allowable stress: 275 Kg/cm²

3.5.1 Calculation
The analysis was performed with AxisVM8, a finite element modeler & solver. The action of these deformations can be relatively calculated taking account the contribution for lateral soil reaction (about 26 t/m²) on the part of the underground pipe modelled with spring applied on shell surface. It is necessary to define the values of the maximum pressure, so that they are consistent with the intensity and wave level considered, therefore the scheme of calculation to be adopted is illustrate in the following.

Considering a height wave of 2.62 m, the pressure applied to the part of pipe outside the ground (1.5 m) is:

\[ \Delta P = \rho g \Delta H = 1000 \frac{kg}{m^3} \times 9.81 \frac{m}{s^2} \times 2.62 m = 25702 \text{Pa} = 25.7 \text{kPa} \]  
(8)

Once the maximum stresses according to Von Mises are calculated with AxisVM8, then the appropriate Stress Intensification Factor (SIF) according to ANSI is applied in order to compare actual stress to allowable stress. The actual SIF value was calculated modelling with CAESAR II – the piping modeler and stress analysis solver program – the geometry of the piping spool. For both 1600 mm and 1800 mm branch connection, the calculated SIF is 2.3.

4. Results and discussion

4.1 Vertical pipe φ1600 mm.

The figures below show the load case geometry and the relevant mesh definition:

![Figure 3. Vertical axial tube geometry](image)

![Figure 4. Node definition and constrains](image)

Maximum stress according to Von Mises = 85.5 Kg/cm². Maximum stress after SIF application = 85.5 \times 2.3 = 196.7 Kg/cm². Allowable stress = 275 Kg/cm². Safety margin 40 %.

4.2 Vertical pipe φ1800 mm.

![Figure 5. Loads application on geometrical model](image)

![Figure 6. Stress with Von Mises method](image)

![Figure 7. Stress with Von Mises method](image)
Maximum stress according to Von Mises = 71 Kg/cm$^2$.
Maximum stress after SIF application = 71 x 2.3 = 163.3 Kg/cm$^2$
Allowable stress = 275 Kg/cm$^2$.
Safety margin 68 %.

5. Conclusion

The structure will be exposed to waves that are generated offshore that propagate through the entrance in the bay towards the site from west and north. The site will also be exposed to waves generated locally by winds from the south-east and south.

Mathematical modeling of the waves and their distribution spectra showed a satisfactory approximation of the real situation in the Vlora bay.

Hydraulic model of the structure, the flow balance having as the criterion that the suction velocity should be in accordance with the environmental directives, led to a clear concept of materialization of the structure with seven vertical tubes and a common horizontal collector.

Finite element modeling of the structure for calculating its mechanical stability, taking into account the action of the waves in the direction of the most significant height as well as the accurate calculation of their pressure from the energy balance, produced a highly reliable model for successfully assembling of the structure in an extremely complex environment of the sea.

6. References

Дифракционен модел на астероидно затъмнение

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Резюме: Предоставен и изследван е дифракционен модел на астероидно затъмнение, получено от пулсарен сигнал. Астероидът е априкосимиран като сферичен обект и в модела се предполага, че той пресича базовата линия, образувана от пулсар и радиотелескоп. Пулсарите са неутронни звезди, излъчващи електромагнитни вълни, които притежават на Земята като импулси сигнали с определена форма и период на повторение. Тези естествени източници на импулси сигнали е възможно да се използват за създаване на системи за откриване на астероиди и/или метеорити. При преминаване на космически обект между пулсара и Земята в радиотелескопа постъпва сигнал от дифракционното поле на обекта, което е носител на информация за параметрите на обекта. В настоящата статия ще бъде изложен модел на дифракционната картина на сигнала от сферичен обект, получен от сферичен обект, облъчен с пулсарен сигнал в близка и далечна зона на дифракция. Изследвани са зависимостите между параметрите на летящи космически обекти и параметрите на сигнала от пулсара в условията на явлението пряко разпространение на сигнала.

КЛЮЧОВИ ДУМИ: ДИФРАКЦИОНЕН МОДЕЛ, ПУЛСАР, СФЕРИЧЕН ОБЕКТ

1. Въведение

Дифракция се нарича явление, водещо до отклонение на вълнови сигнали от праволинейното им разпространение, когато преминават през отвор или срещат препятствие на пътя си на разпространение [1]. Дифракцията е характерна за всички видове вълни: звукови, водни, радиовълни, светлинна и др. Според принципа на Бабинет, дифракционната картина на непрекъснат обект е идентична с дифракционната картина на отвор с една и съща форма и размер, но интензивността на сигнала е с противоположна стойност. Принципът на Бабинет е в основата на явлението пряко разпространение на сигнала (Forward Scattering), използван в бистатичната радиолокация за откриване на подвижни обекти, пресичащи базовата линия между приемника и предавателя [2, 3]. Съгласно принципа на Хюйгенс-Френел, когато фронтът на светлинен лъч достигне отвор, всяка негова точка става източник на сферична вълна. Множеството генерирани вълни са кохерентни, като при разпространението си се получава сумиране или изваждане на тези вълни, което води до редуване на тъмни и светли дифракционни ивици. При наличие на преграда се наблюдава дифракционен ефект на навлизане на светлинните лъчи в геометричната сянка на тяхното съсредоточение в центъра на дифракционната картина.

В настоящата статия е изложен дифракционен модел на сферичен обект (астроид или метеорит), облъчен с пулсарен сигнал. Пулсарите са неутронни звезди, отстоящи на няколко светлинни години от Земята, които излъчват постоянно магнитно поле като резултат на въртенето на пулсара около оста си на Земята. Магнитните полюси на пулсари са с малки размери, но с голма плътност и се въртят около останата си с висока скорост. Един оборот на пулсара е периодичен на секунди или мили секунди [10]. Магнитното поле на пулсарите е много плътно и с висока интензивност. В резултат на въртенето около останата си неутронните звезди излъчват електрони през магнитните си полюси, което представлява микровълново лъчение от двата съсредоточени полюси на звездата. Някои от неутронните звезди проблясват и във видимия диапазон на спектъра, а не само в радиодиапазона. Магнитните полюси могат и да не съвпадат с оста на въртене, както е показано на фигура 1.

2. Пулсар

Пулсарите са неутронни звезди, които са с малки размери, но с голма плътност и се въртят около останата си с висока скорост. Един оборот на пулсара е периодичен на секунди или мили секунди [10]. Магнитното поле на пулсарите е много плътно и с висока интензивност. В резултат на въртенето около останата си неутронните звезди излъчват електрони през магнитните си полюси, което представлява микровълново лъчение от двата съсредоточени полюси на звездата. Някои от неутронните звезди проблясват и във видимия диапазон на спектъра, а не само в радиодиапазона. Магнитните полюси могат и да не съвпадат с оста на въртене, както е показано на фигура 1.

В резултат на въртенето на пулсара електромагнитният лъч осветлява Земята на равни интервали от време, съвпадащи с периода на въртене на пулсара. Излъченият сигнал е възможно да се използва за откриване на астероиди и метеорити, намиращи се между пулсара и радиотелескоп, позициониран на Земята. За по-доброотно откриване на сигналите от пулсара е за предпочитане да се използват радиотелескопи, работещи в диапазона от 1 до 30 GHz с цел минимално влияние на атмосферата на Земята по отношение на затихването на сигнала [11] (фиг. 2).

При облъчване на небесното тяло със сигнал от даден пулсар се получава дифракционен ефект, в резултат на което на Земята попадат дифрактиралите сигнали (фиг. 3).

Дифракционната картина зад кръгъл непрекъснат обект представлява редуване със светли и тъмни концентрични кръгове.
Фиг. 2 Пропускане на космически сигнали през земната атмосфера [11]

Фиг. 3 Дифракционен ефект от облъчване на астероид с пулсарен сигнал

3. Дифракция

Явлението дифракция се появява, когато вълна срещне препятствие на пътя си, в резултат на което тя променя праволинейното си разпространение в пространството. Пример за дифракция е промяната в посоката на разпространение на вълната при срещане на препятствие или при преминаване на вълната през отвор (фиг. 4). Дифракция се наблюдава при всички видове вълни, включително звукови, електромагнитни, радиоълчи и рентгенови лъчи. Районът зад препятствието, в който не стига вълната, се нарича сянка. Размерът на сянката зависи от размера на препятствието и дължината на вълната. Ако дължината на вълната е много голяма в сравнение с препятствието, то почти няма зона на сянка.

Фиг. 4 Модел на дифракция

Видът на дифракционния модел съществено зависи от връзката между размера на препятствието, дължината на вълната и разстоянието от препятствието до наблюдавателната точка z. В тази връзка се разграничават два типа дифракция:

1. Дифракция на Френел, когато върху препятствието пада плоска или сферична вълна и на екрана се наблюдава дифракционната картина, състояща се от концентрични кръгове. В този случай точката на наблюдение се намира на малко разстояние от препятствието, така че фронтът на вълната, попадащ върху екрана на наблюдение, е сферичен.

2. Дифракция на Фраунхофер или дифракция с успоредни лъчи се получава, когато върху препятствието пада плоска вълна. Този дифракционен модел се наблюдава при сравнително голямо разстояние от препятствието до екрана, така че вълновият фронт, пристигащ в точката на наблюдение, е плосък.

По принцип дифракцията на Фраунхофер не се различава от дифракцията на Френел. Количествен критерий, който позволява да се установи какъв тип дифракция се извършва, се определя от безразмерния параметър $\frac{\omega z}{\lambda}$, където $\omega$ e характерният размер на препятствието, z e разстоянието между препятствието и екрана, върху който се наблюдава дифракционната схема, и $\lambda$ е дължината на вълната. Съответно:

$$\frac{\omega z}{\lambda} \ll 1 \text{ Дифракция на Френел}$$
$$\frac{\omega z}{\lambda} \gg 1 \text{ Геометрична сянка}$$

(1)

За построяването на дифракционен модел ще разгледаме схематично показаното на фиг. 5 непрозрачен екран с кръгъл отвор (отляво), вляво от него има източник на светлина. Изображението се фиксира на втори екран в дясно. При преминаване на светлината през отвора тя дифрактира и в областта, която би била осветена, се наблюдават колебания в интензитета на осветяване под формата на концентрични пръстени. Дифракционният модел зависи от разстоянието между екраните и от местоположението на източниците на светлина. В местата на наблюдение на втория екран вълните или се сумират, или се изваждат в зависимост от изминатия от тях път.

Фиг. 5 Геометричен дифракционен модел

Ако източникът на светлина и точката на наблюдение не са разположени твърде далече от препятствието и при преминаване на светлината през отвора тя дифрактира и в областта, която би била осветена, се наблюдават колебания в интензитета на осветяване под формата на концентрични пръстени. Дифракционният модел зависи от разстоянието между екраните и от местоположението на източниците на светлина. За да се изчисли интензитетът на светлината в наблюдателната равнина, се прилага принципът на Хюйгенс-Френел [12]:

$$U_2(x_2, y_2) = \frac{z}{\lambda} \int_{-\infty}^{\infty} U_1(x_1, y_1) e^{jkr_{12}} dx_1 dy_1$$

(2)

където $r_{12}$ е разстоянието между точка от изходната равнина -1 и точка от равнината на наблюдение -2, $\lambda$ е дължината на вълната на монохроматична светлина, z e разстоянието между двете равнини. Стойността на $r_{12}$ се:

$$r_{12} = \sqrt{z + (x_2 - x_1)^2 + (y_2 - y_1)^2}$$

(3)
Използвайки разложението на Тейлър и пренебрегвайки членовете с ред по-голям от три, тъй като са пренебрежимо малки, се получава изразът:

\[ r_{12} \approx z + \frac{1}{2} \left( \frac{2 - x_2 - x_1}{x} \right)^2 + \frac{1}{2} \left( \frac{2 - y_2 - y_1}{y} \right)^2 \]  \hspace{1cm} (4)

Използвайки приближението \( r_{12} = z \), се получава:

\[ U_2(x_2, y_2) = \frac{e^{ \frac{i k x}{2 z} } }{j k x} \int_{-\infty}^{\infty} U_1(x_1, y_1) \exp \left[ j \left( \frac{k}{2 z} (x_2^2 + y_2^2) \right) \right] dx_1 dy_1 \]  \hspace{1cm} (5)

Този израз може да бъде записан като:

\[ U_2(x_2, y_2) = \int_{-\infty}^{\infty} U_1(x_1, y_1) \exp \left[ j \left( \frac{k}{2 z} (x_2^2 + y_2^2) \right) \right] dx_1 dy_1 \]  \hspace{1cm} (6)

където \( h(x, y) \) е импулсен отговор:

\[ h(x, y) = \frac{e^{ \frac{i k x}{2 z} } }{j k x} \exp \left[ j \left( \frac{k}{2 z} (x_2^2 + y_2^2) \right) \right] \]  \hspace{1cm} (7)

Преобразуването на Фурие на импулсен отговор е предавателната функция [13]:

\[ H(f_x, f_y) = e^{\frac{i k x}{2 z} } e^{-\frac{i k}{2 z} (f_x^2 + f_y^2)} \]  \hspace{1cm} (8)

Благодарение на теоремата за свиване сигналът в равнината за наблюдение се получава:

\[ U_2(x_2, y_2) = \mathcal{F}^{-1} \{ \mathcal{F} \{ U_1(x_1, y_1) \} H(f_x, f_y) \} \]  \hspace{1cm} (9)

Ако източникът на светлина и точката на наблюдение са отделени от препятствиято на голямо разстояние, толкова голямо, че лъчите образуват успореден сноп лъчи, се наблюдава дифракция на Фраунхофер. В този случай интензитетът на полето е:

\[ U_2(x_2, y_2) = \exp \left[ j \left( \frac{k}{2 z} (x_2^2 + y_2^2) \right) \right] \]  \hspace{1cm} (10)

Предположението, че имаме голямо разстояние до мястото на наблюдение допуска, че:

\[ z \gg \left( \frac{k (x_2^2 + y_2^2)}{2} \right)_{\text{max}} \]  \hspace{1cm} (11)

Това води до израза на приближаването на Фраунхофер:

\[ U_2(x_2, y_2) = \frac{e^{ \frac{i k x}{2 z} } }{j k x} \exp \left[ j \left( \frac{\pi}{2 z} (x_2^2 + y_2^2) \right) \right] \]  \hspace{1cm} (12)

Полученият интегрален израз всъщност е преобразуване на Фурие с променливия:

\[ f_x \rightarrow \frac{z}{2 \pi} \text{ и } f_y \rightarrow \frac{z}{2 \pi} \]  \hspace{1cm} (13)

Апроксимацията на Френел и приближението на Фраунхофер са формули, реализирани в дифракционния модел за изчисляване на разпространението на вълната. Изборът между двата вида дифракция (9, 12) се прави по отношение на (1).
Модел и профил на облъчване, получен от сферичен обект и различно разстояние до равнината за наблюдение. От получените резултати се вижда, че в близката зона до сферичния обект се получава геометрична сянка. В зоната на Френел ясно се наблюдават концентричните кръгове, като амплитудата на сигнала е сравнително голяма и е съсредоточена в област, съизмерима с площта на облъчвания обект. При преминаване в зоната на Фраунхофер се получава ефект на пряко разпространение на сигнала, в резултат на което имаме един преобладаващ максимум. С увеличаване на разстоянието от обекта до екрана се получава увеличаване на площта на централния максимум, но в същото време амплитудата на максимума намалява.

Предложеното дифракционно моделиране може да се използва за огледане и изследване на параметрите на дифракция, получена от космически тела, облъчени с пулсарни или друг вид космически сигнали.

6. Заключение

В настоящата статия е реализиран и тестван дифракционен модел, получен от сферичен обект. Предложеното моделиране е тествано за определяне на параметрите на пряко разпространение на сигнал, получен от пулсар при попадането му върху астероид, пресичащ базовата линия между пулсар и радиотелескоп. Този дифракционен модел успешно може да се използва за изследване на явлениято пряко разпространение на сигнали, както и откриване и определяне на параметрите на астероиди и метеорити.

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7. Литература

Data security model in cloud computing

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Abstract: In the last decade, cloud computing has become an extremely important business assistant that offers significantly lower costs than traditional computer-aided resource provision and greater adaptability to business changes. Thus, it helps them to achieve their business goals. The development of cloud computing poses significant risks, which serve as a partial barrier to their use by the businesses. Security and protection of information are considered to be one of the most critical points in the use of cloud computing. Compared to traditional solutions, cloud computing moves application software and databases to large data centers where information and service management are not always secure and reliable. As a result of this, the community and businesses have many concerns and questions about the security of data and applications in cloud infrastructures. In addition, concerns about data security and applications also arise due to the fact that both user data and applications are managed by the cloud provider. Clouds typically use a standardized data and application security architecture, while the demand for consumer and business services is steadily growing and becoming more diverse and with more sophisticated software design that leads to continuous upgrades to data security models in cloud computing. Due to the different methods of implementation in cloud computing service delivery models, the demand for a reasonable level of data protection is of utmost importance. The purpose of this publication is to propose a new information security model, which offers a solution for improving the use of sensitive data by introducing a three-factor authentication – an improvement of preventive control.

Keywords: CLOUD SERVICES, INFORMATION SECURITY, CLOUD SERVICES ARCHITECTURE, CLOUD SECURITY, DATA SECURITY MODEL

1. Introduction

In the traditional calculation model, the data and software are saved entirely on the user’s computer, while in the cloud model the user’s computer may contain almost no software or data [1]. Cloud technologies are based on the idea that applications and software can be completely moved to an “invisible” place with shared resources on the Internet [2]. Cloud services offer a virtual platform of flexible shared resources (such as hardware, software and datasets), which are provided dynamically on demand with minimal effort made by users [3]. The main features of cloud services are the following [4]:

• Resource flexibility: Users and businesses can add or remove given resources on the basis of their immediate need. For example, at peak times, they can use more resources, which can be easily and quickly released during the rest of the time;
• Pay-as-you-go: Users pay only for the resources they use, as well as for the time they use them and for the other parameters;
• Multi-tenancy (Shared resources): Cloud services are based on a business model, whereby resources are shared at different levels - e.g. a network layer and an application layer. This means that numerous users use the same resources;
• Self-hiring of resources: Users can hire additional resources independently without much efforts (memory, software, network resources, etc.);
• Extremely scalable: Cloud technologies enable scaling up to tens of thousands of systems, as well as server space and memory.

To find a sufficiently suitable data security model in cloud technologies and especially models related to it is a particularly difficult task in today’s ongoing changes in businesses and the IT sector.

Sh. Ajoudanian, for example, proposes a new data security model based on the CIA triad (Confidentiality, Integrity, Availability) and shows the role of the respective user and provider for each model [5]. However, the proposed model does not guarantee the security of sensitive data, as it allows simple user authentication. If you aim at a higher level of data security and protection, such as very sensitive data of an organization or entity, particular attention should be paid to authentication, which is not considered in the proposed model.

Another new data security and protection model is proposed by M. Mohamed, who considers three layers [6]: In the first layer, he proposes the authentication to be placed; in the second layer, he proposes the protection of information, data integrity and protection for private users; and in the third layer, he proposes fast data recovery to be provided.

With the proposed model, the problem of sensitive data is partially resolved but the question remains as to whether it can be widely used. There is also a problem in terms of hybrid clouds, for example, if an organization has a private, public and community cloud, how will the three clouds be authenticated and how will the community and private clouds be protected, if the user logs in through the easily accessible public cloud and tries to gain unauthorized access to the other two hybrid clouds.

The Internet is not a place that cloud service providers can fully control and manage, which requires additional methods and techniques to ensure the security and protection of all participants in the cloud infrastructure.

The security of information and cloud infrastructure participants is of paramount importance to any cloud service provider and organization. As cloud technologies use a virtual environment, particular attention should be paid to the inherent risks, vulnerabilities and threats that threaten the security and protection of information and programs and differ significantly from the inherent risks, vulnerabilities and threats of a physical system.

This publication proposes a new data security model that improves the preventive control and the use of sensitive data by introducing three-factor authentication.

2. Security of service delivery models in cloud computing

Due to the specifics of each service delivery model in cloud technologies, the security is considered according to SLAs between the user and the provider for each of the following three main models:

1. Software as a Service

With this model, users pay a subscription for a software product, whereby part of the information or the full information is saved on a remote location and users can access this service via the Internet [7].

With SaaS, users do not have any control or authority to modify or manage cloud infrastructures or even specific applications that
are already developed [8]. Users have limited options to configure settings related to the use of these applications. The provider fully controls the cloud infrastructure and is responsible for the confidentiality, integrity and accessibility of the data and information.

2. Platform as a Service

This model enables users to develop their own cloud infrastructure applications using programming languages and additional software tools, which are provided by the cloud service provider (such as .NET, Ruby, Java, etc.). PaaS provides users with all the resources they need, so as to be able to develop applications and services entirely on the Internet without the need to download or install additional software. The user is not yet able to manage the underlying cloud infrastructure but only the applications developed by him/her [7].

One disadvantage of PaaS is the lack of interoperability and transfer of applications, which are already developed by the user, to other providers. I.e. if the user wants to transfer the applications developed with the current provider to another cloud provider, this cannot be done or if it can be done, the costs will be extremely high. Another disadvantage is that if the provider decides to leave the business, the applications and information in them will be deleted. With this model, the providers’ liability is associated only with the integrity and accessibility of data. The user is responsible for the confidentiality and protection of the information.

3. IaaS

The infrastructure as a service allows the respective organization to create its own software environment. In the SaaS and PaaS models, the provider provides the user with applications but in the IaaS model, this is not done [7]. This model only provides the hardware on which the organization can install whatever it wants.

The control, exercised by providers, is at an extremely low level. They are only responsible for the accessibility of the services provided by them. Compared to providers, the users’ responsibility is at a quite high level. They are responsible for the confidentiality, integrity of the data and its protection. The following table shows the responsibilities of cloud service providers and users for each model.

Before an updated version of a data security model in cloud technologies is proposed, the evolution of cloud technologies should be known very well, as well as their advantages and disadvantages. The following figure shows the overall development of these technologies by years.

![Evolution of Cloud Computing](image)

The beginning of cloud technologies dates back to 2005, when the main models for the provision of cloud services were presented for the first time, namely the Software as a Service, Platform as a Service and Infrastructure as a Service. Subsequently, Cloud technologies began to focus more on data storage, accessibility and other indicators. In 2012 the main goal was to increase the data and information storage speed (High Speed Storage).

In early 2016, cloud technologies encountered one of the biggest problems in this field, which have not yet been resolved - security and protection of information and data. Figure 1 also shows that the main work done in 2017 and 2018 focused on ensuring security and protection of these technologies.

In recent years, emphasis has been placed on creating more possibilities and transformations in cloud technologies, such as productivity, speed, security, etc. Unfortunately, the problem with the security and protection of these technologies remains unresolved.

In cloud service delivery models, it is important to properly allocate the responsibilities of the user and the provider for each model. Table 1 presents these responsibilities with respect to the so-called CIA triad.

| Table 1. Responsibility of providers and users in cloud computing models |
|---------------------------------|------------------|------------------|
| **Provider** | **User** |
| Software as a Service | Confidentiality, Integrity and Availability | X |
| Platform as a Service | Integrity and Availability | Confidentiality |
| Infrastructure as a Service | Integrity | Confidentiality and Availability |

As it can be seen in the table, for each model, the responsibilities of the user and the provider are different. For example, in case of the most widely used model globally - the Software as a Service - the provider is required to ensure the confidentiality, integrity and accessibility of data and information, while the user has no responsibilities. These are the so-called services or products for which a subscription fee is payable for the right to use the product or service. All new versions, patches, new modules, security and data protection, information, etc. are the sole responsibility of the provider of cloud services or products. In the other two models, the responsibility is divided between the provider and the user. For example, in case of the Infrastructure as a Service, the responsibility of the provider is only to ensure the integrity of the data and information (i.e. the provision of basic resources). Any other things are the responsibility of the user.

3. Information security in cloud computing

With the development of modern information technologies and systems, the problem of data security and protection remains one of the biggest problems of the 21st century. It is a particularly sensitive issue of cloud technologies and related service delivery models.

![CIA triad of Information Security](image)
To secure information in cloud technology, we should consider the main information security triad, the so-called CIA triad.

On the basis of this triad, all modern models of information security are considered.

1. Confidentiality of information in clouds

Information confidentiality aims to prevent disclosure of information by unauthorized users or systems. There are two categories of privacy in cloud infrastructure: privacy in a private cloud and privacy in a public cloud. Private cloud privacy is not a major concern, as it relates to private networks in an organization. There are several privacy issues with public clouds. The first one concerns controls of authentication and authorization. As numerous users use public clouds, they must be properly authenticated in the system by additional rigorous policies and procedures in addition to username and password controls. Some of the most up-to-date security models aim at either two-factor or three-factor authentication or web proxy logon [8] using Security Assertion Markup Language (SAML). With SAML, each organization manages its users by using trusted links to share authentication between sites. SAML is a very good solution for scaling up authentication. It uses the so-called Single sign-on, which is a process by which the user enters a username and a password to access numerous sites/applications with the same data securely and reliably [9].

2. Data Integrity in Clouds

Data integrity is the overall accuracy, correctness, and consistency of data. Data integrity also refers to the safety of data. Data integrity is not only whether the information is correct but whether it is reliable. In addition to this, users often use different cloud service providers and in some cases there is no guarantee of data security at the input and transaction management levels. Cloud providers must implement data integrity standards in their cloud services [9]. Some of the data integrity standards for today’s cloud services are Data Integrity Field (DIF), SNIA Cloud Management Interface (CDMI), XML Based Solutions, etc.

3. Availability of Data in the Cloud

Data availability is the process of ensuring that data is available to end users and applications, when and where they need it. It defines the degree or extent to which data is readily usable along with the necessary IT and management procedures, tools and technologies required to enable, manage and continue to ensure data availability. One of the most significant security challenges for cloud technologies is the availability of data. Many providers aim at improving the availability of cloud infrastructures. There are several ways to improve the accessibility of cloud services. One of them is to provide users with back up information. A better option is to provide them with a caching proxy server that can respond to queries without contacting the specific server using content retained from a previous request by the respective user or even by another user. Another option is the transfer data from an online server to a so-called “hot” server that always has the contents of a cloned server and in case of a server failure, the user’s information is not lost [10-13].

4. A new data security model in cloud computing

The development of the new data security model in cloud technologies and related service delivery models is based on the CIA triad for cloud services, which is described above. The CIA shows the responsibilities of providers and users for each of the three most widely used cloud service delivery models. For example, in the case of the most widely used model globally – the Software as a Service, privacy, data integrity and availability are the sole responsibility of the provider of cloud services or products. For the other two models – the Platform as a Service and Infrastructure as a Service, the responsibilities are allocated differently between the user and the provider, as shown in Table 1. In this allocation, the most significant problem with cloud technology remains - the problem of data security and protection.

The new data security model aims at increasing the level of security of data and programs by checking users with the so-called three-factor authentication from another server. Three-factor authentication uses a combination of the following methods:

- **something the user knows**: it is a symbolic sequence that is known only to a given user and is unknown to others. When it is claimed with the user ID, it is taken as proof of possession of the identity. Typical examples of something known are passwords, PINs, private keys, etc. The most common and accessible means of authentication are passwords, which are a sequence of characters chosen by the system administrators or by the users themselves.
- **something the user owns**: it is a material object (card or other medium) on which additional information is usually recorded. In the process of authentication, the user claims the owned object by placing it in a device that can read its contents and confirm or reject the declared identity. Such techniques, for example, can help authenticate users using electronic signatures to share information with different institutions.
- **biometric data**: it represents unique data that can belong to only one individual. Fingerprints, iris, retina, voice recognition, etc. can be included in this category.

The model achieves a higher degree of security, as it focuses mainly on the preliminary control – the highest degree of efficiency. SSL or IPSec, as well as DoS protection, are added here.

The model also uses the so-called Single sign-on, which also requires authentication from an external server. Once the user is admitted to the system (cloud), he/she can access all cloud infrastructures in the environment (private, public, community) through Single sign-on without the need to enter authentication data again. That is, once a user is successfully admitted to the cloud infrastructure, this means that he or she has successfully passed the three-factor authentication described above and has the right to use his or her access to enter other cloud infrastructures in the environment, without the need to authenticate to each cloud individually (as it will be the case without a Single sign-on).

![Figure 3. A New model for data security in cloud with three-factor authentication (based on CIA triad)](image-url)
The model encrypts the information before it sends it to users by SSL, IPSec protocols. Another improvement of the model is that authenticated users and end users cannot be eavesdropped, which guarantees a high degree of confidentiality of the model. The model is mainly used in a cloud environment that requires maximum security and protection of data and information and enables the successful collection of biometric data.

Cloud providers are primarily responsible to secure the information. Each provider uses special techniques to secure its resources in this system. Upon entry of a username and password, Single sign-on also allows some authenticated users to use this registration for other sites and applications.

5. Conclusion
After the massive implementation of cloud technologies in businesses and enterprises, the security of users’ information and authentication has become increasingly important issue, which is discussed by many organizations around the world. Because of security issues, many users and businesses still refuse to use the cloud-based model. Risks, threats and vulnerabilities in virtual environments of cloud technologies significantly differ from the ones in physical environments. This publication introduces a new CIA triad data security model. It adds a three-factor authentication (3FA), as well as a Single sign-on using the OpenID standard. Thus, the effectiveness of preventive control is increased – this is the most important and effective control in an organization. The model focuses on data security and protection. Security management in an organization should also be in line with IT policies and standards for cloud technologies, as well as with business objectives for data security through the CIA triad – confidentiality, integrity and availability of information.

The proposed model will significantly increase data security in cloud technologies and thus reduce the risk of misuse and misuse of personal data, as well as the misuse of identity. Cyber threats and cyber-crimes will be reduced. The use of smart technologies will be safer and psychological stress and distrust in consumers will be reduced.

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7. References
A fuzzy logic-based Anti-Lock Braking Systems

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Abstract: In today’s automobile industry, the need to adjust the speed of the vehicle and stabilize the wheels control is still a task due to road conditions and traffic. The Anti-lock Braking System (ABS) is a tool used in automobiles to prevent wheels from locking while brakes are pressed. The objective of this work is the maintenance of the wheel slip value to a desirable slip ratio as the vehicle model is simulated using a fuzzy logic controller. The analyses are made based on the slip ratio, angular velocity and stopping time.

Keywords: FUZZY LOGIC CONTROLLER, ANTI-LOCK BRAKING SYSTEMS, TIRE MODEL, FRICTIONAL FORCE

1. Introduction

The industries of car manufacturing have always struggled to provide the best driving experience and yet one of the challenges of their work is ensure total safety. Among all the features a vehicle includes there is still a lot of improvement to be done on the systems that control its movement. Anti-Lock Braking system (ABS) [2, 4-6, 8, 10-12] is one of these features which nowadays is a pre-attached technology to the brakes implementation to prevent wheels from slipping while rapid stops. Road surface conditions may vary therefore an active system is required to stabilize the vehicle after the driver has lost steering control. The friction between tires and the road surface tends to be reduced after the brakes are pressed. It is an ABS system’s duty to detect the locked wheels and to quickly release the brakes. In this way the vehicle’s drift could be avoided so technically the drivers also the vehicles safety would be provided. Basic functionality of braking includes shorten stopping distance, steerability during braking through ABS system and stability during braking to avoid overturning. In this study, Fuzzy Logic [1] has been used as an adaptive controller for the simulated system model in order to enhance the performance of the vehicle.

The organization of the paper is as follows: In session 2 we describe the anti-lock braking system background and its components and a practical idea of how it is implemented in vehicles. It also describes the mathematical model of the non-linear quarter tire model and provides the details of the respective functions for the essential features. Session 3 will introduce Fuzzy Logic and a discussion on its application for the ABS system. The developed Simulink model of the Fuzzy controlled ABS system will be represented in session 4. Detailed analyses and the numerical results will be provided in session 5. Finally, conclusions and recommendations for future work will be emphasized in session 6.

2. Anti-Lock Braking System

The ABS System [7, 9] also known as anti-slip braking system is an automobile safety system that prevents the lock of the vehicles wheels as the brake pedal pressure is applied. Considering the emergency cases that can happen in traffic or under different circumstances where the road’s surface might be very unpredictable, slippery or uneven it is necessary that the driver would be able to maintain the control of steer and vehicle stability on short distance stops. Ideally, while a vehicle is in motion, when brake pedals are hardly applied, this system would reduce the wheel speed and provide the shortest stopping distances.

Let us emphasize how the brake system works. The braking process starts when the driver commands the brake pedal position which is translated into a brake pressure by the electronic control unit. The brake pressure results in a braking force on the brake disc which becomes a braking wheel torque at the wheel. The braking torque on the wheels creates a negative longitudinal force to decelerate the vehicle. Thus, the moment the driver hits the brake pedal it applies pressure at the hydraulic system that causes brake pedals to squeeze against the discs. That causes the vehicle to slow down by reducing the speed of both vehicle and the wheels. An important indicator of a vehicle speed is slipping ratio. The difference in the wheel speed and vehicle speed is defined by this factor.

\[
\text{Slip ratio} = \frac{\text{vehicle speed} - \text{wheel speed}}{\text{vehicle speed}} \times 100\% \quad (1)
\]

The implementation of the system is as illustrated in Fig. 1.

![Fig. 1: ABS System Components.](image)

The four main components are speed sensors, a pump, pressure release valves and controller. The sensors which are a combination of a toothed wheel, electromagnetic coil or magnet and a Hall Effect Sensor are used to calculate the acceleration and deceleration of the wheel. The toothed wheel is fitted to the rotating wheel hub proximately close to the magnetic sensor. There are four sensors, one per each wheel and sometimes they are placed on the differential. The sensor primarily detects a change in acceleration in the longitudinal direction of the vehicle and outputs it to the ABS control module. The Electronic Control Unit, shortly known as ECU is the controller that receives information from each individual speed sensor. In case it receives a signal from the sensor that a wheel has lost friction with the ground, it activates the ABS modulator.

The ABS system detects the right moment when a specific wheel is about to lock after the brake pedal is hit and the wheel speed is being reduced rapidly than the rest and quickly opens a pressure release valve in the hydraulic system that reduces the brake pressure on this specific wheel. The system automatically does this process in pulse form to prevent the wheels from locking. The modulator actuates the braking valves on and off. Hence, the pressure in the brake pipe is lowered. The wheel begins to rotate faster and tends to achieve the same speed as the rest. The valves might be separated in some systems or combined in others and they might work in three different positions. In either case, they communicate with the controller and the pump to add or release pressure from individual wheel brakes. The modulator valve has an
addition hold phase more like a cycle (5-6 times per second) which maintains pressure till the vehicle comes to a controlled stop. This process might be repeated continuously until the wheels reach equal speed. The valves suffer from clogging problems which causes them to have difficulty in opening, closing or change position. Thus the system might result in failure due to inoperability of the valves and the valves should be frequently checked. As discussed above the other component of the system was the pump. Once the pressure is released from the valves of the system, it needs to be restored on the individual wheel brakes when required. The pump status is adjusted by the controller in the required pressure level. While pump is cycling the driver might experience some vibration on the pedal. The cycling happens at a range of milliseconds thus the vibration is naturally felt.

2.1 Mathematical Model

In this session a briefly explanation of the mathematical formulation for the model is provided considering a simplified quarter vehicle model (Fig. 2). We begin by developing the linear braking model parameterized according to the Pacejka model (2002)[9] known as Magic Formula. Table 1 shows the notations used below.

The torque at the wheel center is as given above:

\[ J_ω\alpha = \mu RF_n - T_b \]  
\[ ma = -\mu x F_n = m \frac{dv}{dt} \]  
\[ \lambda = \frac{V_x - \omega R}{V_x} \]  
\[ \mu_\alpha = a(1-e^{-\lambda t} - \lambda t) \]  
\[ T_d = e^{-\lambda t} \sum_{i=0}^{n} T_d \]  

3. Fuzzy Logic Controller

The performance of the proposed model has been tested against general variations in road conditions. The theory of fuzzy sets and rules that was initially developed by Zadeh can be used to evaluate these imprecise linguistic statements directly. Considering the easy adaptation of fuzzy logic controller to varying road surfaces, traffic or uneven pavement the implementation of this controller for the actual model would give us some benefits. When compared to other types of controllers, Fuzzy controller has shown better performance and effectiveness. This soft computing system doesn’t need a precise model. Moreover Fuzzy logic has the ability to make decision even with uncompleted information and provides effective means of capturing the approximate nature of the physical world and human way of thinking logic. In this study we use MATLAB environment as a useful tool to determine the Fuzzy rules for the Fuzzy Inference System. The purpose of the controller is to keep the slip at a desirable optimal value 0.1. The method we have used is Mamdami as shown in Fig. 3.

The FIS has two inputs, respectively the first one determines slip error values (actual slip minus the fixed slip ratio of 0.1) and the second is the difference rate in slip error which is the vehicle deceleration. Nomenclature used for the rule base is as follows: NB - Negative Big | NS - Negative Small | ZE- Zero | PS – Positive Small | PB – Positive Big

Rules are determined in Fig. 4.

The Fig. 5 describes the relation of pressure as output and the two input data.

4. Fuzzy Controlled ABS Simulink model
In this session we tend to use as a nonlinear control scheme the fuzzy controller attached to the tire model proposed for the ABS system. The corresponding data for subsystems values are put in MATLAB source code. Fuzzy logic Controller block is linked with the FIS we described in session III. Figure 6 shows the full Simulink vehicle model.

![Fig. 6: Simulink vehicle model.](image)

The actuator subsystem refers to the equation (6) which is a first order model used for simplifying the design, where Td is the actuator time delay and the Ts is the saturated value, the parameter a is a pole set to a value of 70. The second subsystem is the tire model described by the equation (5) of the longitudinal friction coefficient where $\lambda$ is the slip value and coefficients a, b, c determine road conditions. The fixed slip value is set to 0.1 refereed to the Pacejka tire model. Test are made on dry asphalt condition as we have emphasized earlier.

5. Simulation Results

After the simulation of the model we continue to describe the graphics that we derived. Fig. 7 shows the deceleration of the vehicle.

![Fig. 7: Model results for velocity deceleration](image)

As we can see from the graphic lines, the starting value is a velocity of 30km/h given by the yellow line. The stopping time is approximately 2.80 seconds where the vehicle comes at halt. This is a great value compared to other controller systems. Fuzzy Logic controller tends to respond faster when brakes are applied. Thus, it could make this controller more preferable to other systems.

From the Fig. 8, we can observe the desired slip ratio of the vehicle once the brakes are pressed. We can see the curves of its line as is rises up to a fixed desired slip value. This settling time is approximately 0.15 seconds which is still a very short time when compared to other controllers. We can strongly emphasize that the system stabilization is achieved faster and fuzzy controlled systems are more robust.

6. Conclusions

ABS system control is treated as a nonlinear system designed with a soft computing controller as it is fuzzy logic controller. In this work, we use this controller to define the required parameters as slip ratio and angular velocity. The simulation results showed the good performance achieved when using fuzzy logic controller. This is due to its ability to provide shorter stopping distance and smaller slip ratio of the vehicle as the brakes are pressed. The fixed slip ratio of 0.1 has shown good results in ABS system model. The stopping time is quite small and this system performs better than some other works with different controller for the ABS system. Further consideration must be taken in the future and other simulations with different road condition will be performed.

References


Enhancement of corrosion resistance of steel, coated with various coatings on the base of 
SiO₂, TiO₂, ZrO₂ and CeO₂

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Abstract: Different corrosion-resistant coatings based on various SiO₂, TiO₂, ZrO₂ and CeO₂ oxides have been applied to various steels by the sol-gel method and spray pyrolysis. The obtained experimental coatings were investigated by X-ray diffraction (XRD), scanning electron microscopy (SEM) and weight loss measurements in 3.5% NaCl medium. TiO₂ / SiO₂ and CeO₂ / SiO₂ coatings treated at lower temperatures (500°C) have been shown to exhibit higher corrosion resistance than ZrO₂ / SiO₂ samples. Increasing the treatment temperature decreases the protective properties of the investigated coatings. The enhanced protective properties of TiO₂ / SiO₂ are probably due to their low crystallized fine grained structure and relatively dense surface without visible cracks.

Keywords: SOL-GE, SPRAY PYROLYSIS, CORROSION RESISTANT COATINGS

1. Introduction

The high hardness, corrosion stability, high temperature strength and oxidation resistance make stainless steel an ideal material; but unfortunately, in the presence of aggressive environments (for instance halide ions) proceeds excessive corrosion attack on the steels surfaces. [1] Corrosion of the marine environments (le crude oil tankers, oil platforms and gas extraction) is very serious problem, because in salt water, which is a conductor of electricity, the potential difference between adjacent metals cause electrons to flown from one metal to the other, causing galvanic corrosion. The eventual corrosion destruction of shipping facilities could lead to spills and other environmental disasters, damaging ecosystems and environmental pollution, which not only results in material losses, but is dangerous for human life. Inorganic substances especially arsenic and chromium salts are often used to prevent steel corrosion, but they are highly toxic for human health and environment and have to be replaced. Many other strategies are applied - one of most effective is the deposition of non-toxic oxides coating as barrier layers, such as CeO₂, ZrO₂, TiO₂, hybrid coatings etc. [2]. The effect of the change of various technological parameters such as the type of precursor, heat treatment, introduction of various dopants, etc. are investigated on the crystalline structure, the density and hydrophobicity of the coatings and hence their corrosion protective properties. Several types of monocomponent and bicomponent oxide coatings have been synthesized using the sol gel method. The aim of this study is to obtain corrosion resistant coatings of various inorganic oxides (pure and composite) TiO₂, CeO₂ and ZrO₂ deposited on SiO₂ by sol gel method. The selected sol gel method have advantages such as low cost of equipment, the ability to apply larger size pads that give potential for industrial application [3].

2. Experimental

AISI 316 stainless steel, 7.5x 2.5 cm in size, was ultrasonically cleaned in ethanol and acetone as substrates. The SiO₂ layers were applied from a solution of tetraethoxysilane (TEOS) in a mixture of ethanol, water and hydrochloric acid as a catalyst and stirred for 2 hours to form a 0.5M solution. The molar ratio of H₂O: TEOS is 3.7. The solution is aged for 7 days to form bonds in them. The metal pads are immersed in the solution and drawn at a constant speed of 3 cm / min and then dried successively at 60°C and at 90°C and 300°C. These steps are repeated 2 times.

The coatings are characterized by a set of physicochemical methods such as X-ray diffraction (XRD), scanning electron microscopy (SEM), atomic force microscopy (AFM), X-ray photoelectric spectroscopy (XPS), energy dispersive analysis (DDA) analysis, EDA , infrared spectroscopy (IR), and more. Corrosion resistance was assessed by two techniques: weight analysis after residence in NaCl salt fog.

3. Results and Discussion

Multilayer coatings of ZrO₂ / SiO₂, TiO₂ / SiO₂ and CeO₂ / SiO₂ inc.
3.1 Multilayer coatings of ZrO₂ deposited on SiO₂ support by sol-gel method with immersion technique. 3.2 Multilayer coatings of CeO₂ deposited on SiO₂ by sol-gel method with immersion technique. 3.3 Multilayer coatings of TiO₂ deposited on SiO₂ support by sol-gel method with immersion technique.

In connection with 3.1, three layers of ZrO₂ from the solution obtained as follows are applied to the specimens. ZrOCl₂ · 8H₂O dissolved in ethanol to 0.4M solution was used as a precursor. 0.016 mol of acetylacetone is added as a complexing agent of droplets and a few drops of nitric acid to prevent hydrolysis. Substitutes of silica deposited are immersed in the solution and drawn at a constant speed of 3 cm/min and then dried successively at 300°C for 80 min. at a heating rate of 3°C/min for some of the samples, while for others the above technology is repeated as the final heat treatment is carried out at 700°C for 1 hour in air.

Initially, 2 layers of silicon dioxide were applied in accordance with 3.2 using the above-described technology, after which 3 layers of CeO₂ were applied. Ce(NO₃)₃ · 6H₂O dissolved in isopropanol to 0.4M solution was used as a precursor. Substitutes of silica deposited were immersed in the solution and withdrawn at a constant speed of 3 cm / min and then sequentially dried at 300°C for 80 min. These steps were repeated 3 times, finally finishing at 500°C for 1 hour in air at a heating rate of 3°C/min.

The initial 2 layers of silica were applied in accordance with 3.3 according to the above technology, after which 3 layers of TiO₂ were applied and titanium isopropoxide (TTIP) was used as a precursor; Ti (OC₃H₇)₄ (98% purity) which was dissolved in a mixture of ethanol (EtOH) and butanol (ButOH). The reaction of complex formation is exothermic. After vigorous stirring at room temperature, a mixed solution of distilled water and ethanol was added drop wise to the above solution with stirring. Hydrochloric acid is added drop wise as a catalyst. The molar ratio of the components is TTIP: EtOH: ButOH: H₂O: HCl = 1: 19: 1: 0.03. The silicon-coated substrates were immersed in the solution and drawn at a constant speed of 3 cm / min and then dried successively at 300°C for 80 min. These steps were repeated 3 times, finally finishing at 500°C for 1 hour air with a heating rate of 3°C / min, while in others the above technology is repeated, with the final heat treatment being carried out at 700°C for 1 hour of air.

The XRD of samples slightly crystallized the anatase TiO₂ phase. A similar result was reported by Cheng and co-authors for sol-gel layers of titanium dioxide doped with SiO₂. They demonstrate that the anatase phase peaks attenuate with increasing silicon dioxide concentration, as for the doped with 0% SiO₂, the titanium dioxide layer is amorphous [4] Another group of researchers also showed that the introduction of SiO₂ into TiO₂...
nanoparticles slows the crystallization of the anatase phase. Figures 1 and 2 show the results of the XRD performed on the obtained experimental coatings.

Figures 3 and 4 show the morphology of coatings. The multilayer coatings of CeO2/SiO2 after corrosion attack have a preserved surface, without craters and cracks, which proves their high corrosion stability (Fig. 4 a). In contrast, the surface of ZrO2/SiO2 coatings is much more rough with many craters and pits, and these corrosion effects are exacerbated by samples treated at higher temperature (SZ7) (not shown). TiO2/SiO2 coatings after the corrosion test slightly increase their roughness but retain their characteristic grain structure, without exhibiting corrosion effects such as cracks, pores and other defects (Fig. 4b).

**4. Conclusions**

It was proved that TiO2/SiO2 and CeO2/SiO2 coatings treated at a lower temperature exhibit higher corrosion resistance than ZrO2/SiO2 samples (Fig. 5), as evidenced by the weight loss test in NaCl medium and the studies of morphology. Increasing the processing temperature impairs the protective properties of the two types of coatings. The better protective properties of TiO2/SiO2 heated at 500°C may be due to their very weak crystalline structure and relatively dense surface. In contrast, the other 2 types of coatings exhibit weaker barrier properties, which is probably due to the increased crystallization and the type of surface morphology.

The new TiO2/SiO2 multilayer structures obtained are promising with a view to increasing the corrosion resistance of the steel.

**5. References**

APPLICATION FIELDS OF POROUS TITANIUM GAS FLOW DISPERSERS AT ENTERPRISES OF THE AGROINDUSTRIAL COMPLEX

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Abstract. The effective fields of application of products made of porous filter materials based on titanium powders as gas flow dispersers at enterprises of the agro-industrial complex are given. The results of their use in the dispersion of ozone-containing air mixtures, air and vapor for the purpose of disinfecting the fish habitat in equipment of a closed water supply, saturating the culture fluid with oxygen in the growth of microorganisms in bioreactors and heating the heat carrier to ensure sterilization of liquid media in dairy plants, respectively, are described.

KEY WORDS: POROUS FILTER MATERIALS, DISPERSERS, GAS FLOW DISTRIBUTORS

1. Introduction

Powder metallurgy methods made it possible to create a new type of permeable materials – porous materials based on metal powders. Compared with other permeable materials (felt, paper, fabrics, polymers, ceramics), porous powder materials (PPM) have a number of advantages: they have a good combination of throughput and cleaning fineness; they have a high strength; they are resistant to thermal shocks; they yield to welding, soldering and machining; they are able to repeatedly regenerate by various methods. Choice of the appropriate material provides the necessary corrosion resistance, heat resistance and heat conductivity. Depending on the characteristics of the initial powder and manufacturing technology, porous materials produced on the base of powders of bronze, copper, stainless steel, nickel, titanium, tungsten, niobium, and tantalum have a wide range of properties: porosity from 0.2 to 0.8 and pore sizes from ten to 1000 µm. In the classification by application, one of the most common groups of PPM are flow distributors, which are used in the pneumatic transport of granular media, aeriation of liquids for their mixing or saturation with gases, as elements of porous cooling or heating, and other purposes.

The purpose of the work is sharing experience on the effective use of porous powder materials (PPM) as distributors of gas flows at enterprises of the agroindustrial complex.

2. Results and discussion

Based on the background of experience, there are three the most promising fields of application: aeriation of the air flow in order to saturate the culture fluid when growing aerobic microorganisms in bioreactors, dispersation of the flow of ozone-containing air mixture to decontaminate the fish habitat (including fish juveniles) in recirculating aquaculture system (RAS) and uniform distribution of vapor flow by volume of heat carrier (water) to control the temperature in working tanks during heat treatment of milk, milk mixtures and process media used in milk processing.

An essential condition for the cultivation of aerobic microorganisms is the aeration of the fermentation medium, i.e. the process of its saturation with oxygen in the air. Microorganisms growing aerobically, depend on the content of only dissolved oxygen in the fermentation medium. The most common method that provides effective dissolution of oxygen in a liquid medium is the method of blowing atmospheric air through a fermentation solution. Under other equal conditions, the intensity of the oxygen dissolution is determined by the properties of the aerator, which directly distributes the air flow in the culture fluid. The most preferred, in comparison with others, are powder aerators [1-3].

Below are the results of laboratory studies and approbation under production conditions of the use of titanium powder-based aerators in the cultivation of the yeast microorganisms Debaryomyces Hansenii var. Hansenii (D.f.v.); culture medium was prepared on the base of whey. It was established that a porous powder aerator based on titanium powder has a saturation rate 1.6 times higher than the standard (perforated) one. Comparison in the process of cultivation of D.f.v. yeast microorganisms during air dispersion through standard and powder dispersers on a laboratory fermenter (Fig. 1) also showed an advantage of the latter: an increase in biomass was about 25% with the same air-flow rate (1 l/min per 1 liter of culture fluid) [1, 4-6].

Studies under production conditions were performed at “Bobruisk plant of biotechnologis” (Belarus) in a pure culture propagator (a production fermenter for the preparation of D.f.v. seed material intended for whey processing in a working device in order to obtain a protein feed additive). The drawing of the device for saturation of the culture liquid with oxygen in the air is shown in Fig. 2; the mounted device is shown in Fig. 3. Tests have shown that the device for saturation of the culture medium provided the completion of the cultivation process after 12 hours, against 14 hours while working with the standard (perforated) disperser [7].

One of the main tasks of recirculating aquaculture system (RAS) is to maintain optimal water quality, both the primary water preparation and its regeneration in the recirculating process is played by the decontamination operation. Ozonizing is one of the most common methods of purification. 0.5-4 mg/l is enough for...
water purification (the more turbid the water, the more ozone should be consumed) [8, 9].

Powder titanium dispersers made of PPM were installed instead of ceramic ones in recirculating aquaculture system (RAS) (Figure 4, a, b), and showed good results in the work process. After two years of operation, the indicators of dispersers did not change in RAS, while similar ceramic products became unfit for use as a result of self-destruction after one and a half years of operation (Figure 4, c).

The design of the device for saturating water with oxygen from ozone-containing air mixture with a titanium disperser, presented in Figure 4, was successfully tested. Its purpose is to intensify the process of catalytic deironing of drinking water. Removing iron from water, without exaggeration, is one of the most necessary tasks in water purification.

The device makes it possible to study the process of water saturation with oxygen during the dispergation of ozone-containing air mixture with a replaceable porous disperser in the form of a disk. The appearance of the porous powder disperser made of titanium powder is shown in Figure 5.
The device makes it possible to study the process of water saturation with oxygen during the dispergation of ozone-containing air mixture with a replaceable porous disperser in the form of a disk. The appearance of the device for saturating water with an ozone-air mixture is shown in Figure 5; a porous powder disperser made of titanium powder is shown in Figure 6.

Fig. 5. Device for studying the water saturation with oxygen: 1 – housing; 2 – support; 3 – base; 4 – base plate; 5 – laying; 6 – upper flange; 7 – bottom flange; 8 – pin; 9 – top long fitting; 10 – top short fitting; 11 – lower fitting; 12,13,15 – fastening elements; 14 – manometer

Fig. 6. Device for preparing ozone-containing mixture

Fig. 7. Appearance of porous powder disperser made of titanium powder for water saturation with oxygen during dispergation of ozone-containing air mixture for water deironing

An example of the effective application of a disperser is the use of PPM made of titanium powders for heating the heat carrier in milk processing industries. Heat treatment is one of the basic and necessary technological operations of milk processing. The equipment developed by Moltekstroymontazh company and successfully operated uses closed devices with a heat exchange jacket, in which the flow through the jacket of the heat carrier (water) is heated by mixing it with vapor. This ensures the velocity of the process and, accordingly, reduces the time of the full technological cycle. At the same time, powder titanium disperser provides a uniform distribution of the vapor flow throughout the heat carrier volume, while simultaneously cleaning the vapor from solid inclusions [9]. Figure 8 shows the tanks for the heat treatment of process media and the heating unit of the heat carrier supplied to the heat jacket of the device intended for pasteurizing milk mixtures. Figure 9 shows the appearance of tubular dispersers installed in the tank for the heat treatment of process media.

Fig. 8. Tanks for the heat treatment of process media (a) and the heating unit of the heat carrier supplied to the heat jacket of the device intended for pasteurizing milk mixtures (b)
The heating unit with a powder disperser with relatively small dimensions and a simple design provides for heating the tank with a working load of a liquid medium with a mass of one ton to 95 °C for 45 minutes; vapor is supplied under pressure of 0.4-0.5 MPa at a temperature of 140-160 °C.

3. Conclusion

The paper presents possible options for the effective use of porous powder materials as distributors of gas flows at the enterprises of the agro-industrial complex. The results of their use in the dispergation of ozone-containing air mixtures, air and vapor for the purpose of decontamination of the fish habitat in recirculating aquaculture systems, as well as saturation of the culture fluid with oxygen in the growth of microorganisms in bioreactors and heating the heat carrier to ensure sterilization of liquid media in dairy plants, respectively, are described.

4. References

Typical mistakes made in the catalog of led lighting products and recommendations for their elimination

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1. Introduction
Since the beginning of 2010, a large number of large and small enterprises for the production of office, industrial and street LED-lamp have emerged in a number of Russian cities. At the same time, the bulk of their developers did not have higher lighting engineering education. As a result, in the technical documentation of many LED-lamp, errors were initially made in the representation of the dimension and accuracy of a number of their indicators, in their name, as well as in the form of the presentation of indicators, which allowed them to be attributed to the model [1,2].

2. Problem discussion
The discussion of certain errors allowed in the technical documentation of domestic and foreign developers has been the subject of our discussion in different journals (Poluprovdnikovaya svetotekhnika, Svetotekhnika, Practichesksaya silovaya elektronika, Inzhenernyj vestnik Dona) and at different Lighting Forums. In addition, information was sent to a number of light engineering research institutes. Despite this, the situation is changing very slowly. The German Institute of Lighting Engineering (DIALUX) was also informed twice about the presence of an erroneous representation of the dimension of the indicator given on the curves of light power. The problem remains unchanged, because in this case it is necessary to modify the software product slightly in order to calculate the illumination in the premises, which practically use the whole world. Therefore, it is necessary to return more than once since 2012 to the consideration and description of both old and new standard errors, the list of which is almost only replenished [3-7].

3. Objective and research methodologies
On the basis of the study of the content of sites more than 100 firms, 6 typical mistakes were identified, which are the subject of consideration at this scientific conference in the following sequence in the order of their presentation in the journals of Russia:

1. The dimension of the light flux is erroneously given as Lm or LM, at that time it should be given as lm. The error in dimension is due to the fact that the first developers of the lowercase letter “l” many in Russia without having a lighting education took for a capital one. Today it is still being replicated in the documentation of 57 firms out of 100 [3].

2. The second typical error is that on the Light Power Distribution curves (KSS) the dimension of the light force is given in the normalized form kW/km, that is, the strength of light leads to the amount of light flux expressed in km. The given normalization of the light force on the KSS is erroneous, since the comparative evaluation of the radiation angle of models of different firms is usually not comparable results. In order to avoid this error, it is necessary to present dimension in kl or relative values on generalized KSS and when using the software product DIALUX. This error is found in the technical documentation of more than 85% of firms [2, 4].

3. The third error is the non-uniform representation of the types and subtypes of the wide angle of radiation LED-lamp. On the websites of firms there are up to 14 designations of subtypes of a wide angle of radiation in the form: W2, W1, W2, W3, W7, W8, W9, W13, W22, W 24, W25, W1, WM. Such a large number of designations is caused by the fact that a number of firms try to offer their system of designations. The absence of unification in the designation of subtypes of a wide angle of radiation is a source of discrepancies. More specific information can be obtained if, instead of arbitrary notation of the subtypes of a wide radiation angle, the angles of radiation of the KSS in 3 planes are indicated: In the longitudinal, transverse and in the plane of maximum radiation in the form of W 45x140/1.5, where the first digit indicates the angle of radiation in the longitudinal plane, the second indicates the angle of radiation in the transverse plane, and the third number reflects the ratio of the maximum value of light to the minimum [5]. This form of display of radiation angles immediately allows you to quickly imagine the shape of the KSS LED-lamp.

4. A fourth typical error is allowed in the Power Factor Name view. In the technical specifications of LED-lamp, its name is often quoted as “power factor (cos Φ),” “power factor, cos Φ”. This form of designation of an important energy indicator and coefficient of distortion power leads to the difference of its values [6], so that does not reflect the ratio between values and cos Φ.

5. Typically, the LED-lamp technical documentation lists primarily the values of indicators such as luminous flux (Φ) and power consumption (P). The LED-lamp can be compared only after its light output is calculated. The indicators themselves do not actually carry direct information. After calculating the light output it turns out that it is often overestimate [7]. Sometimes there are cases when the calculated value of light output from the presented values of light flux and power is even higher than the maximum permissible values of the currently released LEDs (table). All of this indicates that the format adopted for the presentation of indicators is a source of error and may well be attributed to the fifth standard error. Thus, in order to improve the reliability of the results given in the technical documentation, the value of light output, which is found by the formula:

$$\eta = \frac{\Phi}{P}$$

If necessary, the luminous flux values can easily be determined by multiplying the light output value by the power value.

6. A very common error (sixth) is the incorrect rounding of the given parameters in the technical characteristics and in scientific publications. Let’s consider first of all the character of the representation of the luminous flux. Even in certified lighting laboratories, the absolute error of measuring the light flux is at the level of 3-5%, give its values with an error of up to 0.01-0.001%, that is, more than 100-100 times more precisely. For example, LED-lamp with a power of about 300-500 W produces a luminous flux in the form of 67567, that is, the value is represented with an error of about 0.008%. This representation from the metrological provisions is erroneous. If you present this number as 67600, even then the representation error is sufficient and equal to 0.06%. For illustrative purposes, we shall present the stages of the rounds of the given number in the form:

<table>
<thead>
<tr>
<th>№</th>
<th>Name of the company</th>
<th>Model of lamp</th>
<th>Φ, lm</th>
<th>P, W</th>
<th>H, lm/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PROMILED</td>
<td>Prof v3.0</td>
<td>18800</td>
<td>100</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof v3.0</td>
<td>26250</td>
<td>150</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof v3.0</td>
<td>36000</td>
<td>200</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof v3.0</td>
<td>45000</td>
<td>300</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof v3.0</td>
<td>52150</td>
<td>350</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof v3.0</td>
<td>57000</td>
<td>400</td>
<td>1.44</td>
</tr>
</tbody>
</table>

| Tablica |

It can even be represented by a number equal to 68000. This number in this case will be overestimated only 0.7%, which is more than 5 times less than the error of photometric measurements. The error of the average σ should be given only two significant figures, because the third significant digit is unreliable, and one significant is not enough.

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since when comparing the average values of the two samples it is possible to mistakenly interpret the results when analyzing the data of the other authors [8].

In technical documentation many non-standard errors are allowed, on which it does not make sense to stop. I want to pay attention to several errors that consumers can make when purchasing LED-lamp. First of all, the consumer is oriented to the price of the product. It can be cheap but not quality, because it can have low light output. Even leading manufacturers produce products whose light output can differ by 2 times (from 80 to 160-170 lm/W). Therefore, it is not possible to be guided only by the price of the product. Integral measure must be used. For these purposes, it is proposed to use the technical and economic efficiency coefficient LED-lamp, which is calculated by dividing the light output of the product by the price of one lumen (dollar / lm). As a result, the sensitivity of this indicator increases by almost 5 times, which allows the buyer to purchase a better product. With the advent of filament lamps (Fig.), many talked about its advantages over a typical LED lamp. However, special studies of its characteristics are devoted only to single works [9, 10]. Initially, it seemed that the advantage of filament lamps is the small temperature of their hull, usually not exceeding 36-39° C. Multi-day tests as at room temperature their life is less than typical lamps, and at the maximum permissible temperature (50° C) it is even less [10]. This is due to the fact that in filament lamps the temperature of the LEDs is actually higher than in the typical LED-lamp. Another mistake in the evaluation of the quality of filament lamps is the perception of the power of the lamp in its dimensions. The largest and most medium-sized lamps have a power output of only 4 and 6 watts and are made for their greater implementation and partly for design.

### 4. Conclusion

The results of the research should help to eliminate a number of errors in the presentation of technical documentation, which many firms are allowed to make. The conducted analysis of the content of the sites of many and leading lighting engineering firms allows us to judge the quality of their presentation of technical documentation on the firm, the level of qualification and even forecast the quality of the produced products.