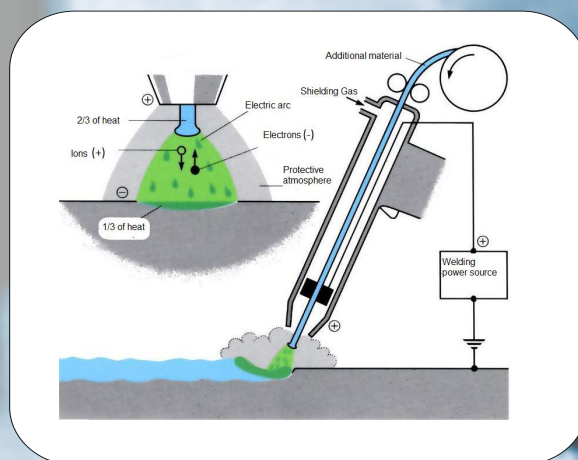


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Tribological properties of layers created by progressive technologies

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Abstract: The paper presents the results of research focused on the renovation of worn surfaces. Four progressive welding technologies were used - Cold Metal Transfer, MIG Pulse, TOP-TIG and laser technology. The layers were evaluated by non-destructive tests - visual, capillary and ultrasonic methods. The layers were evaluated under dry-friction adhesive wear conditions by the Ball-On-Disc method. A Si₃N₄ bead was used. Analyzes confirmed the impact of the renovation method on the quality of the resulting surface.

Keywords: DIE CASTING, SURFACE DAMAGE, MOLTEN ALUMINUM, CLADDING, LASER, MIG PULSE

1. Introduction

High Pressure Die Casting (HDPC), or high-pressure casting, is a technological process widely used for casting complex aluminum castings, mainly associated with the automotive industry. In this process, molten metal with a temperature of 670-710 °C is pushed into the mold cavities at filling speeds of 30-100 m/s, under pressures ranging from 40-80 MPa [1]. This load, combined with the corrosive properties of liquid aluminum, leads to aluminization or oxidation of the surface of the molds, which causes thermal fatigue of the surfaces followed by their cracking, soldering and erosive wear. The service life of mold matrices made of steel alloys is approximately 100,000 cycles and can be increased either by heat treatment, application of thin coatings or welding [2-4]. Nowadays, the issue of surface treatment of various materials is increasingly coming to the fore. It offers the saving of strategic materials and at the same time enables the production of components with specific surface and volume properties [5-6]. As resources are limited by conventional technologies, it is increasingly difficult to satisfy more advanced customer needs. There are many methods for substrate treatment, but coatings developed using, for example, electrostatic, chemical, physical deposition techniques have a lower bond strength with the base material or very little reproducibility compared to those by welding. Refurbishment of worn parts of machines is a very effective and ecologically acceptable form of their maintenance. This option can reduce the impact on the environment during the entire life cycle of the component by up to 63.8% [7].

Laser welding

Laser welding is a technology used to create coating layers with improved properties, or to restore defects in worn parts of the surface and base layers of components. Due to the high energy density and relatively small thermally affected area, this method is suitable for processing a wide range of materials [8]. It is mainly used in the automotive, aviation, medical, nuclear and oil industries. In the aviation industry, the welding of layers on aluminum alloys to improve their surface properties has an increasing potential.

This technology uses highly concentrated light waves, concentrated to a certain point [9]. Atomic bonds break down in the area hit by the laser beam, which causes it to heat up. The three most common types of lasers used in laser welding equipment are gas, semiconductor and fiber [10]. The laser beam is guided to the welding device by one or more optical fibers concentrated at one point. With each added fiber, the intensity of the laser beam increases. Before the laser beam leaves the welding equipment, a combination of a collimator and a focusing lens is often used to direct this radiation into a very small area [11]. An important part of the laser welding equipment is also the nozzle supplying the gas of the protective atmosphere, most often CO₂. this gas prevents contact between the weld pool and the atmosphere [12]. Another option is laser welding without a protective atmosphere, for example when welding plastics. Although vacuum welding is possible, it is difficult to use, due to the high demands on the construction of the welding equipment [13].

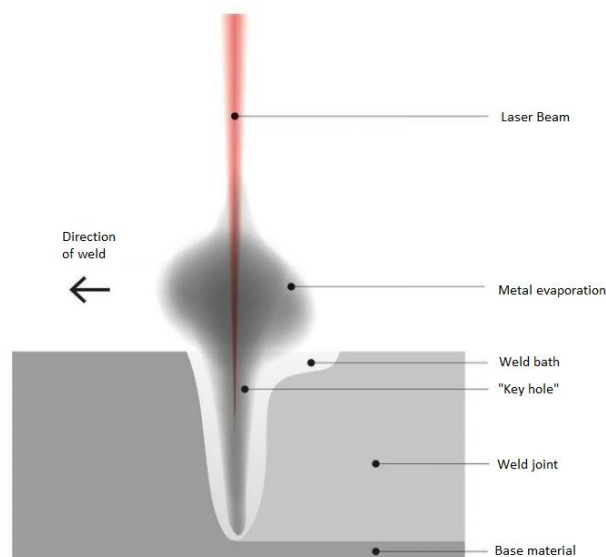


Fig. 1 Schematic representation of laser beam welding [13]

MIG/MAG welding (GMAW)

MIG/MAG welding is currently the leading method in most industries. Gas metal arc welding (GMAW) also referred to as metal inert gas (MIG) if the shielding gas is inert, or metal active gas (MAG) with an active shielding gas [14]. The main advantage of this technology is its flexibility. The construction of the welding equipment allows welding in all positions, to weld surface-treated metals such as zinc-coated steel, as well as all commonly occurring materials such as stainless steel, alloys of aluminum, copper, nickel, and the like [15]. The disadvantage is its limited use outdoors, where the protective gas may be blown off due to air flow [16].

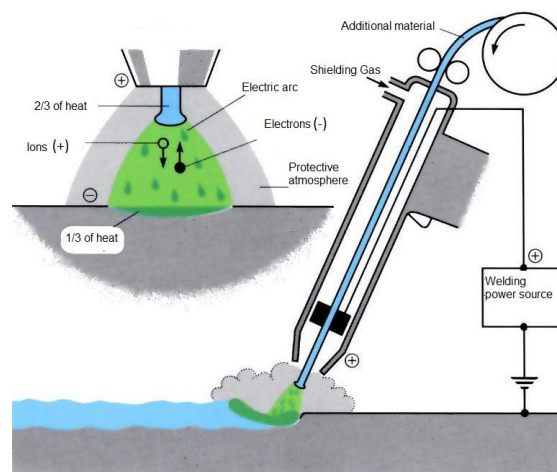


Fig. 2 Schematic representation of the MIG/MAG method

The principle of the MIG/MAG method consists in the burning of an electric arc between a continuously supplied melting electrode and the welded material [17]. The welding wire is wound on a coil, from which it is fed to the welding gun through a system of drive rollers. Electrical voltage is applied to the electrode through the contact nozzle, which is usually connected to the positive pole of the source, while the workpiece is connected to the negative pole. The shielding gas is supplied through a gas nozzle surrounding the contact nozzle. With an increased load of 300-500 A, the welding gun is usually cooled by water. Additional material in the form of wire is divided into 2 basic groups [18]. The first is solid wire intended for welding with inert and active gases in diameters of 0.6-2.4 mm. Such wires, especially if they are of larger diameters, are coated with a thin layer of copper, due to the increased power supply. The second group are wires with a core, which consist of a metal outer shell, covering the flux, or metal powder located in the electrode core [19]. such electrodes are mainly used when welding thicker sheets, for rounded and butt welds, or when welding with robots in a horizontal position. The use of these wires increases the resistance of welds to cracking, they ensure deeper penetration into the welded material, and increase the range of usability of the welding equipment [20]. The disadvantage is the higher price, finishing operations of the weld surfaces and increased production of harmful fumes.

2. Materials and Methods

Two different technologies were used for the production of the samples listed below, while the aim of the work was to determine the impact of individual technologies not only on the quality, but also on the chemical composition of the welds and the minimization of the heat-affected area. Each of the technologies listed below has a different heat input, which, in addition to the quality of the weld, is also reflected in the degree of mixing of the base material with the weld metal.

Two samples of disc laser welding (sample 01), MIG Pulse (sample 03) were applied to the additional material. Sample welds marked 01, 03 were applied to a substrate of nickel-chromium-molybdenum-vanadium steel 1.2714, DIN - 56NiCrMoV7. The welding wire Uddeholm Dievar 1.2344, DIN - X40CrMoV51 with a diameter of 1.2 mm was used as an additional material. Peg tests and hardness curves were performed on the samples.

Coatings were applied to samples of two basic materials. On the basic material nickel - chrome - molybdenum vanadium steel 1.2714, DIN - 56NiCrMoV7, with a hardness of 44 HRC

Tab. 1 Chemical composition of the base material **Table 2.** Chemical composition of the additive material [16]

Element	Wt. [%]
C	0.397
Mn	0.72
Si	0.238
Cr	0.969
Ni	1.253
Mo	0.438
V	0.089
W	0.12

Element	Wt. [%]
C	0.35
Cr	5.00
Si	0.20
Mo	2.30
Mn	0.50
V	0.60

The welding wire Uddeholm Dievar 1.2344, DIN-X40CrMoV51 with a diameter of 1.2 mm and a hardness of 51 HRC [8] was used as an additional material for the formation of welding layers.

Table 3. Parameters of laser welding

Welding technology	Disc laser welding
Welding equipment	The TruDisk 4002 solid-state disk laser with BEO D70 focusing
Focal length	200 mm
Laser power	1.8 kW
Optical fiber diameter	400 μm
Welding speed	10 mm. s^{-1}
Focusing	- +6 mm
Wire feed speed	70cm. min^{-1}
Shielding gas flow rate	Ar30l. min^{-1}

Table 4. Parameters of Mig Pulse welding

Welding technology	MIG Pulse Welding:
Welding equipment	Fronius TPS600i welding power source
Welding current	196 A
Welding voltage	23.8 V
Wire feed speed	6.5 m. min^{-1}
Welding speed	8 mm. s^{-1}
Arc length correction	3
Pulse/dynamics correction	0.0
Shielding gas flow rate	Ar 30 l. min^{-1}

3. Results

Chemical analyzes have shown that in the heat-affected area, individual materials are mixed, ie. base and additional material in the weld metal. The value of chromium in the weld metal is crucial, which in no case reached the limit of 5.00%, soaked in the additive material. The decrease of this element can be attributed mainly to the thermal influence of the material in the process of welding. The value of mixing the base material and the weld metal is minimal, which is confirmed by the fact that the hardness of all welds evaluated in the previous analysis was around 500 HV0.5.

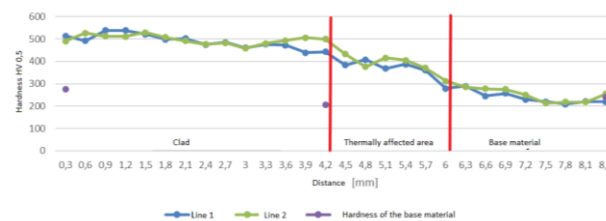


Fig.3 The graph shows individual weld hardness values measured in two lines and the hardness value of the base material on sample 01, created by disc laser welding

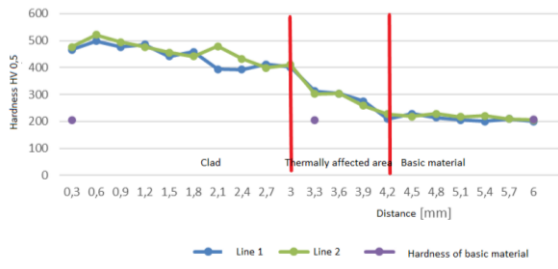


Fig. 4 The graph shows individual hardness values measured in two lines and the hardness value of the base material on sample 03, created by MIG Pulse technology

Since one step was 0.3 mm in the hardness measurement, the weld thicknesses ranged from 2.8 to 4.7 mm. Weld 01 had an average hardness value in the range of 450-500 HV0.5. In sample 03, see In Figure 5, 20 measurements were made, while the average value of the weld metal hardness was in the range of 400-500 HV0.5. From the fact that the hardness of all samples is in the range of 500 HV0.5, it is clear that the mixing of the base material and the weld metal has been eliminated, therefore there is no need to apply an additional layer during welding in either method. In weld 03 (MIG Pulse), the width of the heat-affected zone was around 1.2 mm. a wider heat-affected area was recorded by disc laser welding on the sample marked 01, the width of which was about 1.8 mm.

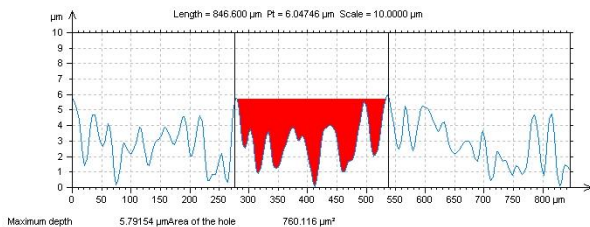


Fig. 5 Schematic of the tribo wear track on sample 01 produced by the Pin-on-Disc test

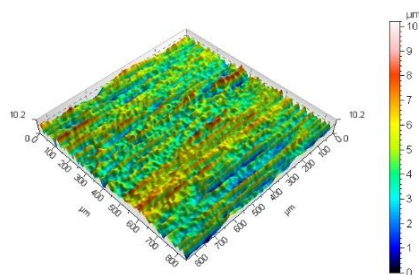


Fig. 6 3D image of the tribo wear track on sample 01 produced by the Pin-on-Disc test

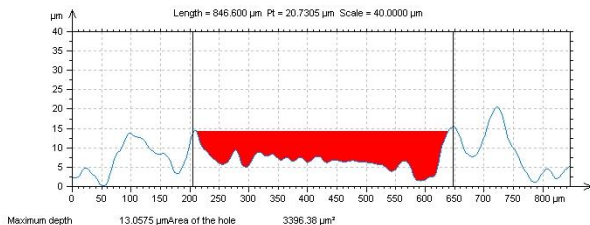


Fig. 7 Schematic of the tribo wear track on sample 03 produced by the Pin-on-Disc test

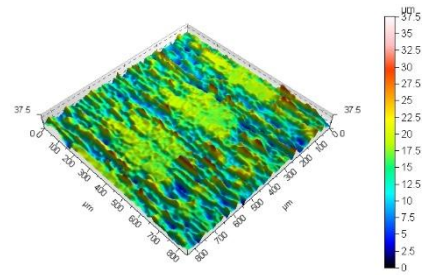


Fig. 8 3D image of the tribo wear track on sample 03 produced by the Pin-on-Disc test

A comparison of the coating surface of sample 01 (see Figure 6) with that of sample 03 (see Figure 8) showed that the wear mark of this coating was much shallower and smoother, and that the coating material moved from the center to the sides of the wear mark was less pronounced.

Weld 01, made by disk laser:

The width of the scanned area in the ultrasonic inspection of the weld marked 01 was 72mm and 6 scanning lines were used. The direction and designation of the scan lines are shown in Fig. 9.

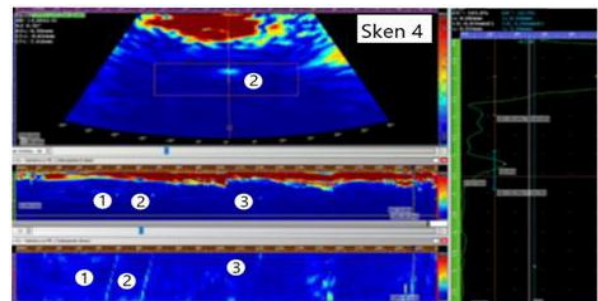


Fig. 9 Top - S-scan, right - A-scan (amplitude in the path), bottom - B-scan (cross section), in the middle - C-scan (area distribution of errors)

On scan no. 1, 2 internal errors were found, differing in depth, which was 3.8 mm at size 1 and 3.3 mm at size 2. On scans no. 2, 5, 6 no relevant internal errors were found, while scans 5, 6 are the same as scan 2 without internal errors, therefore they are not in Fig. 9 shown. In scan no. 3, only one relevant internal error with a depth of 3.6 mm was found. On scan no.4, internal defects were found, with depths ranging from 3.2 mm to 3.6 mm.

Weld 03, made by MIG Pulse technology:

The width of the scanned area in the ultrasonic inspection of the weld marked 03 was 82 mm and 8 scanning lines were used. The direction and designation of the scan lines are shown in Fig. 10.

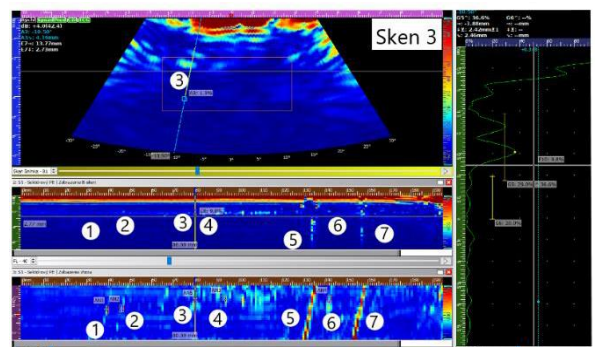


Fig.10 Top - S-scan, right - A-scan (amplitude in the path), bottom - B-scan (cross section), in the middle - C-scan (area distribution of errors)

On scan No. 1, 3 internal errors were found, while the depth of the error varied in the range from 1.7 mm to 1.8 mm. On scan No. 3, 6 internal errors were found, while the depth of the error varied in the range from 1.9 mm to 2.7 mm. No relevant internal errors were found on scans 2, 4, 5, 6, 7, 8, with scans 4, 5, 6, 7 being the same as scans 2 and 8 without internal errors, therefore they are not shown in Fig. 10.

4. Conclusions

The presented article is focused on the analysis of the quality of two types of deposits intended for the renovation of molds in high-pressure aluminum casting. Two different welding technologies and disc laser welding and MIG pulse welding were used for the production of test specimens. In all samples, UddeholmDeivar 1.2344 welding wire was used as a supplementary material, because this material is used in the restoration and renovation of functional parts of molds for aluminum pressure casting. In the theoretical part, the issues and mechanisms of die matrix wear for high-pressure aluminum casting are characterized, along with an overview of welding technologies used in the formation of weld layers in various industries. The experimental part was aimed at determining the quality of the above-mentioned navars. The quality of the welds was assessed on the basis of the heat-affected zone, which was determined from the course of the graphs, when measuring the hardness. The tribological parameters of the welds were investigated using the Pin-on-disc test. From the hardness measurement of the individual samples, it can be deduced that the narrowest heat-affected area had a weld marked 03, created by the Mig Pulse method. The widest heat-affected area was recorded on the sample marked 01, created by the disc laser. Based on the Pin-on-disc test, it can be used that sample 03 is much smoother and the shift of the coating material from the center to the worn sides was less pronounced. Based on the experimental work carried out, it is possible to recommend these technologies in practice for the purpose of renovating molds. Better results were achieved with the sample of weld 3 labeled Mig Pulse.

Acknowledgments:

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3. References

[1] Changrong Chen et al.: Energy based approach to thermal fatigue life of tool steels for die casting dies. In: International Journal of Fatigue Volume 92, Part 1, November 2016, Pages 166-178.
 [2] J. Lin et al.: Design methodology for optimized die coatings: The case for aluminum pressure die-casting In: Surface and Coatings Technology 201 (2006) pp. 2930–2941.
 [3] K. Domkin, J.H. Hattel, J. Thorborg, Modeling of high temperature- and diffusion-controlled die soldering in aluminum high pressure die casting, J. Mater. Process. Technol. 209 (8) (2009) 4051–4061.
 [4] Sundqvist M., Hogmark S.: Effects of liquid aluminium on hot-work tool steel Tribol. Int. 26 (1993) in International Journal of Fatigue p. 129.

[5] H. Zhu, J. Guo, J. Jia, Experimental study and theoretical analysis on die soldering in aluminum die casting, J. Mater. Process. Technol. 123 (2) (2002) 229–235.
 [6] Z.W. Chen, M.Z. Jahedi, Die erosion and its effect on soldering formation in high pressure die casting of aluminium alloys, Mater. Des. 20 (6) (1999) 303–309.
 [7] K. Venkatesan, R. Shivpuri, Experimental and numerical investigation of the effect of process parameters on the erosive wear of die casting dies, J. Mater. Eng. Perform. 4 (2) (1995) 166–174. R. Markežič et al. Engineering Failure Analysis 95 (2019) 171–180179.
 [8] A Mohammed, M.B. Marshall, R. Lewis, Development of a method for assessing erosive wear damage on dies used in aluminium casting, Wear 332–333 (2015) 1215–1224.
 [9] L.F. Hou, Y.H. Wei, Y.G. Li, B.S. Liu, H.Y. Du, C.L. Guo, Erosion process analysis of die-casting inserts for magnesium alloy components, Eng. Fail. Anal. 33 (2013) 457–564.
 [10] D.W.C. Baker, K.H. Jolliffe, D. Pearson, The resistance of materials to impact erosion damage, Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. 260 (1110) (1966) 193–203.
 [11] A. Persson, S. Hogmark, J. Bergström, Temperature profiles and conditions for thermal fatigue cracking in brass die casting dies, J. Mater. Process. Technol. 152(2) (2004) 228–236.
 [12] C. Rosbrook, Analysis of Thermal Fatigue and Heat Checking in Die-Casting Dies: A Finite Element Approach, PhD thesis Ohio State University, 1992.
 [13] F. Medjedoub, G. Dour, S. Le Roux, P. Lamesle, M. Salem, P. Hairy, F. Rézaï-Aria, Experimental conditions and environment effects on thermal fatigue damage accumulation and life of die-casting steel X38CrMoV5 (AISI H11), Int. J. Microstruct. Mater. Propert. 3 (2–3) (2008).
 [14] P. Hansson, "Modern prehardened tool steels in die-casting applications," Materials and Manufacturing Processes, vol. 24, no. 7-8, pp. 824–827, 2009.
 [15] Uddeholm, "Dievar," 2014, (18.10.2021) internet: <http://www.uddeholm.com>
 [16] D. Klobčar, J. Tušek, B. Taljat, Thermal fatigue of materials for die-casting tooling, Mater. Sci. Eng. A 472 (1) (2008) 198–207.
 [17] D. Schwam, J. F. Wallace, and S. Birceanu, "Die Materials for Critical Applications and Increased Production Rates," Case Western Reserve University, 2002.
 [18] Methodical measurement and evaluation of adhesive cohesive behavior of thin film - substrate systems, 2005, (19.10.2021) internet: <https://www.opi.zcu.cz/adheze.html>
 [19] J. Tkáčová, E. Zdravecká, E. Evin, M. Tomáš, D. Jakubčzyová: Koroze a ochrana materiálu 63(4) 159-166 (2019).
 [20] D. Klobčar, et al.: Thermo fatigue cracking of die casting dies. In: Engineering Failure Analysis Volume 20, March 2012, pp. 43-53.

Selection of welding technology for AA6060 aluminum alloy tubes using economic analysis

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Abstract: This paper presents a method of economic analysis of welding tubes made of aluminum alloy AA6060 using MIG and TIG arc processes, as well as the non-conventional FSW process in relation to the length of the welded joint. The cost model includes fixed and variable costs, which are broken down into individual components, and their specifics for each of the selected processes are considered. The input values were defined and a calculation was made for obtaining a specific workpiece, that is, for welding a tube with an outer diameter of $\varnothing 150$ mm, and a wall thickness of 5 mm, with a butt joint in real production conditions. The obtained results were analyzed and the price of welding was determined according to the production time and per meter of the welded joint.

Keywords: ECONOMIC ANALYSIS, AA6060, MIG, TIG, FSW

1. Introduction

When it comes to the problem of environmental pollution, the manufacturing sector plays a significant role in CO_2 emissions. This gas is one of the main causes of climate change in the form of global warming of the planet. The general attitude of all developed countries is to reduce these emissions and other harmful effects of humanity on the planet Earth, first of all, by reducing energy consumption and moving away from the use of fossil fuels, primarily for obtaining electricity and transport. Harmful emissions originating from the production sector can be divided into direct and indirect. Direct ones come from the process of burning fossil fuels, while indirect ones are the result of the use of a large amount of electricity, which according to some estimates is about 35% [1].

As conventional welding technologies are energy-inefficient, due to the high consumption of electricity, which is used to melt metals, these processes belong to the group of indirect polluters.

These technologies are most often used when joining various parts of the industry. There are a large number of welding technologies, which we can divide into different ways. One of the divisions can be electric arc and specialized processes [2]. Today, over 115 welding processes exist in the world, which is in daily use. Therefore, when choosing an adequate welding technology, in addition to the basic requirements in terms of mechanical properties (quality of the welded joint), it is necessary to analyze the economic aspect (reduction of costs), but also the ecological aspect (reduction of indirect pollution). Three welding processes (Metal Inert Gas - MIG, Tungsten Inert Gas - TIG, and Friction Stir Welding - FSW) were selected to meet these goals. The method of economic analysis solves the indecisiveness when choosing a priority variant (process), following the rules for choosing the variant that maximizes the total profitability based on the number of functional products, or in the case that revenues are not present or are constant among the variables, only costs are considered and the variant that minimizes the total cost of the functional product is chosen [3].

2. Welding technology

Welding is defined as the localized joining of metals or non-metals caused either by heating the material to a suitable temperature with or without the effect of pressure or only by the effect of pressure, with or without the use of additional material [4].

2.1 Conventional processes: MIG and TIG

MIG and TIG belong to welding processes under an externally supplied protective gas atmosphere. These are arc welding processes that use an electrical power source to form an electric arc between the electrode and the base material. In this way, heat is generated which melts the material of the workpieces to be welded, which after cooling results in joining.

The MIG process is a semi-automatic or automatic welding process with a consumable wire that is fed continuously and has the roles of the electrode and additional material. Inert or semi-inert

shielding gas is continuously supplied next to the wire, which flows around the wire to protect the weld pool from contamination.

The TIG process is a manual or automatic welding process that uses a non-consumable tungsten electrode, a mixture of inert or semi-inert gas, and special filler material. It is particularly useful for welding thin materials, it is characterized by a stable arc and a high quality of the welded joint, but it requires considerable operator skill and can only be performed at relatively low speeds.

2.2 Unconventional FSW process

The FSW welding process makes it possible to obtain a welded joint without melting the material. Compared to conventional electric arc processes and other non-conventional processes such as laser and electron beam welding, this characteristic gives the FSW process a kind of immunity according to the criterion of the appearance of defects and the loss of mechanical properties that accompany the recrystallization of the molten metal. In addition, FSW is an ecologically clean process, which does not use shielding gas or additional material to obtain a welded joint. Also, the FSW process does not create harmful fumes, which in conventional processes are caused by the formation of metal oxides at high temperatures, and does not emit harmful radiation, which is more or less present in all other welding processes. The mentioned advantages of the FSW process have a positive impact on the health of the welder and the environment. In addition to the above, this process is characterized by the following properties:

- lower electricity consumption,
- simple and quick preparation of workpieces,
- absence of equipment protection against electric arc and fumes and accompanying ventilation,
- greater dimensional accuracy, i.e. less distortion of workpieces,
- higher welding speed and
- high degree of automation.

The FSW process is mainly used to join metals with a relatively low melting point [5], which usually means aluminum alloys that are difficult to join by electric arc processes. Known applications of the FSW are the rocket booster of the Space Shuttle in America, structural elements of high-speed trains in the railway industry, ship hulls and decks in the shipbuilding sector, as well as copper containers for radioactive waste [6]. The FSW process found its application in the automotive industry in the form of Friction Stir Spot Welding, which replaced conventional spot welding in chassis made of aluminum with savings of up to 90% in terms of electricity use [7].

3. Preparation of workpieces

As workpieces to be welded in the economic analysis, tubes made of aluminum alloy AA6060-T4 (AlMgSi0.5-T4) were taken. The tubes have an outer diameter of $\varnothing 150$ mm, wall thickness $t = 5$ mm, while the length of the tubes that are welded individually is 250 mm (according to the ISO 25239-4 standard), and the length of the welded joint is $l = 471$ mm. The considered alloy was chosen, first of all,

because of its high prevalence in the industry, as well as because of its relatively good weldability. It is used in the automotive and railway industries, for making pipes for irrigation, heating, and cooling, for pneumatic installations, furniture and carpentry, and many other applications.

For welding workpieces using the MIG and TIG process, it is necessary to carry out preparation, which is reflected in the production of a V-groove (Figure 1), the dimensions of which are adopted (according to the ISO 25239-4 standard) for each of the processes individually (Figure 2).



Fig 1 Workpiece for MIG and TIG process

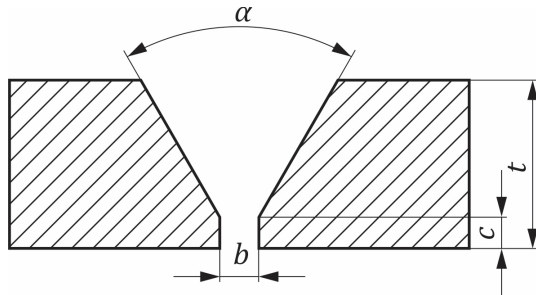


Fig 2 Groove profile for MIG and TIG processes

Where the angle of the groove is α° , the gap of the groove is b mm, and the thickness of the root face is c mm.

For the FSW process, a groove is not made, but it is necessary to obtain a flat face on the workpieces so that they fit evenly in the butt joint during clamping.

4. Components of cost estimation

If the conditions and properties of the alloy allow the welding of a joint using several methods, it is necessary to choose the appropriate one according to economic criteria. Various factors are listed below, the sum of which represents the cost price of a welded joint per meter of weld using a certain process. In addition to the costs listed below, it is also necessary to take into account the selling price of the manufactured product P_r €/m in relation to the length of the welded joint, which differs in relation to the costs representing profit. It should be noted that all cost components are not present in all processes due to their specificities. We can divide costs into variable and fixed.

4.1 Fixed costs

Fixed costs F_t € include the cost of welding equipment (welding machine) as a separate entity and the cost of auxiliary accessories and protective equipment.

$$F_t = T_m + T_a \quad (1)$$

4.1.1 Cost of welding equipment

It includes the cost of the welding equipment (welding machine) itself, the choice of which depends on the process used, the material

and thickness of the workpiece, and the number of workpieces for which the welding machine is used. Depending on the size of the batch, the degree of automation of the process is also chosen, according to which welding is divided into manual, mechanized, automated, and robotic [8]. The adopted notation for this cost is T_m , and the unit is €.

4.1.2 Cost of auxiliary accessories

In industrial welding, special accessories and holders are generally made to bring the workpiece and the welding torch or tool into the desired position, in order to speed up the process. These elements are most often adapted specifically to the workpiece to be welded and their price must be considered for each job individually. This category includes the costs of protective equipment and equipment for the preparation of workpieces. The adopted notation for this cost is T_a , and the unit is €.

4.2 Variable costs

Variable costs V_r €/m refer to human labor, overheads, energy, and preparation of workpieces. In electric arc processes, we have additional material and shielding gas as variable costs, while these costs are absent in the FSW process, where the cost of the welding tool occurs. Total variable costs represent the sum of the specified variable costs characteristic of the selected process.

4.2.1 Cost of labor

The cost of human labor L_c €/m is based on the hourly labor rate L_r €/m, which is currently in Montenegro in the gross amount, as well as the welding speed S mm/s and the reinforcement factor O_f [9]:

$$O_f = \frac{t_z}{t_z + t_p + t_l} \quad (2)$$

Where the welding time is t_z s which is proportional to the length of the welded joint per workpiece l mm, and inversely proportional to the speed, t_p s is the time required for assembly and disassembly of the workpiece and t_l s is the time of "ignition of the arc". Based on these parameters, we can calculate the cost of human labor [9]:

$$L_c = \frac{L_r}{3.6 \cdot S \cdot O_f} \quad (3)$$

4.2.2 Overhead costs

It refers to the overhead costs that the company pays per meter of welded joint O_c €/m and depends on the hourly overhead rate O_r €/h the welding speed S mm/s and the utilization factor O_f [9].

$$O_c = \frac{O_r}{3.6 \cdot S \cdot O_f} \quad (4)$$

4.2.3 Cost of additional material

The cost of additional material C_f €/m is estimated by determining the type and quantity of the required material. Above all, it is necessary to determine the area of the profile of the welded joint A mm² from Figure 2.

$$A = \left((t - c)^2 \cdot \tan \frac{\alpha}{2} + b \cdot t \right) \cdot O_f \quad (5)$$

The strengthening factor O_f is adopted, which represents the overhang of the welded joint. Based on the known area and knowing the density of the additional material ρ kg/m³, we can calculate the mass of the selected welded joint per length meter W_w kg/m.

$$W_w = A \cdot l_a \cdot \rho \cdot 10^{-6} \quad (6)$$

Where $l_a = 1$ m. Knowing the mass of the welded joint per meter length, we can calculate the cost of additional material per meter length V_{ec} €/m [9].

$$V_{ec} = \frac{W_w \cdot E_c}{E_{my}} \quad (7)$$

Where E_c €/kg – the price of the electrode per unit of mass and E_{my} – efficiency factor of added material, i.e. the percentage of wire that becomes weld metal [9]

4.2.4 Cost of shielding gas

This cost is estimated according to the type of gas used and its flow rate V_{gc} €/m [9].

$$V_{gc} = \frac{G_{fr} + G_c}{3.6 \cdot S} \quad (8)$$

Where G_{fr} m³/h gas flow, a G_c €/m³ gas cost.

4.2.5 Cost of energy

It takes into account the energy consumed by the welding machine or apparatus according to the length of the welded joint V_{pc} €/m [9].

$$V_{pc} = \frac{I \cdot V \cdot P_c}{3600 \cdot S \cdot M} = P_e \cdot P_c \quad (9)$$

Where I A electric current, electric voltage U V and M degree of efficiency of the welding apparatus, that is P_e kWh/m is the electricity consumption per meter of welded joint for FSW. The price of electricity is given by the factor P_c €/kWh.

4.2.6 Cost of a welding tool

This cost is specific to the FSW process only. The length that one tool can weld depends on the type of material being welded and its thickness. The cost of the welding tool represents the price of this tool per meter of weld length V_a €/m.

4.2.7 Cost of preparation of workpieces

It includes the time and resources necessary to prepare one workpiece for welding V_{pk} €/m. For conventional processes, it is necessary to make a suitable groove for the welded joint, as well as to clean the workpieces before welding, and after the process to sand and clean them, while with FSW it is enough to clean the workpieces before the welding process.

$$V_{pk} = L_r \cdot t_{pk} \cdot 0.0167 \quad (10)$$

5. Economic analysis models for considered welding technologies

In order to form cost models for the analyzed MIG, TIG, and FSW processes on the basis of the previously given equations, it is necessary to determine the input values of all parameters.

An accessory was developed for mounting and dismounting workpieces on the lathe, which in this case is a chuck on a universal lathe. By tightening one KM nut, the workpieces are positioned. The welding speed is defined by the stepper motor that drives the clamping head. The gun, i.e. the torch, is positioned on a joint that has one degree of freedom. It takes 60 seconds to assemble and disassemble the workpieces from this setup.

As a welding machine for the FSW process, it is planned to use a CNC machining center, which has a pallet system with two pallets, the total change time of which is 26 s. The worker will remove the finished workpiece, and then assemble the new workpieces in the time it takes the machine to pick up another pallet (half the time for changing pallets (13 s), enters the material with the tool (5 s), performs welding (56 s), pulls the tool out of the workpiece (5 s) and returns the pallet with the finished workpiece (13 s). After that, the cycle starts again, which means that the welder has about 92 seconds available for assembly and disassembly. From this, we can see that the actual time wasted on assembly and disassembly is 26 seconds,

i.e. the time of changing the pallet because the rest of the cycle is performed in parallel with the FSW process on another pallet.

Input parameters and their values are given in Table 1.

Table 1: Input parameters for MIG, TIG and FSW processes

No.	Parameter	Designation and unit	MIG	TIG	FSW
1	Cost of welding equipment (machine)	T_m €	3000	7500	63000
2	Cost of auxiliary accessories	T_a €	550	550	850
3	Cost of labor	L_r €/h	7.8	12.3	7.2
4	Welding speed	S mm/s	6.33	3.92	10
5	Assembly and disassembly time	t_p s	60	60	26
6	Time to start the arc	t_i s	3	3	-
7	Tool entry and exit time	t_l s	-	-	10
8	Overhang cost rate	O_r €/h	2	2	2
9	Number of passes	z	1 [10]	1 [10]	1 [10]
10	Joint angle	α °	70 [11]	55 [11]	0
11	Groove gap	b mm	1.2 [11]	1.2 [11]	0
12	The thickness of the root face	c mm	1.2 [11]	1.2 [11]	-
13	Reinforcement factor of the welded joint	O_f	1.1 [12]	1.1 [12]	1
14	The efficiency factor of added material	E_{my}	0.95 [9]	0.95 [9]	-
15	The density of additional material	ρ kg/m ³	2640	2640	-
16	Price of additional material	E_c €/kg	14	12.3	-
17	Gas flow	G_{fr} m ³ /h	1 [2]	0.6	-
18	The price of gas	G_c €/m ³	2.87	2.87	-
19	Welding current	I A	200 [2]	140	-
20	Welding voltage	U V	23.6 [10]	15.5	-
21	Degree of efficiency of the welding machine	M	0.9 [9]	0.9 [9]	-
22	The price of electricity	P_c €/kWh	0.0546	0.0546	0.0546
23	Time of preparation of workpieces	t_{pk} min	10	10	7
24	Electricity consumption per meter of welded joint	P_e kWh/m	0.23	0.17	0.2 [12]

6. Analysis of results

Based on the used model of economic analysis and given input parameters, an algorithm was defined that enables economic analysis for the selected workpiece in a simple way.

In order to calculate the profitability of one of the processes, in addition to the parameters of productivity and costs, it is necessary to define the market value per meter of welded joint $P_r=15$ €/m . Based on the previously given data, we can calculate the profitability P_t € of the selected welding technology for a specific workpiece for a certain number of working hours:

$$P_t = (P_r - V_t) \cdot S \cdot 3.6 \cdot O_f \cdot t_1 - F_t \quad (11)$$

Where t_1 time in hours h .

Figure 3 shows the ratio of profit and working hours (time) for the analyzed processes MIG, TIG and FSW.

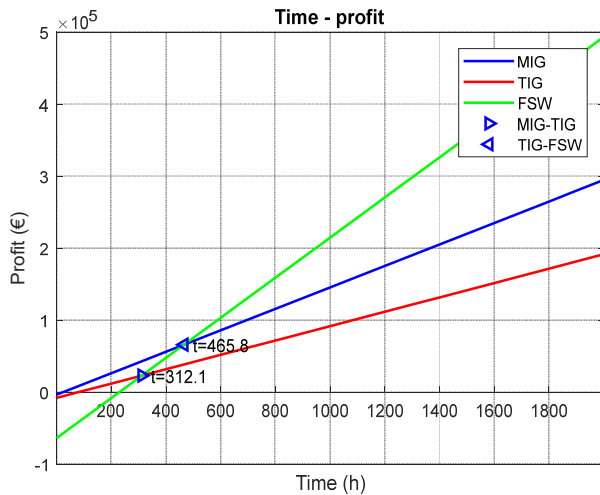


Fig 3 Relation time - profit

As quantity plays a decisive role in the choice of welding technology, it is necessary to consider whether the workpieces are welded in individual, serial, or mass production, which would represent a key criterion for the justification of investment in a certain technology.

From Figure 3, we can see that the FSW process starts with a significant negative value due to the large initial investment, but the absence of additional material, shielding gas, shorter preparation, and higher productivity result in the FSW process having a significant advantage over electric arc processes in serial and mass production. While with single and small series, the advantage is with electric arc processes.

We can also calculate the profitability based on the length of the welded joint produced according to the equation:

$$P_l = (P_r - V_t) \cdot x - F_t \quad (12)$$

Where x is the length of the welded joint m.

Figure 4 shows the profit per meter of the weld from each analyzed process, starting with a negative value due to the initial investment. In this case, the time dimension, i.e. the advantage in higher productivity of the FSW process, is omitted. Despite this, we see that the savings in the cost of the welded joint per meter of length in the FSW process which after a while leads to the intersection of curves, and the FSW process after a certain length becomes the most profitable.

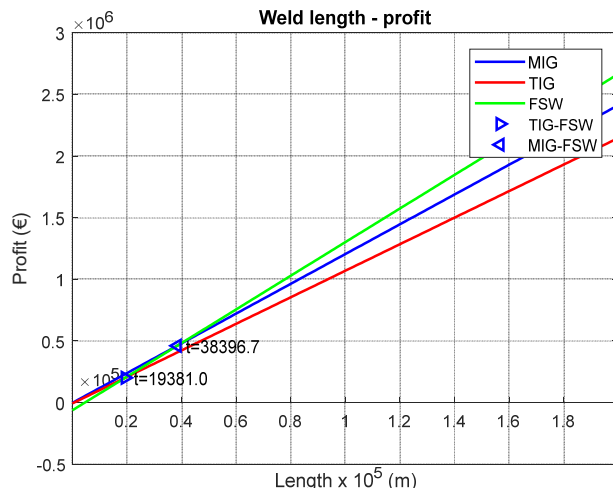


Fig 4 The relationship between the length of the welded joint and the profit

7. Conclusion

The economic analysis carried out in this paper shows that FSW technology for the case of analyzing tubes made of AA6060 alloy, despite a significantly higher initial investment, after 465.8 working hours gains an advantage over MIG and TIG processes. Also when we look at the problem in relation to the length of the welded joint, the FSW technology becomes dominant after 38396.7 meters of the welded joint and continues with the trend of significantly higher profit.

Due to the higher initial investment, the FSW process is proving to be the preferred process for serial production. After the specified period or number of welds, despite the large initial negative value due to the investment, there is an intersection of the curves after which the FSW process takes the lead.

The FSW process, in addition to better mechanical characteristics of the welded joint, an ecologically clean and energy-efficient process, is recommended by the economic analysis for welding the analyzed workpieces, because it achieves great benefits for the user in terms of cost savings, as well as higher productivity. The presented approach is part of wider research and can be applied to a wide class of problems.

Literature

- [1] G. Buffa, D. Campanella, R. Di Lorenzo, L. Fratini, and G. Ingarao, "Analysis of Electrical Energy Demands in Friction Stir Welding of Aluminum Alloys," *Procedia Eng.*, vol. 183, pp. 206–212, 2017, doi: 10.1016/j.proeng.2017.04.022.
- [2] E. R. Bonhart, *Welding Principles and Practices*. 2554.
- [3] M. Vukčević, *Inženjerska ekonomija*. Podgorica: University of Montenegro, Faculty of Mechanical Engineering, 2012.
- [4] D. Bajić, "Postupci zavarivanja." Univerzitet Crne Gore, Mašinski fakultet, 2014.
- [5] "Mazak MegaStir | Friction Stir Welding applications." <https://megastir.com/> (accessed Jul. 17, 2022).
- [6] Z. Feng *et al.*, "Flexible Friction Stir Joining Technology," 2015, <http://www.osti.gov/servlets/purl/1210157/>.
- [7] "MAZDA:Backnumber | News Releases." <https://newsroom.mazda.com/en/publicity/release/2003/200302/0227e.html> (accessed Dec. 28, 2021).
- [8] "Difference between mechanised, automated and robotic welding - TWI." <https://www.twi-global.com/technical-knowledge/faqs/faq-what-are-the-differences-between-mechanised-automated-and-robotic-welding> (accessed Jan. 14, 2022).
- [9] P. B. S. Creese C. Robert, Adithan M., "Estimating and Costing for the Metal Manufacturing Industries," no. July, pp. 1–23, 1992.
- [10] L. Electric, "Aluminium GMAW for Aluminium Guide," pp. 1–69, 2016, www.lincolnelectric.com.
- [11] "Weld Joint Preparation (ISO 9692) Edge Preparation - Need," no. Iso 9692.
- [12] "Weld Cost Calculator." <https://www.esabna.com/us/en/support/value-added-engineering/quick-weld-productivity-analyzer.cfm> (accessed Jan. 17, 2022).

Investigation of the energy-power parameters of forging process in step-wedge strikers

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Abstract: In this paper the deformation force of the forging process in step-wedge strikers was studied. At the first stage, the study of the deformation force using computer modeling in the Deform-3D software package was carried out. At the second stage, an experimental study of the deformation force during the broaching of workpieces in step-wedge strikers using thermometry was carried out. It is established that the experimental results have a high convergence with the simulation values. The increasing level of difference in results is associated with heat losses during intermediate operations, which are usually ignored during modeling.

Keywords: FORGING, STEP-WEDGE STRIKERS, MODELING, EXPERIMENT, DEFORMATION FORCE.

1. Introduction

An important direction in the forging production development is to increase the mechanical properties of forgings made of ferrous metals by introducing new forging technologies into production that ensure the development of shear and alternating deformations throughout the volume of the deformed metal. This ensures the grinding of the cast structure to a fine-grained state and its uniform distribution over the entire volume of the metal. At the same time, one of the main effectiveness indicators of the new forging technology is the reduction of the energy-power parameters.

New forging technologies include the technology of forging forgings such as plates and plates in step-wedge strikers of two configurations:

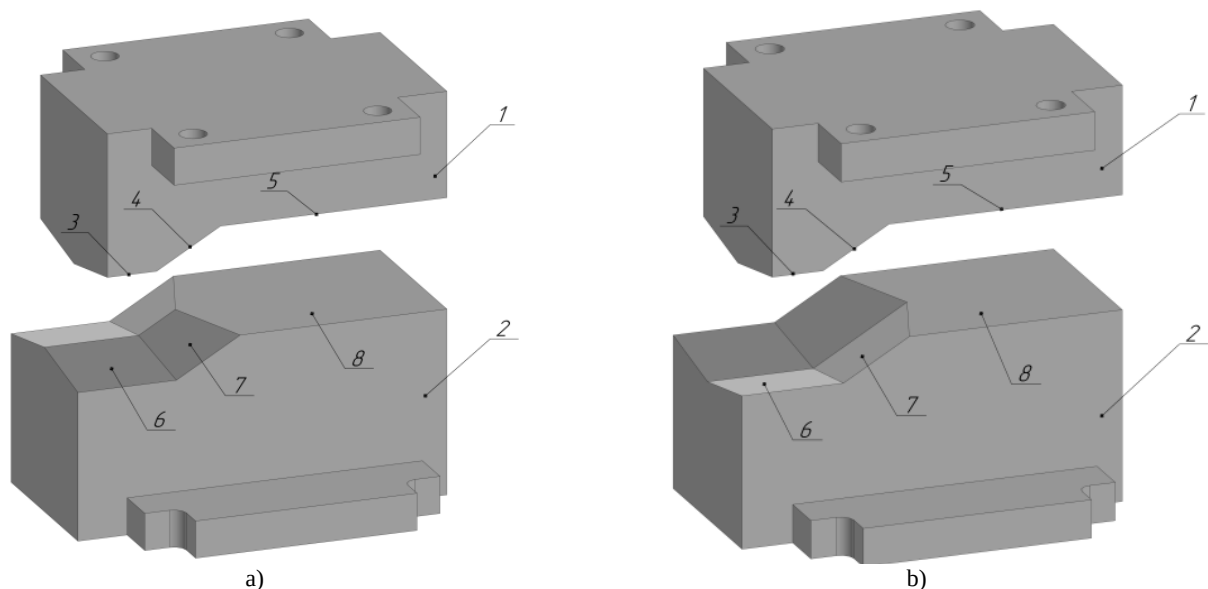
- according to the first configuration, strikers with stepped and inclined sections are made with an inclination angle no more than 45° to the horizontal plane of the section between the steps and the width of the step of a greater length of at least 1.5 of the total length of the smaller step and the inclined section, while the inclined section and the smaller step in the cross section of the upper and lower striker are made in the form of a wedge [1] (fig. 1, a);
- according to the second configuration, the inclined section and the smaller step of the upper striker in the cross section are made in the form of a wedge, and the lower striker in the form of a similar wedge-shaped depression, and the length of the smaller step with

the wedge-shaped depression of the lower striker is made longer than the upper one in order to avoid the formation of clips on the workpiece [2] (Fig. 1, b).

Earlier in work [3] it was shown that the use of step-wedge strikers is more energy efficient compared to the use of conventional step strikers, which formed the basis of step-wedge strikers together with wedge-shaped strikers, since the values of the forging forces in these strikers in comparison with conventional step strikers turned out to be on average less by 30-35%. The purpose of this work is to study the deformation force of the forging process of workpieces in step-wedge strikers.

2. Computer simulation

At the first stage, the study of the deformation force using computer modeling of the forging process of workpieces in step-wedge-shaped strikers (two configurations) in the Deform-3D software package was carried out. Two solid-state models of step-wedge strikers of the first and second configurations with a wedge angle of 160° were built. AISI-1035 steel was chosen as the model material for the workpiece. The cross section of the workpiece was 30x30 mm. Deformation was carried out at a temperature of 1100 °C with a deformation degree equal to 10% of the initial height of the workpiece.



1 – upper striker; 2 – lower striker; 3 – smaller stage with a wedge of the upper striker; 4 – inclined section with a wedge of the upper striker; 5 – large flat stage of the upper striker; 6 – smaller stage with a wedge (a) and wedge depression (b) of the lower striker; 7 – inclined section with a wedge (a) and wedge depression (b) of the lower striker; 8 – large flat step of the lower striker

Fig. 1. Step-wedge strikers

Figure 2 shows graphs of the deformation force during broaching in step-wedge strikers of the first and second configurations, based on the values of maximum deformation force in each pass. It can be seen that when broaching the workpiece in

the strikers of the first configuration (both strikers with a wedge) due to the compression intensification, the deformation force has higher values than when broaching in the strikers of the second configuration, this is especially noticeable when comparing the

central areas of the graphs, which correspond to the presence of metal in the all three zones of strikers. In the last passes, when the workpiece is no longer in the first two sections, the force values become comparable.

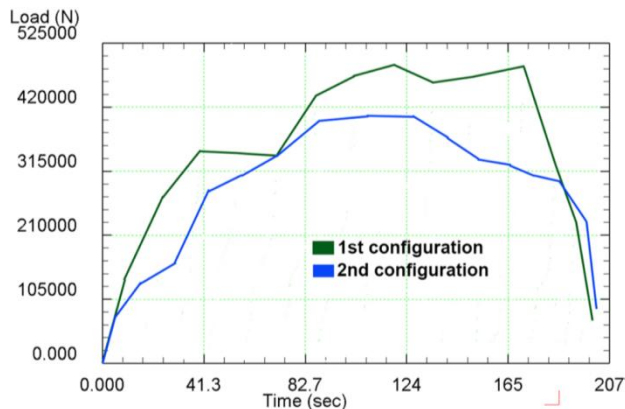


Fig. 2. Values of the force during broaching in step-wedge strikers

3. Laboratory experiment

At the second stage an experimental study of the deformation force during the broaching in step-wedge strikers was carried out. Experiment was carried out only for step-wedge strikers of the second configuration, i.e. with a wedge on the upper striker and with a wedge-shaped depression on the lower striker, since the main purpose of experiment was to confirm the results of computer modeling.

To measure the resulting deformation forces, it was decided to use a well-proven strain gauge method. The following equipment was used for this purpose: strain gauge station ZET-017-T8 (CJSC ETMS, Russia); strain gauges with TCFO1-2-200 resistors (CJSC ETMS, Russia).

The diagram of the sticker connection of strain gauges is shown in Figure 3. This scheme allows to register the change in electrical resistance under the influence of force in the longitudinal or transverse direction, while the second sensor always acts as an element with the thermal compensation function, which is important during hot deformation. Since the broaching in these strikers is carried out in the longitudinal direction, the measuring strain gauge is glued across the striker, and the compensating strain gauge, perceiving only temperature changes, is glued along the striker.

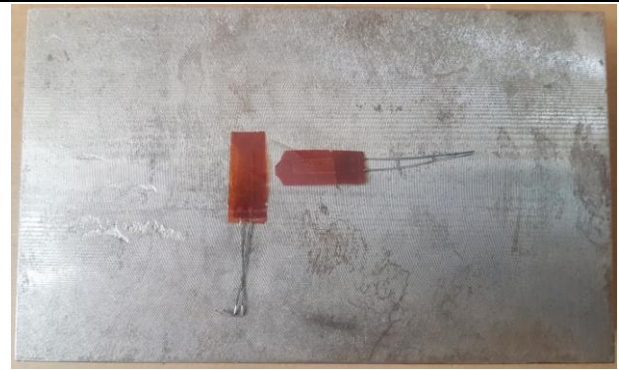


Fig. 3. Load cell sticker diagram

Before the direct test, the upper striker with installed load cells was subjected to compression tests on the torsion-bursting machine MI-40KU. The purpose of these tests was the preliminary calibration of strain gages. On this laboratory stand it is possible to develop forces up to 40 kN with accurate fixation of their values. The essence of pre-calibration is to change the stress-strain state of the strain gages under load, which causes deformation and linear change in the resistance of the strain gages. With a sequential change in the load from zero to 35 kN with a step of 5 kN, the dependence of the electrical voltage in the circuit and the applied force is constructed. This dependence is always linear, so the result of calibration is a mathematical equation of the form $Y = KX + B$, where Y is the force and X is the voltage.

To improve accuracy, 3 passes were carried out over the specified range – up, down, up, or 21 measurements (when 5, 10, 15, 20, 25, 30 and 35 kN). The data obtained during the tests were statistically processed, and a linear regression equation was derived from them, linking the force applied to the instrument (P , N) with the voltage (U , mV) in the circuit. The equation for measuring the deformation force has the form: $P = -4684.2U + 19625$. The coefficient of determination $R^2 = 0.998$; the standard measurement error, according to the results of 21 tests, was less than 0.2%. The obtained data were entered into the program for recording and processing measurements of the ZET-017-T8 strain station to ensure the possibility of recording the signal in the form of a force graph.

After carrying out calibration settings, the striker with strain gages was installed on the upper plate of the press. When fixing the magnitude of the force, it was decided to carry out measurements on each successive feed of the workpiece, i.e. when the workpiece is crimped by one, two and three stages of strikers (stages 2, 4, 6 in Figure 4). This will make it possible to track the sequence of loading of the tool, as well as provide more opportunities for verification of measurement by comparing experimental values with simulation results.

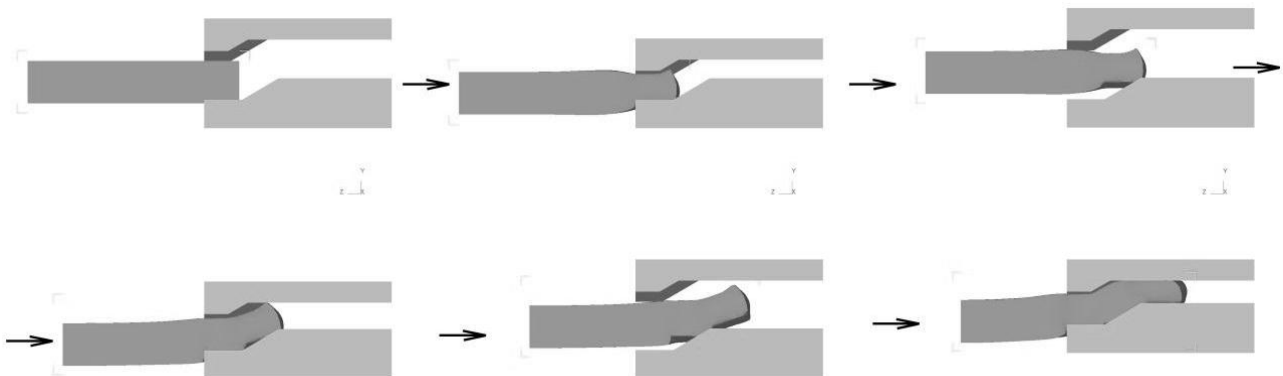
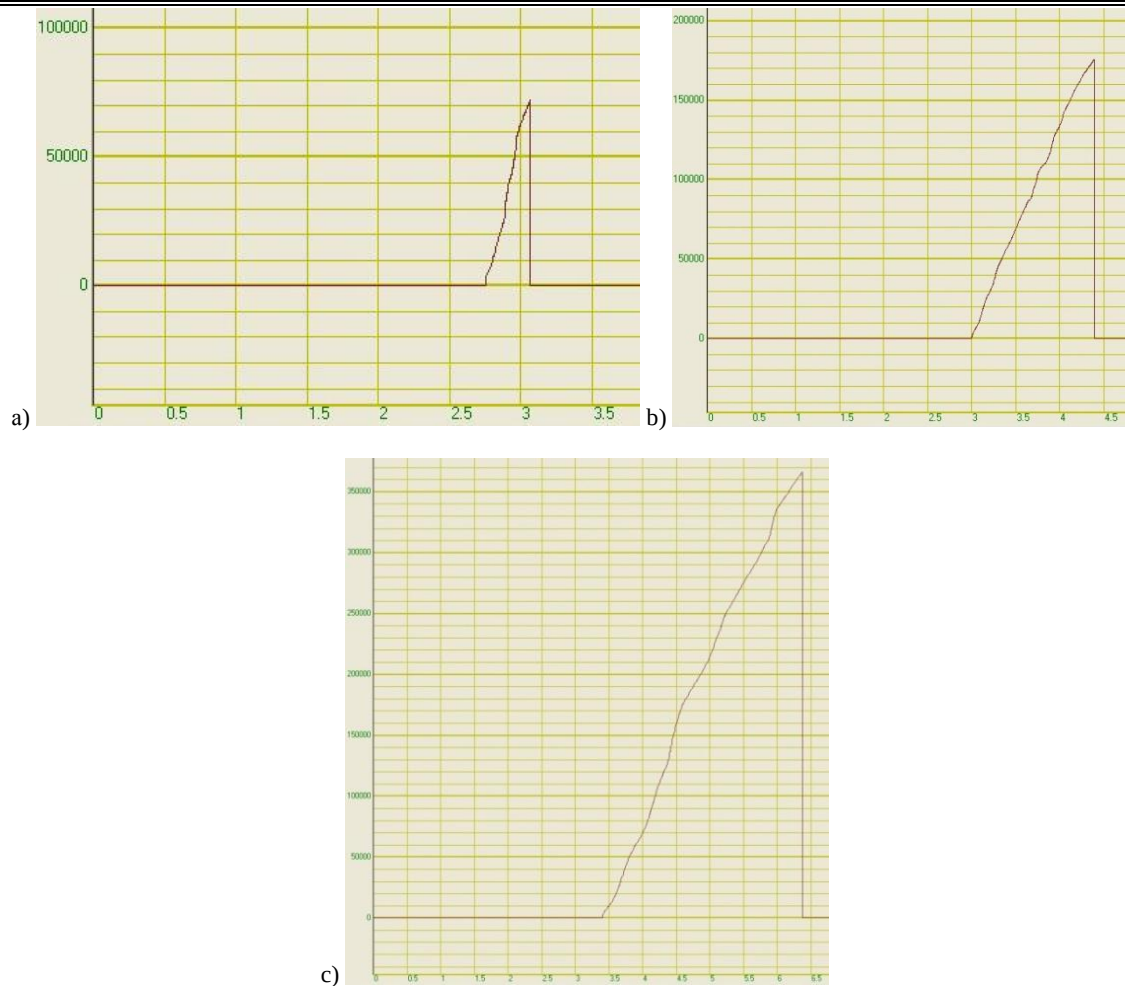


Fig. 4. Deformation scheme in step-wedge strikers

As a result, the following data were obtained (Figure 5).



a – compression by one step; b – compression by two steps; c – compression by three steps
Fig. 5. Change in the force during broaching in step-wedge strikers

When analyzing the results of the effort measurement, it was noted that at all three stages, the nature of the effort curve is monotonically increasing. With the identical nature (appearance) of the curve, they differ significantly in vertical amplitude, which is the result of a significant increase in the area of contact between the metal and the tool at each subsequent stage.

The force measurement data were summarized in Table 1. For each stage of the deformation process, the error values were calculated in comparison with the values obtained during modeling.

Table 1 – Force measurement results

	1st stage	2nd stage	3rd stage
Value of the force during the experiment, kN	70,5	173	367
Value of the force during modeling, kN	70	169	346
Error rate, %	0,7	2,36	6

In the course of the conducted studies, it was found that with each subsequent stage the error value increases, despite the fact that at the first stage the error is extremely small. This is due to some differences in the technologies of modeling and conducting the experiment. After each pass, the workpiece must be advanced by a certain amount of feed. In real conditions, this is done with the help of a manipulator (in laboratory conditions - manually with the help of ticks). These intermediate operations often take an average of 15 to 30 seconds, which is reflected in the additional cooling of the workpiece. When modeling, the movement of the workpiece between the aisles occurs instantly, so there is no heat loss here. As

a result, the values of the force in the experiment are always greater than the force in the modeling.

4. Conclusion

The conducted studies have confirmed the energy efficiency of the forging process of blanks such as plates in step-wedge strikers with a wedge on the upper striker and with a wedge-shaped depression on the lower striker, compared with forging similar blanks in step-wedge strikers with a wedge on the upper and lower striker, and accordingly, compared with forging in conventional stepped strikers.

5. Acknowledgements

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6. References

1. Найзабеков А.Б., Лежнев С.Н., Панин Е.А., Толкушкин А.О. Инструмент для изготовления поковок, Инновационный патент РК №30420, 2015.
2. Найзабеков А.Б., Лежнев С.Н., Панин Е.А., Богатов А.А., Толкушкин А.О. Инструмент для изготовления поковок, Патент РК №33694, 2019.
3. Naizabekov A.B., Lezhnev S.N., Krivtsova O.N., Tolkushkin A.O. Simulation of the new technology of forging of blanks such as slabs and plates made of ferrous metals and alloys // Journal of Achievements in Materials and Manufacturing Engineering. – 2014. - Vol. 62. - P. 75-80.

Financial project for building a technological line and factory for the production of yellow pavers, tiles and other products

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Abstract: A financial project was presented for the construction of a technological line for the production of high-quality replicas of the so-called "yellow paving stones" and an additional assortment of products with different characteristics based on raw materials originating in Bulgaria. After many years of investigation in laboratory and semi-industrial conditions, polycomponent formulations and an original high-temperature technological regime for the preparation of functional and long-lasting silicate products have been developed. The planned technological approach is in accordance with the existing machine park and the qualification of the industrial production personnel, characteristic of the silicate industry. The main possibilities for the realization of the production are the full restoration of the street areas of the central historical part of Sofia and the construction of long-lasting and aesthetic pavements with a variety of functional purposes in different areas of the capital and other populated areas. The current applied development is oriented towards possible potential producers and investors and various specialists from the field of public infrastructure and cultural-historical heritage.

Keywords: YELLOW PAVERS, FINANCIAL PROJECT, TECHNOLOGICAL LINE

1. Introduction

With the intensive development of urbanization processes, an essential factor ensuring a full-fledged, productive and comfortable urban environment is the state of the transport infrastructure [1-3]. Currently, the existing street network is dominated by asphalt pavements, built in different periods by applying different standards and construction technologies. During the greater part of the 20th century, the presence of a developed asphalt street infrastructure was seen as an indispensable criterion for the development and modernization of settlements. In recent decades, with the active introduction of environmental norms and the perception as a basic priority of the requirement to ensure a safe and healthy environment, a basic reassessment of the role of a number of modern materials and the prospects for their future global application is being carried out. The International Agency for Research on Cancer (IARC) classifies fumes from asphalt pavements as a possible carcinogen [4] assigned to class 2B. This implies the existence of a potential risk, both in the process of laying the asphalt mixtures (with the necessary technological temperature) by the specialized road construction and repair teams, and in the long-term operation of the routes, especially in the summer season. As the main critical factors, the temperature of the asphalt products and the duration and levels of exposure, with a possible carcinogenic effect [4] of the asphalt emissions are considered. At the same time, the intensive daily car traffic, the cyclical day-to-day changes in the operating properties of the pavement under the influence of the increased daily temperature values in the summer months and the relatively destructive effect of the various anti-icing agents used in the winter period significantly accelerate the depreciation of the asphalt pavements. On the other hand, the local repair activities carried out on individual destroyed sections do not fully restore the original parameters of the route and create an unaesthetic effect.

In modern urban planning, paved pavements continue to represent an up-to-date alternative to the dominant asphalt coverings [5-7]. The use of various paving systems dates back to a long historical period, which allows the study of the long-term impact of various factors (traffic, climatic, atmospheric, seismic and a number of others) on the general condition of the infrastructure and the development of modern adequate approaches to urban planning. The use of various paving elements (granite, concrete, ceramic and others) provides an opportunity to build a variety of ecological and aesthetic pavements with sustainable indicators [5-10] within the intended operating conditions and terms. A specific aspect of the application of the pavements is their use in areas with historical architecture [6,7], which allows preserving and restoring the authentic appearance of the urban environment. A typical example is the practically exhausted possibilities for restoration (due to the lack of available new reserves) of the amortized and crumbling original pavement of the so-called "yellow paving

stones" (declared a cultural value) from the central city part of Sofia [5-7,11]. Some of the street areas originally paved with "yellow cobblestones" have been overhauled by laying another type of pavement.

The main reasons for the lack of significant interest among existing enterprises in organizing modern production of "yellow paving stones" are the need for investments [5] for additional equipment, factory infrastructure and personnel, using the services of highly qualified specialists outside the factory, large-scale research of raw materials from various potential deposits, conducting a series of laboratory and energy-intensive industrial experiments to specify the optimal technological conditions for the preparation of a new product with identical characteristics to the authentic samples. At the same time, during the long-term research laboratory activity [5-7, 10-21], the implementation of a funded scientific research project [5] and a series of semi-industrial experiments [6, 7, 11, 12], the team of IMSTCHA-BAS, based on raw materials originating in Bulgaria, develops an effective technology for the production of full-fledged replicas (with superior complex indicators) of the original "yellow paving stones". The development allows, in the presence of interest (of representatives from the industrial sector), to prepare a detailed technological regulation, tailored to the individual production capacities of a specific enterprise from the silicate industry. In the presence of more significant investment capital, it is planned to design [5] and build an experienced plant, equipped with a technological line and separate production areas for the production of wear-resistant «yellow paving stones», other forms of paving elements, paving slabs, boards for decorative cladding and others. The production of some products in different color variants allows expanding the main assortment and increasing its competitiveness. The planned target application of the prepared «yellow paving stones» foresees [5-7, 11, 12] the priority restoration of the authentic condition of the street areas, part of the architectural ensemble of the People's Assembly Square and adjacent areas. Promising opportunities for the realization and creative combination of the entire spectrum of production are (if the municipal authorities are interested) the construction in suitable areas of the capital and in other cities of long-lasting and aesthetic pavements [5] with a diverse functional role: street and sidewalk areas, long-lasting markings, pedestrian areas, bike lanes, square spaces, yard spaces of single-family houses or closed residential and hotel complexes, transport infrastructure in tourist complexes and cultural and historical sites (settlements with the status of museums, restored archaeological monuments, etc.), park lanes, specialized open commercial area and amusement parks, car parks and a number of others.

The aim of the present work is to present a financial project for the construction of a technological line and the organization of a cost-effective production of replicas of the so-called "yellow paving stones" and an additional product assortment based on the original technological regime and raw materials of local origin.

A plant schematic drawing for the production of yellow paving stones and tiles from marl clay.

This publication examines some economic indicators needed to prepare a realistic business plan for the construction of a plant (Fig.1) for the production of various marl clay products such as pavers, tiles - yellow and other colors for covering urban spaces applicable in construction in populated areas and for other purposes.

The production of different products ensures higher mechanical stability and allows the load-bearing function of the final products. The total investment value for the construction of the plant was

determined to be EUR 2.5 million, on the basis of calculations for the prepared business plan.

In this material, some economic indicators are presented in order to create a real Business Plan for the construction of a plant for the production of materials from marl clay - paving stones for covering streets and squares and tiles with small and large sizes for pavement spaces. Finally the material, the total investment value for the construction of the plant of 2.5 million euros was determined, with which value the following calculations for the Business Plan were realized.

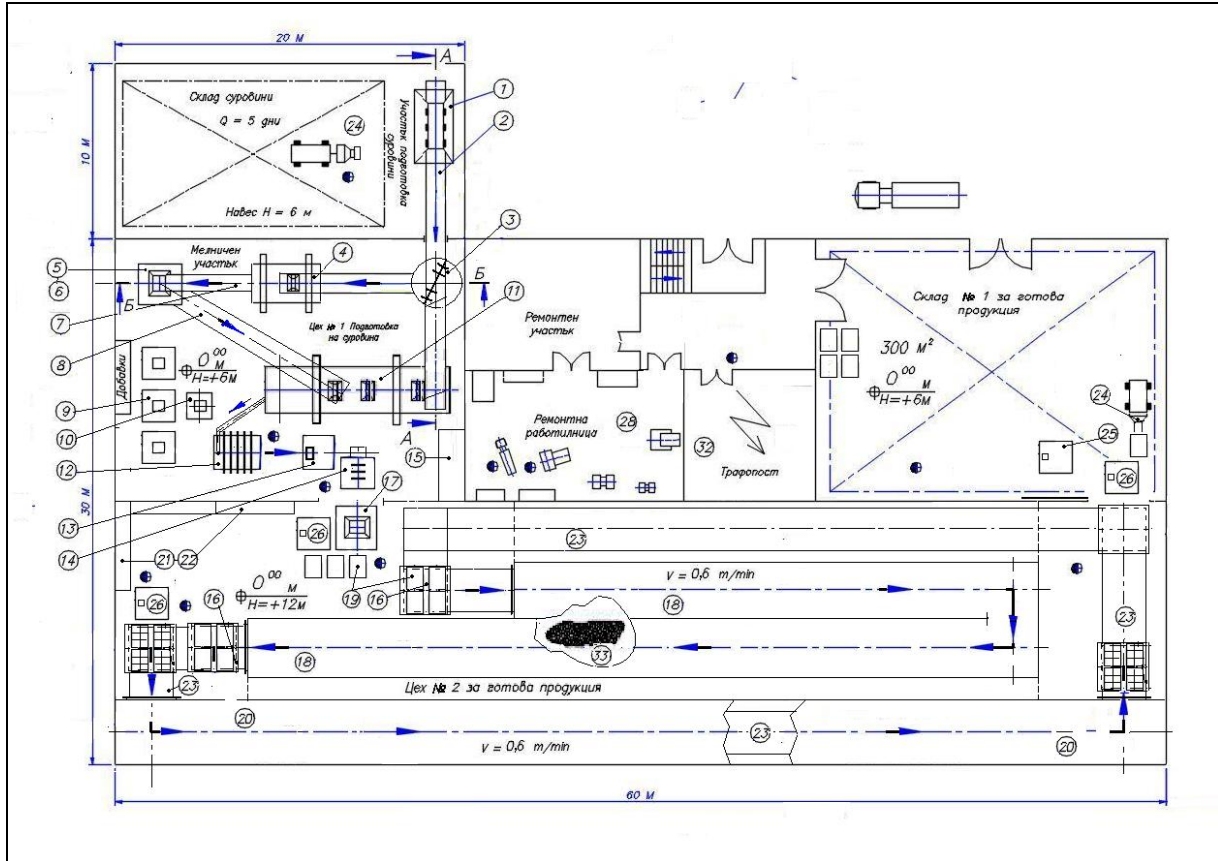


Fig.1. A plant schematic drawing for the production of paving stones and tiles from marl clay.

2. Some financial parameters

2.1. Establishing production needs for a 10-15 year period - marketing analysis.

Complete marketing research is difficult to do. After consultation with specialists, independent research has been carried out, approaching reality.

The study plan includes the following parts:

The aim of the research

The purpose of the marketing research is to prove the necessity of the product pavers and tiles and the possibility of establishing itself on the market, both in Bulgaria and abroad. The need for the product is proven by its technical indicators, and the imposition on the market depends on the needs, company policy, advertising, the economic possibilities of the users, mainly city councils, etc.

Investigation method - through client quotas.

The effort is aimed at determining the possible volume of orders from possible users - construction organizations and mainly city and municipal councils.

Sofia, as the capital and largest city in the country, has approximately 94,000 acres of streets, squares and sidewalks. In the past, 60 acres were paved with yellow pavers.

The goal of the collective is to help the capital to restore these areas and reach 100 acres. But this is only 0.1% of those of the existing areas.

The regional cities - 28 of which are 1/10 of the capital - in total have approximately the same area of streets and sidewalks. The small towns, due to depopulation of the country, have shrunk to 5-6,000 inhabitants, and have a total area of even more. The country is estimated to have about 300,000 acres of streets, squares and sidewalks.

It is assumed that half of this volume of areas will not be realized due to conservatism and economic reasons. We distribute the other half between existing and other types of street and pavement coverings appearing on the market. For petrified paving stones and tiles, the percentage distribution indicated in table 1 among the different types of street coverings is obtained.

Although these products are the best of the materials listed so far with optimal qualities, we set certain quotas for similar pavers and tiles - 1.5% of 300,000 approximately 4,500 acres.

50,000 pavers and 25,000 tiles are included in 1000 sc. m (1 acre) area, which makes 250 tons of pavers and 75 tons of tiles. For the first stage of the plant, an annual production of 300 tons of pavers and 150 tons of tiles can be assumed. (See Table 1.). Table 2 shows the volumes of annual consumption (in the most minimal version) for the different types of products. It also includes volumes for abroad, to determine the total consumption of this material.

For single export abroad, the export of petrurgical products in color and only yellow and white for delineating a permanent horizontal road marking is considered.

Table 1. Competitive materials.

№	Competitive materials	Market, %
1	Pavers carved from stone - granite Paving tiles from natural stone pieces	16
2	Asphalted street and sidewalk surfaces	45
3	Different types of colored natural stone pavers with smaller sizes for figurative coverings (red, white, etc.), Marble paving slabs	5
4	Concrete pavers and tiles - different sizes and quality	30
5	Petrochemical pavers and tiles	1.5
6	Others	2.5

Table 2. Types of products.

№	Production - types of products for the first stage of the plant's development	Volume in tons
1	Paving stone	300
	Yellow pavers	200
	White pavers	50
	Colorful pavers	50
2	Tiles	150
	Yellow tiles	100
	Colored tiles	50
	Total	450

Increased interest in such products was registered at exhibitions.

As a result, a capacity of 300 tons of pavers and 150 tons of tiles per year is offered - a total of 450 tons/year for the first stage and doubling the production for the second stage to 900 tons/year. It is insufficient to meet the full needs of such petrurgical materials. After the implementation of the project, appropriate management decisions can be made to change the volume of production, but at the beginning of the activity it is advisable to work in a market with greater opportunities for implementation, i.e. in a "black hole" market. The bottom line is that in the next 10-15 years, the marl clay ware plant will be operating at full capacity.

Production program

Through the marketing analysis, the initial production program was determined, as a basis for calculating the productivity of the technological line.

Table 3. Production program.

Years	1*	2	3	4	5	6	7	8	9	10
Production tons/year	450	900	900	900	900	900	900	900	900	900

Note:*During the first year a preparing and designing of the plant is carried out and the building and installing the plant's equipment includes half a year. Finally a report of the obtained results during 10-year research is considered.

The production program envisages obtaining the capacity of the technological line with the necessary margin for failure, even though small, taking into account the necessary planned repairs of the facilities and all other prerequisites for regular, full-fledged and fault-free operation of the plant for the production of petro-chemical products. Table 3 shows the production schedule for a 10-year research horizon commensurate with the real life of the process line and the real production development cycle.

2.2. Analysis of costs of raw materials and auxiliary materials-modifiers, dyes and others. Material and heat balance of production.

Marl clay - main raw material

For products with a specific weight of 2500 to 2600 kg/m³, we determine the necessary main raw material with a 20% reserve. The operation mode of the main equipment of the technological line - dryer and oven 1 pc each - is continuous. We accept for 1 year 330 working days. The remaining 35 days are for planned repairs. We determine the daily, monthly and annual need for raw materials with a 20% reserve and a minimum density of 2500 kg/m³ and a maximum density of 2600 kg/m³. It is as follows: (see table 4). Calculations such as cost rates are made for maximum compactness. The price of the raw material is 30 euros.

Table 4. Consumption of base raw materials.

Productivity, tone		Material		
		Daily	Monthly for 27.5 working days	Annual for 330 working days
Consumption of raw material - marl clay, kg				
450	min	1363	37500	450000
500	max	1515	41662	500000
900	min	2727	75000	900000
1000	max	3530	83324	1000000
Consumption of raw material - washed kaolin, kg				
450	Min20%	272	7480	89760
500	Max20%	303	8333	91650
900	Min20%	544	14960	164560
1000	Max20%	606	16665	183315
Consumption of raw material - colorants, kg				
450	Min2%	27,2	748	8976
500	Max6%	81,6	2244	24684
900	Min2%	54,4	149,6	16456
1000	Max6%	163,2	4488	49368

Consumption of additives, modifiers and colorants.

To obtain basic, modified and colored material, it is necessary to take these materials as a weight % of the basic raw material. Washed kaolin is usually added to the base material for additives - 20% over 100% in classic production with a price of 50 EUR/ton. Dyes are also used - from 2 to 6% also over 100% with a price for the different colors of the dyes from 20 to 100 euros per kilogram. The main production is without colorants, i.e. in yellow color, and the special one in white color for horizontal marking. The three cheapest colors are used for dyes - dark red (burgundy) with dye Fe₂O₃, green dichromium trioxide Cr₂O₃ and blue - 1% cobalt carbonate. The expert estimate made for the price of 1 ton of material and additives is shown in table 5.

Table 5. Consumption price of additives, modifiers and colorants.

№	Type	450 tons/year		900 tons/year	
		min	max	min	max
1	Marl clay, EUR/t	36.00	37.44	72.00	74.88
2	Kaolin, EUR/t	20.00	20.80	20.00	20.80
3	Dyes, EUR/t	0.00	400.00	0.00	400.00

Packaging costs

The pavers are packed on pallets with dimensions of 800 x 1200 x 150 mm. The arrangement on the pallets takes place at the palletizing machine at the end of the technological line, after which it is wrapped or not depending on the customer with polyethylene film, tied with a chamber and stored. The height of the finished pallet is 1.2 meters. Other products, if necessary, are also packed on a similar pallet.

2.3. Electricity consumption by aggregated indicators.

The electrical energy (table 6) that is consumed is divided into two groups: electrical energy used for preparatory - closing operations and main electrical energy or other energy for drying and annealing. The first group is carried out by the various facilities described in the title list of the technological line, and the second group is carried out in a new, ecological way by burning high-calorie pellets in a special generator, heating air supplied up to 200 °C in the dryer and up to 1300 °C in the furnace, and in a cooling cycle while the excess heat is supplied to the drying space. The length of the dryer is 76 meters, and the length of the furnace is 60 meters. The facilities are divided into zones, and according to the technological mode, the speed of movement of the carts in the dryer and in the furnace, respectively, is determined. The electrical energy consumed by all consumers of the technological line, with the same numbering from the title list is presented in the table 6.

Some facilities have no electricity consumption. The price of consumed ENERGY is 0.22 EUR/kWh at a three-tariff electricity meter (average value of 0.33: 0.198 and 0.132 BGN per kWh for 2020) until the end of 2021.

It is possible to use gas if no ecological fuel is used for heating.

Table 6. Use up power by consumers.

№	Installation	№	Installed power	Productivity 450 t		Productivity 900 t	
		kW	Time for work hours	Power consumed kW	Time for work hours	Power consumed kW	
	Workshop No. 1 Preparation of raw materials						
	Raw material warehouse						
1	Feeder hopper with vibrator. It is filled with marl clay, with a volumetric weight of up to 2300 kg/cubic m. Volume V=5 cubic meters.	1	-				
2	Conveyor. Serves to transfer the clay to the Homogenizer pos.11 and to Kollergang pos. 3. Dimensions L=20 m, B=500 mm, V=15 m/min, N=2.2 kW, with 2 pcs. flaps.	1	1 x 2,2 = 2,2	6	13,2	12	26,4
	1.2. Preparatory section of raw clay	1	-				
3	Kollergang for crushing raw material to sizes 5-10 mm., D=3 m, N=7.5 kW	1	1 x 7,5 = 7,5	2	15	4	30
	1.3. Fireclay preparation mill section						
4	Rotary furnace firing marl clay for chamot, total power N=15 kW, n=20rpm, dimensions D=0.8m, L=4 m, H=1.5m, T = 850 °C.	1	1 x 15 = 15	3	45	6	90
5	Vibrating type mill for chamot crushing. Productivity 1000 kg/hour. N=5 kW. Sizes of the obtained particles below 100 μm, with a volume weight of 2,500 kg/m³.	1	1 x 5 = 2,2	6	30	12	60
6	Aspiration device around a fireclay mill N=2.5 kW	1	1 x 2,5 = 2,5	6	15	12	30
7	Belt conveyor for transporting the fine particles from Kollergang pos. 3 to Mill pos. 5, volumetric weight 2,800 kg/m³, dimensions B=500 mm, L=18 m, N=2.2 kW	1	1 x 2,2 = 2,2	6	13,2	12	26,4
	1.4. Schlicker (liquid clay mixture) preparation section		-				
8	Belt conveyor for transporting the fine particles from Mill pos. 5 to Homogenizer pos.11, volumetric weight 2,800kg/m³, dimensions B=500mm, L=15m, N=2.2 kW, with 2 pcs. receiving chute at one end, 2 m wooden part and one chute at the other end.	1	1 x 2,2 = 2,2	6	13,2	12	26,4
9	Hopper for additives - 1.5 m³	3	-				
10	Cart for supplements with scales up to 500 kg. Drive automatically. Feeding in Homogenizer pos. 11.	1	-				
11	Homogenizer with ball grinding elements of a schlicker. According to the recipe, crushed clay from Kollergang pos. 3, ground fireclay from Mill pos. 5, additives such as washed kaolin and others and water 60%, and the result is a liquid colloidal mixture - a slip with a maximum particle size of less than 100 μm. Volumetric weight of the homogenized slip 1400 kg/cubic m. Grinding time up to 8-10 hours. Approximate dimensions: useful volume V=3 m³. D=0.8-1 m, L=10 m, n=20 rpm, N=15 kW.	1	1 x 15 = 15	3	45	6	90
	1.5. Plastic table preparation section						
12	Filter press to remove water up to 12-15% until a plastic mass is obtained D=0.8-1 m, L=2 m, n=10 rpm, N=5 kW	1	1 x 5 = 5	6	30	12	60
13	Screw vacuum press for removing air bubbles from the plastic mass D=0.8–1 m, L=2 m, n=10 rpm, N=5kW	1	1 x 5 = 5	6	30	12	60
14	Extruder screw D=0.1 m, n = 10 rpm, N = 5 kW	1	1 x 5 = 5	6	30	12	60
	Workshop No. 2 Receiving finished products						
	2.1. Section for pressing products						
15	Mold equipment for 7 types of raw products - 5 for pavers and 2 for tiles.	-					
16	Trolley up to 1000 kg on rails. Drive automatically by pusher in dryer and oven. Supply to Dryer with air circulation, Usable area length 2.40 x width 2.60 m.						
17	Press for pressing raw products, N = 7.5 kW	1	1 x 7,5 = 15	6	45	12	90
	2.2. Drying section						
18	Dryer with air circulation passage with large volume and programmer - up to 684 m³ and temperature up to 200°C with different drying modes for different products, N=5 kW, L=76 m, without the energy for drying. Generator for heating ecological fuel with a power of 20 kW	1	1 x 5 = 5 1 x 20 = 20	12 12	60 240	24 24	120 480
19	Drying racks measuring 1.2x0.8x1.8 go into a cart-mounted air circulation dryer.	600	-				
	2.3. Furnace section						
20	Walk-through furnace with a trolley with intermediate partitions for high-temperature firing of various products up to 1200°C in capsules - special boxes with or without a lid N=5 kW, L=60 m without energy for baking. Generator for heating ecological fuel with a power of 150 kW	1	1 x 5 = 5 1 x 150 = 150	12 12	60 1800	24 24	12 3600
21	Racks for capseles (drying adjustment boxes) with sizes 4 x 0.8 x 1.8	3	-				
22	Capseles for products	10000	-				
23	Rail track, H = 1435 mm L = 150 m.	150	-				
	Transport inside the factory						
24	Transport inside the factory - stapler machine for feeding raw clay (fadrome), tractor with trailer, motorcycle (or gas) car or electric car. Euro pallet size A = 800 mm, B=1200 mm H=150 mm and load height H=1800 mm.	3	-				
25	Packaging machine for products with tape and foil. N=3 kW	1	1 x 3 = 3	2	6	4	12
	Total plant facilities						
26	Workshop crane - with robotic manipulators, load capacity Q=5 tons. N=7.6 kW	1	1 x 7,5 = 7,5	4	30	4	30
27	Laboratory for quality assessment - (apparatus and appliances) - complete laboratory equipment. Total power N=up to 3 kW	1	1 x 3 = 3	0,5	1,5	0,5	1,5
28	Repair workshop - machines, fixtures and tools most necessary for the repair of the furnaces and other equipment, and a repair section for repair, installation and dismantling of the insulation and heaters of the furnaces. Total power N=40 kW	1	40	1	40	2	80
29	Domestic premises - equipment with the most necessary household items and amenities.	1	-				
30	System for control and computer management of the technological process.	1	1 x 1,5 = 1,5	24	36	24	36
31	Factory telephone connections-system-Director's office.	1	-				
32	Substation	1	-				
33	General rack for air drying of products on Dryer with air circulation pos. 18 and Pest pos. 20-742 sq.m.	1	-				

Note: The annual consumption is taken at 330 working days of the facilities, with some facilities operating in one shift, some in 2 shifts, and the furnaces in a continuous duty cycle (3 shifts). Calculations for green energy generators for heating are currently made with the cost of electricity due to lack of data. If these generators are applied, the cost price of the products will be reduced.

Consumption of other types of energy – heat, cold, water, steam, fuel, etc. - none except for household needs - 1 EUR/ton each.

2.4. Cost of labor and other costs.

Industrial - production personnel (IPP) and salary fund. Distribution of IPS (industrial - production staff) by categories of shifts and productions.

The required number of workers has the following list composition:

- One superior of shift, automation and control engineer, higher education, male or female, works 3 shifts, 3 people;
- Two equipment maintenance technicians - 1 mechanic and 1 electrician, secondary special education, men, working in 1 shift, 2 people.

Table 7. Total power used.

Power	For 450 t/year	For 900 t/year
1. Total installed capacity of machines for preparatory - final processing	101 kW	101 kW
2. Total installed power for heating - drying and baking	170 kW	170
3. Total used daily capacity for preparatory - final processing	517 kWh/day	968 kWh/day
4. Total used annual capacity for preparatory - final processing	170610 kWh/year	319440 kWh/year
5. Total power used for preparatory - final processing for 1 ton of finished product	379.13 kWh/t	354.93 kWh/t
6. Total used daily power for heating the material for 24 hours (12 hours - max consumption works with on and off to maintain temperature) max	2040 kWh/day	4080 kWh/day
6a. Commonly used daily power for heating the material for 24 hours (8 hours - min consumption - works with on and off to maintain temperature) min	1360 kW	2720 kW
7. Total used annual power for heating the material - max	673200 kWh/year	1346400 kWh/year
7a. Total used annual power for heating the material - min	448800 kWh/year	897600 kWh/year
8. Total used power for heating the material for 1 ton - max	1496 kWh/t	1496 kWh/t
8a. Total used power for heating the material for 1 ton - min	997,33 kWh/t	997,33 kWh/t
9. Total power used for preparatory - final processing and for heating the material for 1 ton max	379,13+1496= =1875,13 kWh/t	354,93+1496= =1850,93 kWh/t
9a. Total power used for preparatory - final processing and for heating the material for 1 ton min	379,13+997,33= =1755,59 kWh/t	354,93+997,33= =1707,19 kWh/t
10. Total annual power used for preparatory - final processing and for heating the material - max	843808,5 kWh/year	1665837 kWh/year
10a. Total used annual power for preparatory - final processing and for heating the material - min	790015,5 kWh/year	1536471 kWh/year
11. Total value for 1 ton in Euro max	412,53	407,20
11a. Total value for 1 ton in Euro min	386,23	375,58

Note: The annual consumption is taken at 330 working days of the facilities, with some facilities operating in one shift, some in 2 shifts, and the furnaces in a continuous duty cycle (3 shifts):

- Two technicians for work of all furnaces and equipment, technicians of silicate materials, secondary special education, men, work in 3 shifts, 6 people;
- Three workers (for preparatory and final processing of the materials) and 1 forklift driver, work in 2 shifts, 8 people;
- One technician controller, secondary special education "Silicate technology", man or woman, works 2 shifts, 2 people.

A total of 21 service personnel are needed for one industrial unit operating with 5 shaft furnaces and 1 rotary furnaces for granules for the first stage of commissioning of the plant. An additional 14 people are needed for the second stage of capacity implementation as follows:

- Two equipment maintenance technicians - 1 mechanic and 1 electrician, secondary special education, men, working in 1 shift, 2 people;
- Two technicians for work of 5 shaft furnaces and 1 rotary furnace for granules, technicians, secondary special education "Silicate technology", men, working in 3 shifts, 6 people;
- Two the workers for preparatory and final processing of the materials, 1 employee (secondary special education "Silicate technology") and 1 forklift driver (secondary special education), men or women, work in 2 shifts, 4 people;
- One technician controller, technicians, secondary special education "Silicate technology", man or woman, works 2 shifts 2 people.

A total of 35 staff are needed for the plant at full capacity.

Annual salary fund and accruals for social security and retraining and unemployment fund (calculation base)

In the calculations it is assumed for labor, including additional labor remuneration such as classes, night allowances, etc. as 60% of the normally inherent costs of materials for this type of industry and with 20% harmful, including 35% for social security and 7% retraining and unemployment fund:

In total, for the first stage of the introduction of the plant's capacities, 21 people serving PP staff are needed, with a total value of monthly wages of 196060.5 EUR per year or falling at 435.69.07 EUR/ton. For the second stage of introducing the capacities for the additional 14 people, the salary of the working staff is maintained as follows:

In total, 35 IP personnel are required for the plant at full capacity, with a total annual salary of 410049 EUR and falling at 455.61 EUR/ton.

Depreciation charges.

Depreciation charges are different for different capital investments:

For land and infrastructure - deductions are not foreseen.

For a building - with a 20-year term of deductions.

The formulas by which we determine the depreciation and the residual value are:

$A = P / T$, where P is the value of the depreciable capital, and T is the time for amortization.

For 1 ton we receive 50 EUR/ton for the first stage and 25 EUR/ton for the second stage.

For the technological line - we use a formula with a non-linear dependence of calculating the residual value.

$P_{\text{Growth}} = P(1 - k)^T$ and

$A = P - P_{\text{Growth}}$; $k = 0.2$ and $T = 5$ years for this type of industry

For 1 ton, we sum up the total depreciation for the ten years for the first and second stage respectively, i.e. we get 138.84 EUR/ton for depreciation charges for the first stage and for the second stage 110.76 EUR/ton, which is an average value for the annual depreciation charge. Real values are variable quantities that will be reflected in the corresponding annual real costs.

For the second stage of operation of the technological line, depreciation deductions are allocated after the third year from the start of operation of the plant.

2.5. Determination of full production cost and production and sales price.

These values are presented in the following table 8 in EUR. The factory price constructed in this way in two versions with minimum and maximum costs for the two stages of production shows the limits of the real factory price, which will probably be somewhere in the middle of the resulting interval, i.e. for the first stage it will be **1999.27** EUR/ton and for the second stage respectively **2011.79** EUR/ton/.

Full cost of production and production cost by cost element and analysis of basic costs.

From the cost table, it can be seen that the elements for building the full cost are from item 1 to item 6, respectively, raw materials, energy costs, labor costs, other costs, depreciation deductions, additional costs, some of which are given as exact values, and others are defined as a percentage of the costs incurred so far, taken from the statistics for the relevant type of production.

Table. 8. Determination of full production cost and Factory price.

No	Type of expenses	Amount in EUR/ton of petrified material at a density of 2500 kg/m ³			
		Productivity			
		450 tons/year		900 tons/year	
		min	max	min	max
1	Raw materials				
1.1	Main - marl clay	36.00	37.44	72.00	74.88
1.2	Basic – washed kaolin	20.00	20.80	20.00	20.80
1.3	Dyes	0.00	400.00	0.00	400.00
	Amount for item 1	56.00	458.24	92.00	495.68
	Average value	257.12		293.84	
2	Energy costs at current 0.22 EUR/ kWh	386.23	412.53	375.58	407.20
	Average value	399.38		391.39	
	Amount for item 1 to item 2	442.23	870.77	467.58	902.88
3	Labor expenses				
3.1	Salary 60% of cost of materials	265.34	348.31	280.55	361.15
3.2	Accrued 35% for Income tax	92.87	121.91	98.19	126.40
3.3	Accrued 7% for unemployment and retraining	18.57	24.38	19.64	25.28
	Amount for item 3	376.78	494.60	398.38	512.84
	Average value	435.69		455.61	
4	Other expenses				
4.1	Transportation of raw materials	1.00	6.00	1.00	6.00
	Amount for item 1 to item 4.1	819.01	1365.37	865.96	1415.72
4.2	For maintenance and repair, 10% for the amount from items 1 to 4.1	81.90	136.54	86.60	141.57
4.3	Marriage up to 20% for the amount from items 1 to 4.1	163.80	273.07	173.19	283.14
	Amount for item 1 to item 4.3	1065.71	1780.98	1126.75	1846.43
4.4	Packaging costs - pallets	9.60	11.60	9.60	11.60
	Amount for item 4	993.41	1656.04	1049.75	1716.46
	Average value	1324.73		1383.10	
5	Depreciation deductions A (calculated according to a special formula)				
5.1	For buildings	50.00	50.00	25.00	25.00
5.2	For a technological line	138.84	138.84	110.76	110.76
	Amount for item 5	188.84	188.84	135.76	135.76
	Average value	188.84		135.76	
	Production cost price amount for item 1 to item 5.2	1264.15	1981.42	1272.11	1993.79
6	Additional costs - 10% of the amount for items 1 to 5, (advertising, salaries for administration and management)	126.42	198.14	127.21	199.38
	Average value	162.28		163.29	
	Full cost - amount for item 1 to item 6	1390.57	2179.56	1399.32	2193.17
7	Profitability - 12% of the amount for item 1 to item 6	166.87	261.55	167.92	263.18
	Average value	214.21		215.55	
	Factory price - amount for item 1 to item 7	1557.44	2441.11	1567.23	2456.35
	Average factory price for electricity 0.22 EUR/kWh	1999.27		2011.79	
	Average factory price of 1 paver weighing 5 kg, EUR/piece	7.79	12.21	7.84	12.28
	Average factory price of 1 paver weighing 5 kg, BGN/piece	15.57	24.41	15.67	24.56
	Average factory price of 1 tile weighing 3 kg, EUR/piece	4.67	7.32	4.70	7.37
	Average factory price of 1 tile weighing 3 kg, BGN/piece	9.34	14.65	9.40	14.74
		No coloring -Original yellow*	With color – other: red (burgundy), green, blue	No coloring -Original yellow*	With color – other: red (burgundy), green, blue
		No profit			

*Note: The marl clay used creates the specific yellow color [10].

The production price also includes a minimum planned profitability - 12% of the costs incurred for the full production cost.

The following analysis of the main costs was made:

-costs for raw materials are constant;

-energy costs are also constant if the price of electricity does not increase above 0.22 EUR/kWh, which depends on government policy;

-labor costs are variable, on the one hand, until the optimal composition of jobs is established, on the other hand, in order to have lasting interest on the part of the work team, it is necessary to foresee a progressive increase in wages by approximately 5% per year separately from inflation, which can be guaranteed from the profit, after paying off the used credits or in parallel with them;

-other costs, including transportation of raw materials, maintenance and repair costs, which we define as 10% of the costs incurred so far and marriage costs are variable in the direction of reduction, which is the concern of the plant management;

-depreciation deductions set aside in a separate fund are constantly decreasing for each subsequent one-year period. The total cost includes the average value for the first stage and the average value for the second stage of production. Their calculation is shown above. The decision to use these funds is the responsibility of management;

-additional costs, including funds for advertising the produced material and funds for payment of the work of administrative and management personnel. These funds are necessary for the successful implementation of the production. Finding the optimum -

on the one hand, not to weigh too much on the cost price, on the other hand, to be as much as possible for the quality work of the governing body will largely lead to success and positive results. Of the 10% determined, 2.5% is set aside for advertising, and the remaining 7.5% is paid for the labor of the governing body. Here, too, it is necessary to provide for an increase in wages by 5% per year separately from inflation.

For the 10-year period of consideration, the total amount for advertising is distributed over years unevenly in order to promote the finished product at the beginning of its production.

The composition of the administration is minimized. Necessary expenses are also for paying patent authors, consulting fees for plant planning and construction, and other fees, and a minimum reserve is required.

The foreseen 12% minimum planned profitability, also allocated in a separate fund, determines the size of the minimum planned profit compared to the cost of production, and from there the average profitability compared to the production funds, which is 10.6% for the first stage and 38.8% for the second stage of plant operation. This will help determine the exact value of the minimum selling price of the produce.

Factors influencing full cost, production price and selling price.

The factors having some influence on these parameters of the manufactured products are of two types - external and internal. External are the normative documents affecting the making of legally justified management decisions and internal, leading to the accumulation of maximum profit and an optimally effective result of the production of this type of production in the created macro - external economic environment, i.e. the maximum possible selling price in order to realize the maximum profit and at the same time sell the entire quantity of output produced. The selling price is 18 BGN per paver and 10 BGN per tile without VAT. With which calculations the Business Plan is made.

Capital investments and production funds.

Capital investments are worth EUR 2.5 million for the two stages.

Structure of capital investments and fixed production funds.

We divide capital investments by the following costs:

For land - EUR 50,000.

It is planned to purchase a plot of land with dimensions of 90 x 60 m = 5,400 sq.m., on which to build a workshop - a building with dimensions of 60 x 30 m = 1,800 sq.m.

For infrastructure - EUR 50,000.

For construction or building - 400,000 EUR.

The workshop building with dimensions of 60x30 m = 1800 sq.m built-up area

For technological line - machinery and equipment 2 million EUR.

Working Capital.

Working capital is the sum of the value of the working funds and the circulation funds. Working funds consists of the following components:

- raw materials expenses - energy costs
- labor expenses - other costs
- transport, maintenance and repair, marriage, packaging, etc.
- additional costs

Working funds also includes unfinished production and stock of raw materials in the amount of 15% for 1 year.

Circulation funds is made up of the following components:

- unrealized finished product - as quantity and value we accept finished product less than a unit of transport volume (no. 3/4 of the volume of a truck - TIR);
- costs for finished goods on the road (full volume of a TIR truck).

Total value of Working capital - represents the sum of the above components increased by 20% for unforeseen additional costs.

The minimum and maximum value of Working capital indicates the limits within which they can move. After analysis we accept 500,000 EUR.

Available main funds that will be used under the project

Available capital funds at the time of creation of the conceptual project do not exist. After implementation of the project management form, ways to collect these funds will be found.

Production funds.

The production funds necessary for the realization of the project are the value of the technological line, respectively **2,000,000 EUR.**

One-time costs

The one-off costs are for the purchase of land, construction of a building and infrastructure, the total cost of which is **EUR 500,000.**

The total cost of realization of the factory for the production of petrugical products is **2.5 million EUR**, which price changes over time to increase with the inflation index and other, external factors. These data are included in the developed business plan.

Note: In the entire project, the value of 1 EUR is equal to 2 BGN, limited by the Currency Board in the Republic of Bulgaria. The calculations were made until June 2021, with inflation reflected proportionally in the changing economic situation.

3. Conclusions

A primary substantiated financial project has been prepared for the construction of a technological line and pilot plant for the production of full-fledged replicas (with complex indicators superior to the original samples) of the so-called "yellow paving stones" and a wide assortment of products based on the developed original technology and raw materials with Bulgarian origin for an ideal new site.

The financial means necessary for the implementation of the individual stages of the prepared project have been analyzed: acquisition of an industrial plot, construction of a production factory infrastructure, warehouse base, laboratory and additional units, provision and installation of a complex of specialized facilities and equipment for automation, video surveillance, communication and management, intra-plant transportation, extraction and transportation of raw materials, purchase of auxiliary materials, appointment and training of qualified production, administrative and general personnel, energy carriers, advertising, expenses for design and legal services and others. The estimated cost of the products and the current production factory price with the required profitability are determined.

The presented development is mainly aimed at the attention of industrial producers, potential investors, responsible persons in the field of urban planning and public infrastructure and specialists in the field of cultural and historical heritage of the country.

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4. References

- 1 .P. Berrone, J. E. Ricart Costa, A. Duch T-Figueras, "Cities and Mobility & Transportation: Towards the next generation of urban mobility", Book, Create Space Independent, 2016.
2. J. Chow, "Informed Urban Transport Systems Classic and Emerging Mobility Methods toward Smart Cities", Book, 1st Edition, Elsevier, 2018.
3. J. R. Vacca, "Solving Urban Infrastructure Problems Using Smart City Technologies: Handbook on Planning, Design, Development, and Regulation", Book, Elsevier, 2020.
4. IARC, "Bitumens and Bitumen Emissions, and some N- and S-Heterocyclic Polycyclic Aromatic Hydrocarbons", IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 103, Lyon, France, 2013.

5. Contract: KP-06-OPR 03/4 of 14.12.2018 (MES 02/18/4), Competition for funding of fundamental science investigations on social challenges - 2018, Research project of topic: "Study of the conditions of synthesis and properties of colored petrugical materials based on sedimentary and metamorphic rocks", Head of the research team: Dr. Eng. Krassimira Antonova Toncheva, Beneficiary: Institute of Metal Science, equipment, and technologies with Center for Hydro- and Aerodynamics "Acad. A. Balevski" - BAS, Sofia, Project status: current.
6. L. Lakov, N. Stoimenov, P. Conev, V. Vasilev, B. Jivov, Kr. Toncheva, "Physic and chemical, mechanical properties and tomographic analysis of the new "yellow brick" from petrurgic material", DCB 2016, International Conference on Civil Engineering Design and Construction (Science and Practice), 15-17 September 2016, Varna, Bulgaria, 2016, pp. 115-120.
7. L. Lakov, Sv. Encheva, P. Conev, V. Vasilev, B. Jivov, Kr. Toncheva, "Manufacturing technology, chemical and phase composition of new "yellow brick", obtain on a based of sedimentary rocks", DCB 2016, International Conference on Civil Engineering Design and Construction (Science and Practice), 15-17 September 2016, Varna, Bulgaria, 2016, pp. 121-127.
8. P. Mukhtarov, R. Bojilova, "Influence of solar and geomagnetic activity on the ionosphere over Bulgaria", Comptes rendus de l'Acad'emie bulgare des Sciences, 70, 9, Publishing House of BAS "Prof. Marin Drinov", 2017, pp. 1289-1296.
9. R. Bojilova, P. Mukhtarov, "Relationship between the critical frequencies of the ionosphere over Bulgaria and geomagnetic activity", Comptes rendus de l'Acad'emie bulgare des Sciences, 73, 8, Publishing House of BAS "Prof. Marin Drinov", 2020, pp. 1113-1122.
10. L. Lakov, G. Mutaftchieva, G. Peev, M. Aleksandrova, B. Jivov, "Physicochemical and technological researches of marls from the area of the village Llovets related to the production of the new "yellow paving stones". International Scientific Journal Materials Science. Non-Equilibrium Phase Transformations, Year VII, Issue 3/2021, Scientific Technical Union of Mechanical Engineering INDUSTRY 4.0, 2021, pp.107-109.
11. L. Lakov, S. Encheva, P. Tsonev, B. Jivov, M. Aleksandrova, K. Toncheva, "Production of prototypes of "yellow paving stones" in Bulgaria PART I: Physical and chemical properties", Journal of Chemical Technology and Metallurgy, 53 (6), 2018, pp. 1144-1149.
12. L. Lakov, M. Kandeve, P. Tsonev, V. Vasilev, B. Jivov, M. Aleksandrova, K. Toncheva, N. Stoimenov, "Production of prototypes of "yellow paving stones" in Bulgaria PART II: Tribological and mechanical indicators", Journal of Chemical Technology and Metallurgy, 53 (6), 2018, pp. 1150-1156.
13. L. Lakov, M. Gacheva, Sv. Encheva, St. Yordanov, B. Jivov, A. Aleksandrova, Petrographic analysis and structure of new colored petrurgical materials. International Journal "NDT Days", Volume 1, Issue 3, Published by Bulgarian Society for Non-Destructive Testing Member of ICNDT and EFNDT, 2018, pp. 276-281.
14. L. Lakov, M. Gacheva, K. Yankova, St. Yordanov, B. Jivov, S. Rafailov, K. Toncheva, "New petrurgical materials for the production of yellow bricks and artistic-decorative items", Engineering Sciences, LV, 2018, No. 2, pp. 30-39.
15. M. Gacheva, L. Lakov, B. Jivov, S. Yordanov, M. Aleksandrova, "Investigation the conditions for obtaining bulgarian yellowcolored pavings, equivalent in color to the imported produced on base of sedimentary rock". International Scientific Journal "Machines. Technologies. Materials.", Year XIII, Issue 3, 2019, pp. 144-146.
16. M. Gacheva, L. Lakov, B. Jivov, K. Marinova, S. Yordanov, S. Rafailov, "Technology for the Preparation of White and Colored Petrurgical Materials on the Basis of Sedimentary Rocks". International Journal "NDT Days", Volume II, Issue 2, Year 2019, 2019, pp.182-187.
17. G. Mutaftchieva, "Technological development of lighting fixtures in the field of silicate design", Collection reports, Design & applied arts - Sofia, NAA, 2018, pp. 138-144.
18. G. Mutaftchieva. "Modern trends and development of lighting fixtures in the field of silicate design", PhD thesis for the award of the educational and scientific degree "Doctor", NAA, Bibliography 87, 2020, p. 215.
19. L. Lakov, B. Jivov, M. Aleksandrova, S. Yordanov, K. Toncheva, „Synthesis, phase composition and microstructure of colored ceramic materials based on diopside“. International Scientific Journal Materials Science. Non-Equilibrium Phase Transformations, Year VI, Issue 3 / 2020, Scientific Technical Union of Mechanical Engineering INDUSTRY 4.0, 2020, pp. 77-79.
20. K. Toncheva, L. Lakov, M. Gacheva, B. Jivov, "Metal molding equipment for yellow pavet forming", International Journal "NDT Days", Volume III, Issue 2, 2020, pp. 100-103.
21. G. Mutaftchieva, L. Lakov, M. Aleksandrova, G. Peev, "Technology for production of reduced yellow paving stones on the basis of modified marl clay from the Alexandra quarry, the village of Lovets, Bulgaria" (Part 1), International Scientific Journal "MACHINES. TECHNOLOGIES. MATERIALS", Issue 3/2022, pp. 96-99.

Further development of the possibility of creating composite coatings from ash microspheres on a steel basis

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Abstract: The article is devoted to the solution of an important scientific and technical problem of development of new composite coatings with the use of industrial waste of thermal power plants – aluminosilicate empty microspheres. The analysis of existing technologies showed the prospects for the use of electric arc spraying, which will expand the scope of compositions. All-drawn wires of ER346 (Cв-08) and 1066 (65Г) brands were used for coating, ash fillers of aluminosilicate composition were used as fillers. The effectiveness of ash microspheres for the formation of coatings is confirmed by the results of hardness measurements. Coatings filled with ash microspheres have increased Vickers hardness by 7... 22%. The use of ash slags in new technologies is a promising practical area, the implementation of which will help in the search for scarce minerals.

Keywords: ASH MICROSPHERES, SPRAYED COATINGS, ELECTRIC-ARC SPRAYING, THERMAL POWER PLANTS.

1. Introduction

The efficient operation of Ukrainian thermal power plants is accompanied by the release of large amounts of fuel waste, the mineral components of which are converted into ash slag. Ash slag accumulates in ash dumps, which has a negative impact on the environment. Therefore, the issue of fuel waste disposal is very acute. As a result of combustion of coal particles at temperatures of 1600... 1800 °C complex silicates are formed, which in the process of melting under the action of dissolved gases are transformed into spherical droplets (microspheres) with a gaseous atmosphere in the middle, which includes nitrogen, oxygen, and carbon monoxide [1].

Aluminosilicate hollow microspheres (ASHM) are the product of light fraction processing of fly ash in thermal power plants, after capture by electrostatic precipitators from the flue gas composition.

The combination of these unique properties makes the possibilities and prospects of using these microspheres in the oil, gas, chemical industry, automotive industry, refractory ceramics and construction unlimited. Microspheres are a valuable raw material, which is actively used by mining companies and construction industry companies in their technologies, as well as for the production of composite materials.

In the work [2] the authors analyzed the activities of Burshtyn, Prydniprovsk, Trypillia, Kryvyi Rih and Chernihiv TPPs with the production of ash microspheres and their promotion in the industrial markets of Ukraine, Germany, Italy, Slovakia, Kazakhstan, Korea, Netherlands, Moldova, Romania and Romania. Their chemical composition directly depends on the mineral components of coal, in particular the presence of clay minerals, hydromica, quartzite and the content of quartz, pyrite, dolomite, magnesite, siderite, which undergo complex chemical and phase transformations during production processes [3].

The addition of ash microspheres to the composition of dry building mixtures and refractories gives them reduced density and thermal conductivity, the ability to dampen dynamic vibrations and vibrations, chemical inertness, which causes their use in solvents, organic liquids, acids, alkalis, water. Materials manufacturing technologies are low-temperature and are based on high fluidity, compact laying of ash microspheres, their ability to inhibit shrinkage processes during curing and polymerization of mixtures. However, it is possible to expand the areas of application and give the materials new operational properties by combining metallic and non-metallic components in one composition, which will require the introduction of high-temperature technologies.

Theoretical prerequisites for the creation of such compositions are scientific ideas about the physico-chemical processes of joining glass or ceramics with metals [4, 5], the formation of polydisperse composite media using non-metallic microspheres [6, 7] and own developments of the authors of the article on the scientific and technical bases of applying electric arc coatings filled with empty glass microspheres on a steel surface [8]. Due to the convenience and energy efficiency of electric arc spraying is considered a promising high-temperature method by which metal coatings can be

applied metal-glass or metal-ceramic coatings up to 1.5 mm thick, as evidenced by [9]. The fine-grained structure of the coatings is formed during the melting of solid welding wires due to the occurrence of an electric arc between them and the transfer of compressed gas droplets on the spray surface. The experiments considered in [8, 9] include the addition of dispersed nonmetallic particles to the electric arc zone, but the use of ash microspheres in high-temperature technologies, in particular in electric arc spraying, has not yet been studied. Identifying differences and establishing patterns of formation of the structure of new dispersed coatings can be useful for the development of methods of protection of parts and mechanisms in mechanical engineering, energy, chemical industry.

The aim of the work is to experimentally prove the possibilities of using ash microspheres as a part of composite electric arc coatings on a steel surface and to establish the regularities of their structure formation.

2. Materials and Methodology

Experimental work included the formation on a substrate of carbon steel grade A284Gr.D (Cr3) (GOST 380-2005) two types of composite coatings, which used solid wires of the most affordable and inexpensive steels, capable of structural-phase transformations during thermodeformation treatment. These are wire of spring-steel of ferrite-perlite structure of brand 1066 (65Г) (GOST 14959-79) and low-carbon welding wire of brand ER346 (Cв-08) (GOST 2246-70). Aluminosilicate hollow microspheres (ASHM) "Pinosphere" of MPk200-400 brand (manufacturer – LLC "Microspheres Production Association", Ukraine) are used as fillers, which are used in technologies of thermopanel, textured paints, etc. Aluminosilicate microspheres (TU 5717-001-11842486-2006) were used in the research, the chemical composition of which: SiO₂ – 74,9%; Al₂O₃ – 13,9%; K₂O – 2,8%; Na₂O – 1,9%; Fe₂O₃ – 0,9%; CaO – 1,2%; FeO – 0,6%; TiO₂ – 0,2%. A general view of the microspheres is shown in Figure 1.

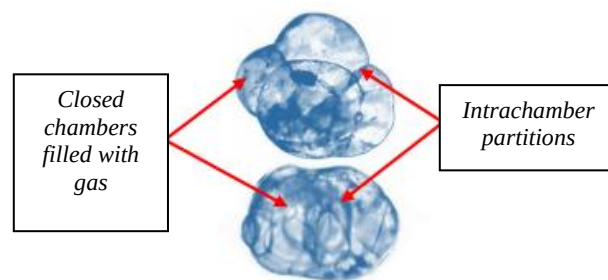


Fig. 1. A general view of the microspheres

ASHM are light gray solid bulk particles with a bulk density of 50... 60 kg/m³ and a dispersion of 200...400 μm. Optical microscopes MMP-2P and BIOLAM-I (BIOJAM-I); scanning electron microscope JSM-7610F were used for researching of

structure. X-ray diffraction analysis by DRON-3.0 (ДРОН-3.0) in molybdenum radiation $Mo_{K\alpha} = 0.071069$ nm with $U = 40$ kW, 40mA were used to study morphological characteristics.

The coating with a thickness of 1.0...1.5 mm was applied on one side to the pre-treated by jet-abrasive treatment of the steel plate with a size of $3 \times 10 \times 140$ mm. Technological modes of electric arc spraying are selected in accordance with the recommendations of the authors [9]: current strength – 80; 120; 160 A; air pressure – 0.4; 0.5, 0.6 MPa; consumption of microspheres – 150 g/min; wire feed speed – 4.2 m/min; distance from the nozzle to the spray surface – 80 mm.

The topography of the sprayed surface was studied by electron microscopy, the phase composition was studied on samples separated from the substrate by X-ray diffraction. The chemical composition of the microregions around the microspheres was studied using micro-X-ray spectral analysis using a microscope-microanalyzer REMMA-102-02 (PEMMA-102-02). The volumetric content of the microsphere coatings was determined by spot analysis with the processing of digital microphotographs.

Hardness (HV_5) was determined according to DSTU ISO 6507-4: 2008 (ДСТУ ISO 6507-4:2008) on a Vickers device with a load of 5 kg.

3. Results and discussion

The chemical composition of microspheres was investigated by X-ray diffraction analysis, which proved the general amorphous nature of microspheres, but showed the presence of α - and β -cristobalite, α - and β -quartz, and crystalline modifications of Al_2O_3 on diffractograms (Table 1).

Table 1: Results of X-ray diffraction analysis of ASHM

Reflection angle, 2θ , °	Interplanar distance, d, Å	Crystal modifications
16.7	2.447	$\gamma-Al_2O_3$
16.9	2.4189	SiO_2 (α - cristobalite)
17.05	2.397	$\gamma-Al_2O_3$
19.45	2.1036	$\alpha-Al_2O_3$
20.45	2.00183	$\gamma-Al_2O_3$
20.65	1.9826	$\gamma-Al_2O_3$
22.3	1.837	SiO_2 (β - quartz)
22.55	1.817	SiO_2 (α - quartz)
22.75	1.8016	SiO_2 (α -кварц)
24.95	1.645	SiO_2 (β - cristobalite)
26.275	1.563	SiO_2 (β - quartz)
29.35	1.402	$\gamma-Al_2O_3$
30.00	1.372	$\gamma-Al_2O_3$

By means of optical analysis of microspheres, the ideal sphericity of experimental particles was established, the Gaussian distribution of which by diameter are: 80% – 200... 300 μm ; 20% – 300... 400 microns.

The problem of energy saving in recent years is one of the main for all developed economies. In this regard, one of the revolutionary solutions for heat preservation can be considered liquid ceramic coatings, which at a thickness of 2...3 mm provide the same thermal insulation effect as a layer of mineral wool with a thickness of 50 mm. The method relates to the field of obtaining coatings with high strength characteristics, heat, fire and weather resistance characteristics for the protection of pipelines of heating systems and air ducts of air heating and ventilation systems.

Variation in the values of current and air pressure during application of the composite coating makes it possible to obtain samples with different fillings of microspheres: from 10 to 25%. Experimental work has shown the tendency of aluminosilicate hollow microspheres to form conglomerates and a high percentage of material loss by spraying (more than 50%), which does not allow accurate calculation of dosage and exact volume content and presents certain technological difficulties.

A schematic representation of a steel-based composite coating with the addition of aluminosilicate hollow microspheres is shown in Figure 2.

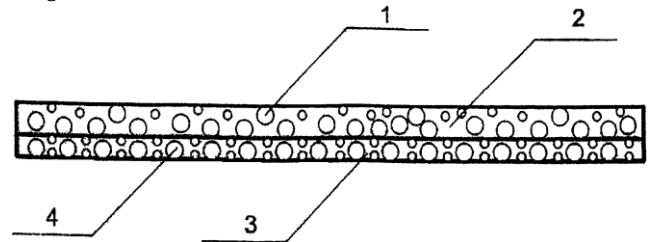


Fig. 2. Scheme of coating with aluminosilicate microspheres:
1 – microspheres; 2 – acrylic latex; 3 – layer with empty microspheres;
4 – aluminosilicate microspheres are covered with metal

Sprayed coatings based on ER346 (C8-08) and 1066 (65I) will have a similar polydisperse porous structure (Figure 3) with spherical inclusions, which according to the results of RSA do not undergo phase transformations. The intensity on the X-ray diffraction patterns of Fe [111] indicates that the microspheres acquire the effect of surface metallization due to envelope of dispersed molten metal, which when cooled on a steel substrate is cooled to form microvolumes with spherical inclusions.

The number of microspheres on the surface can be seen with the help of photographs of microstructures taken with the JSM-7610F scanning electron microscope. Since aluminosilicate hollow microspheres are not conductive, they are lighter in structure (figure 2, b, d).

No new chemical compounds are formed on the interface between the steel matrix and the microspheres, which shows the absence of interfacial interaction processes during electric arc spraying, which is also confirmed by the results of micro-X-ray spectral analysis. In figure 4, as an example, shows a spectrogram from the surface of the microsphere in the coating based on ER346 (C8-08).

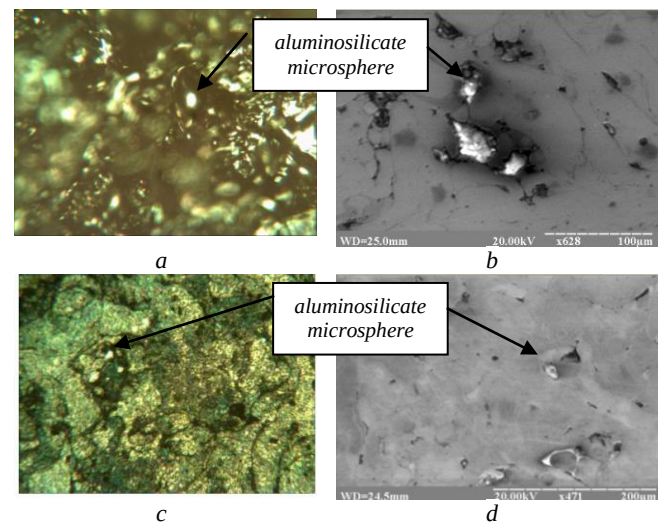


Fig. 3. Optical micrographs of coatings filled with APHM:
a – transverse section ($\times 150$) of the composition of ER346 (C8-08);
b – transverse section ($\times 628$) of the composition of ER346 (C8-08);
c – surface topography ($\times 150$) of the composition with 1066 (65I);
d – surface topography ($\times 471$) of the composition with 1066 (65I)

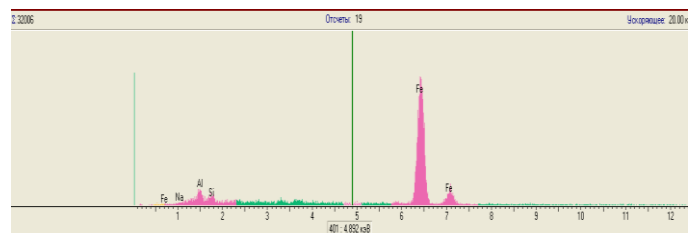


Fig. 4. Spectrogram of aluminosilicate microsphere

The results of research were compared to the features of the structure of electric arc coatings filled with glass microspheres and powders [10]. It was determined that the structure of the experimental coatings, in contrast to metal-glass compositions, is not associated with liquation processes in ASHM: short-term exposure to the arc jet in the walls of microspheres does not form glass phase, which will strengthen adhesive and cohesive bonds.

The effect of filling electric arc coatings with ash microspheres was determined by the results of hardness measurements HV_5 (Table 2), the measurement error did not exceed $\pm 10\%$.

Table 2: Results of X-ray diffraction analysis of ASHM

Material	Coating without filler	Coating with ASPM (volume 18%)	Hardness gain, %
ER346 (CB-08)	2.10	2.56	21.9
1066 (65Г)	2.50	2.70	7.4

Comparison of the results with coatings without filler showed an increase in hardness by 7... 22%, which can be explained by the formation of microstresses around the spherical inclusion in the hardening structure of the steel matrix, which arise due to differences in linear expansion coefficients.

Prospects for further work are related to the study of their physical and mechanical properties.

The use of ash microspheres in the technologies of functional coatings will have a significant economic and social effect, while associated with the creation of new compositions using cheap material resources and identifying ways to dispose of waste thermal power plants. The obtained coatings can be used in the chemical industry, energy, shipbuilding and mechanical engineering.

The research results reveal the regularities of structure formation of ER346 (CB-08) and 1066 (65Г) coatings with the addition of aluminosilicate ash microspheres deposited on steel substrate with A284Gr.D (Cr3) by electric arc method, which is aimed at solving the current scientific and technical problem of developing new coatings for industrial waste power plants. The use of ash slag in new technologies is a promising practical area, the implementation of which will help in the search for scarce minerals.

4. Conclusions

1. The possibility of adding to the composition of electric arc coatings with ER346 (CB-08) and 1066 (65Г) ash microspheres of aluminosilicate composition in a volume of 10...25% has been experimentally proved.

2. Regularities of formation of structure of composite coatings on steel substrate with A284Gr.D (Cr3) are determined: when spraying microspheres, they are enveloped by dispersed droplets of molten metal, but will retain spherical shape, microcrystalline structure, phase and chemical composition; no new phases are formed on the interface between the wall and the steel matrix.

3. The efficiency of ash microspheres for the formation of coatings is determined by increased by 7... 22% Vickers hardness, as well as by economic and social values.

5. References

1. V. O. Demchenko, O. I. Simyachko, V. A. Sviderskyi, *Technolohychnyi audit i rezervy vyrobnytstva*. **6**. 28-34. (2017). (In Ukrainian).
2. N. V. Merezko, V. M. Shkola, *Tovaroznachnyi visnyk*. **12**. 212-220. (2019). (In Ukrainian).

3. V. O. Demchenko, *Visnyk Lvivskoho torhivno-ekonomichnoho universytetu (LTEU). Tehnichny nauky*. **17**. 38-41. (2016). (In Ukrainian).
4. R. M. do Nascimento, A. E. Martinelli, A. J. A. Buschinelli, *Cerâmica*. **49**. 178-198 (2003).
5. Yu. V. Naidich, V. S. Zhuravlev, I. I. Gab, B. D. Kostyuk, V. P. Krasovskii, A. A. Adamovskyy, N. Yu. Taranets, *Journal of the European Ceramic Society*. **28(4)**. 717-728. (2008).
6. G. A. Bagliuk, V. Ya. Kurovskiy, O. Kostenko, *Machines. Technologies. Materials*. **Year X**, Issue 12. 52-57. (2016).
7. Z. An, J. Zhang, *Materials Letters*. **85**. 95-97. (2012).
8. Yu. O. Kazymyrenko, N. Yu. Lebedeva, *East European Scientific Journal Wschodnioeuropejskie Czasopismo Naukowe*. **5 (33)**, vol. **1**. 41-49. (2018).
9. O. Syzonenko, O. Dubovyi, T. Makrukha, A. Karpechenko, M. Bobrov, A. Torpakov, *Machines. Technologies. Materials*. **2**. 240-243. (2021).
10. O. V. Savvova, S. M. Logvinkov, O. V. Babich, A. R. Zdoryk, *Voprosy khimii i khimicheskoi tekhnologii*. **3**. 96-104. (2018). (In Ukrainian).

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Desktop Information System for Employee Management

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Abstract: The report presents a developed Desktop Information System for Employee Management. The system includes database development and encryption using a special algorithm to create an encryption key. The main goal of the development is to provide two types of protection: at the entrance to the system and in the transmission and data storage. The system includes four access levels: Employees, Executives or Managers, Directors and Administrators.

The information system includes the following functionalities, depending on the access levels: entering tasks, registering users, entering priorities for tasks, entering the status of tasks, reviewing entered tasks, editing tasks and their status, deleting tasks, reviewing, add, edit and delete all users in the system; and others.

Keywords: INFORMATION SYSTEM, EMPLOYEE MANAGEMENT, PASSWORD PROTECTION, SQL INJECTIONS, ENCRYPTION ALGORITHM, TASKS, SECURE COMMUNICATION.

1. Introduction

There are a lot of software products that offer services related to personnel management. A research has been done on what some of the better-known software have to offer and based on a research a comparative feature has been made with the current development.

"BambooHR" is a well-designed software solution that helps automate operational tasks. This software collects valuable employee information and provides it to the team so they can streamline processes and be more efficient. Millions of users use "BambooHR" worldwide. It has the following functionalities:

- Centralized employee database;
- Management of job applications;
- Data management, export, reporting, visualization;
- Performance management module;
- Integrations of third party products;
- Information security;
- Online signature;
- Monitoring of working hours.

Advantages:

- Good reporting;
- Good user support;
- Integrated possibility to use the services of third parties.

Disadvantages:

- Difficult to use;
- Not suitable for a large organization with more than 1000 people.

BambooHR strives to assist the workflow as much as possible by extracting reports and reports [1]. The application monitors the time the employee has worked and offers secure storage of the data in the system. A big advantage of "BambooHR" is the ability to integrate third-party software. In this way, the capabilities of the product are expanded without further complicating its logic. However, the product has a limit on the number of employees a business can manage in the system. Like most such developments, there is a monthly fee that increases with each employee.

"IceHRM" is one of the simplest and most effective information systems due to its security and accessibility. Most companies prefer IceHRM because of its centralized support, which makes managing the company and its resources easy. It has a rich user interface that makes it extensible and customizable. "IceHRM" provides the following functionalities:

- Attendance management;
- Cost management;
- Payroll processing;
- Work time tracking;
- Recruitment of candidates;
- Performance review;
- Email integration;
- Information security.

Advantages:

- Convenient for recruiting;

- With its professional version, the software can be deployed locally on the users' system;

- Easy to configure and good customer support.

Disadvantages:

- Some functions are difficult to understand;
- Too many features can sometimes confuse users.
- Some features do not work in the offline version.

"IceHRM" offers a rich interface and multiple functionalities, such as employee time tracking [1]. The big advantage of this product is the automation of monthly salaries, the possibility of insurances and recruitment of candidates. "IceHRM" uses AES 256 data encryption. The software has a 45-day trial period, after which a monthly fee must be paid based on the number of employees in the company. 3D CAD data of a part are imported into the procedural software of the printer EOSINT M 270. Software designed to the data preparation allows choosing the appropriate thickness of production layers with regard to accuracy / resolution and speed of production (0.020 mm or 0.040 mm – thinner layer means higher accuracy, but longer production time) [2].

2. Design of Desktop Employee Management System

The phase of desktop information system development includes: 1) creating a database and 2) design of an encryption algorithm using a special algorithm for creating a key. The main goal of the development is to ensure protection, both at the entrance to the system and in the transfer and storage of data.

The designed information system uses database with 4 tables: TASK_PRIORITIES, TASK_STATES, EMPLOYEES, TASKS_ARCHIVE (Fig. 1).

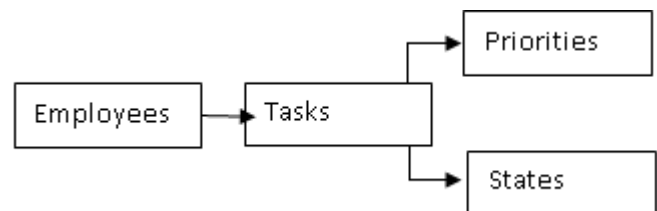


Fig. 1 Table Relations

The system must include the following safeguards:

- Control of access to the system by filling in the personal identification number and password, individual for each employee;
- Control over the number of failed login attempts.
- Ensuring the possibility of secure communication between the application and the server;
- Ensuring protection of input data through irreversible encryption of the password with a specially created system key and measures against SQL injections.

The system must include the following levels of access:

- Employees;
- Executives or managers;
- Directors.

The information system should include information on:

- Introduced tasks;
- Registered users;
- Entered task priorities;
- Entered task states.

Employees must have access to the following functionalities:

- View the data entered for them in the system.

Managers must have access to the following functionalities:

- View the data entered for them in the system;
- View the tasks assigned to them and edit only their status.

Directors must have access to the following functionalities:

- View the data entered for them in the system;
- View, add, edit and delete all tasks;
- Review of all registered users in the system.

Administrators must have access to the following functionality:

- View the data entered for them in the system;
- View, add, edit and delete all tasks;
- View, add, edit and delete all users in the system;
- Setting task status types and task priority types.

Four different levels of access are available in the system (Fig.

- 2):
- employees;
 - supervisors or managers;
 - directors;
 - administrators.

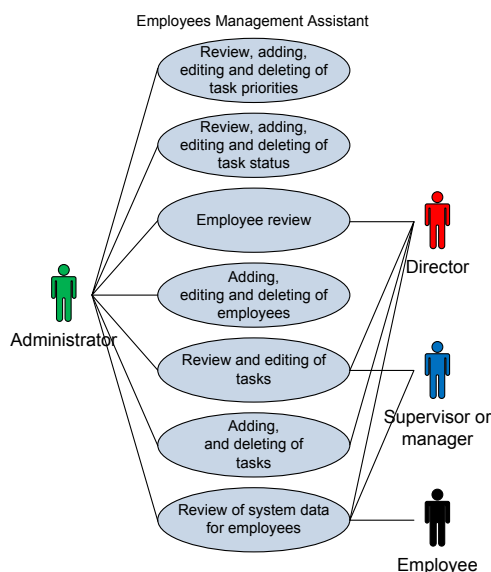


Fig. 2 Use Case Diagram of System

3. Protection types. Encryption algorithm

The current development ensures data protection through the following methods:

- Control of access to the system, by entering the personal identification number and password;
- Control of entered data to protect against SQL injections;
- Password length control;
- Encryption of the access password;
- Ability to maintain an encrypted connection between the application and the server;
- Control of the number of attempts to enter the system;
- Blocking of the account in case of three incorrectly entered passwords.

The access control to the system is achieved with the following steps:

1. When entering the employee's personal identification number and password, it is checked whether the personal identification number is only numbers and 10 characters long, and whether the password is more than 8 characters.

2. If the validation from step 1 is successful, the system opens a connection to the database. It searches for an entry in the table for employees by the entered social security number. If it finds such a record, it reads it and loads it into the system memory.

3. If the record is successfully read, the status is checked to see if it is active.

4. If the status is active, the entered password is encrypted using the same algorithm and key that were used to encrypt the password stored in the database.

5. If the encryption is successful, the two encrypted strings are compared: the entered password and the one loaded into memory from step 2.

6. If there is a match, the employee enters the system. The counter for failed login attempts is reset. Its database ID and privilege level data remain loaded in memory until the application is closed.

In order to provide protection against Traffic Interception attacks, an encryption method has been developed with a key created uniquely for the system [3],[4]. Password encryption is achieved using PBKDF2 (Password-Based Key Derivation Function 2) with 10,000 iterations (Fig. 3) as recommended by NIST (National Institute of Standards and Technology) in their publication "SP800-63B-3" from 02/03/2020. A system-unique key is added to the encryption algorithm for the uniqueness of each user's encrypted password. This also adds an extra layer to security. It is 128 bits or 16 bytes long, and the recommended size from the latest NIST publication is 32 bits or 4 bytes. Entered passwords must be 8 characters long as recommended by NIST. Password encryption is an irreversible process achieved through HMAC (Keyed Hash Message Authentication Code) and the SHA-512 (Secure Hash Algorithm 2) algorithm, using 64-bit words, as opposed to SHA-256, which uses 32-bit.

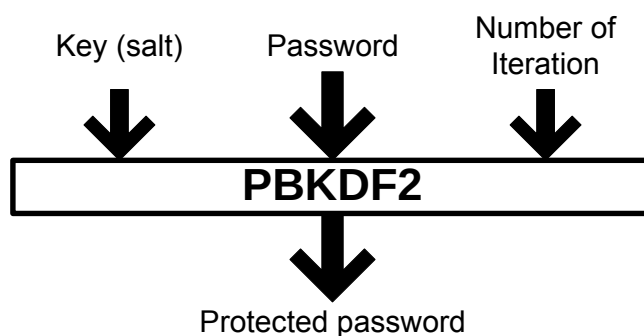


Fig. 3 A method to store the password in the system

The unique key is generated when a new user is registered in the system. It is formed from the current date and time of registration in seconds and the last three digits of the EGN in reverse order. The date is a fractional number and the whole part is divided by the fractional part. The three parts: the whole number of the date and time, the fractional number of the date and time and the three digits of the TIN in reverse order, are combined into one common string, separated by a dash, in the order of enumeration. For an example of creating a key, let's assume that the current date is 17.07.2021 and the last 3 digits of the personal identification number are 123. The date in seconds will be 44394,473993. The generated key will have the form: "44394-473993-321". This key is

recorded in the database as a "unique identification key" to the respective user.

4. System Architecture

The current development is based on the Document-View architecture. The document stores the data, manages its printing, and coordinates the updating of multiple data views. The view displays the data and manages the employee's interaction with it, including selecting, adding, editing, and deleting.

In this model (Fig. 4), the document reads and writes data to persistent storage. A document may also provide an interface to data such as that in a database. A separate view object controls the display of data. It can be from displaying the data in a window for user selection to view, add, edit and delete data. The view receives data from the document and reports to the document any changes to the data.

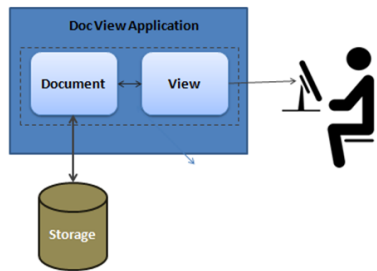


Fig. 4 The Architecture document View.

The architecture are the following base classes:

- CDocument – a class for supporting objects used to store or control program data and provides the basic functionality of documents defined by the programmer.

- CView – provides the basic functionality of views. A view is attached to a document and acts as an intermediary between the document and the user. The view renders the document data on the screen and interprets user input as operations on the document. The current development uses the CListView class, a descendant of CCtrlView, which in turn is a descendant of CView, to visualize the data. CListView simplifies the use of the list control and CListCtrl, the class that encapsulates the list control functionality, with the MFC document view architecture.

- CDialog – this class is used to work with a dialog.

- CFrameWnd – supports objects that provide the frame around one or more document views. In current development, it is inherited from CMDIFrameWnd, which in turn is inherited from CMDIFrameWndEx. CFrameWnd's successors build on its base functionality.

- CDocTemplate – maintains an object that coordinates one or more existing documents of a given type and manages the creation of the correct document window, view, and frame objects for that type. It can be either CSingleDocTemplate or CMultiDocTemplate, depending on whether the system uses one or several different documents for different data.

In current development, "Smart" classes have been developed, inheriting from the base classes and upgrading them according to the needs of the application. Additional classes added:

- CSmartTable to work with the data (read, add, edit and delete) directly from a specific table in the database.

- CSmartDataAccessor takes care of the conditions under which it is read, written, deleted, takes care if changes are required on the other tables, except the one on which it is the main one for the class.

4. Conclusion

The current development offers an information system with access control and different levels of access for each profile. It provides information security against some of the better-known cyber-attack methods. The software allows visualization of reports on registered employees and their tasks. A mechanism has been developed to add different priorities and states to tasks, which allows freedom to customize the system according to the needs of the owner and. Despite the available functionalities, the system can be improved with the following developments:

- Encrypt server access profile password from ServerConfig.ini via AES 256.

- Protect against "Password Spraying" attacks by adding a mechanism to change the password in a certain period.

3. References

1. K. E. Pearlson, C. Saunders, D. F. Galletta, *Managing and Using Information Systems: A Strategic Approach*, 7th Edition, Wiley, ISBN: 978-1-119-56115-6, (2019)
2. K. Sousa, Effy Oz, *Management Information Systems*, Seventh Edition, Cengage Learning EMEA, ISBN: 9781305172180, (2014)
3. R. Maier, *Knowledge Management Systems, Information and Communication Technologies for Knowledge Management*, Springer, ISBN: 978-3-540-71408-8, (2007)
4. R. Stair, G. Reynolds, *Principles of Information Systems 13th Edition*, Cengage Learning, ISBN: 978-1305971776, (2017)

Digital art. Implementation features with the help of software and communication technologies

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Abstract: *Modern communication and digital technologies allow us to talk about digital art as a separate concept with a complex structure. Communication technologies combine the individual components of digital art into a single whole. Modern digital technologies contribute to the implementation of creative ideas, promotion and implementation of projects in the field of art. The technologies used in this area have their own characteristics.*

KEYWORDS: DIGITAL ART, COMMUNICATION TECHNOLOGIES, COMPUTER PROGRAMS, AUDIO AND VIDEO PROCESSING PROGRAMS.

Introduction. Prerequisites

Currently, digital technologies are used in various areas of human activity, for example, in advertising, in the implementation of legal frameworks, the provision of legal information, the creation of legal documents, in managerial and economic activities, in education, and so on. Modern art uses technology to create artistic images, to create electronic music. Digital formats immerse viewers in virtual reality. The computer writer has an almost instant connection with the reader. This, as well as the development of modern communication technologies and the features of the current political and epidemiological situation in the world, allow us to talk about digital art as a separate direction.

Basic provisions

Digital art can be characterized as a direction for the implementation of activities in the field of art, based on the use of modern computer and telecommunication technologies in order to create both independent works of art in various forms, and individual components of a composite work, as well as for the targeted exchange of information both between specialists and between professionals and end users of services to ensure the accessibility and quality of art projects. By specialists we mean persons involved in the creation and implementation of projects in the field of art. These include authors, directors, actors, artists, producers, administrators, accountants, cashiers, and so on.

The system-forming principle of digital art is based on the fact that one of the target points of the system should be the end user, that is, the viewer. Other components are digital media (telecommunications, computer programs) and professionals involved in the creation and implementation of art projects of various forms. The main components of digital art include works realized with the help of digital technologies (video clips, digital music, etc.), "digital" blocks of complex works (media stage design, on-line museum tour, etc.), digital advertising, virtual platforms for on-line ticket sales, on-line training, management and planning software, economic activity software, accounting and tax accounting software, legal activity software. Activities are carried out with the help of digital software and modern communication technologies. Modern digital software offers a set of convenient tools for producing new non-trivial information in an efficient and attractive way.

Communication technologies are an important link between individual blocks and links of this system, which allows you to interact remotely. They allow us to talk about digital art as a separate concept. [1]

Digital technologies offer optimal solutions for collecting statistical information, remote monitoring of the primary preferences of the audience, that is, end consumers, taking into account the characteristics of groups, such as gender, age, social and geographical location, determining the most significant indicators

of end consumer preferences, solving a number of management tasks, including digital advertising, automated accounting, economic and management accounting, for the operational analysis of legal norms and the creation of up-to-date legal documents. The latter is the most relevant in the current situation of a rapid change in the legal framework, the introduction of a number of legal acts, some of which also relate to issues of international law. Modern digital technologies allow you to quickly get acquainted not only with domestic legal acts, but also with the legal acts of other states, if necessary, turning to the help of computer auto-translators, which is especially important when implementing, for example, licensed projects, the copyright holders of which are located in other countries.

Another trend is digital learning. Conducting lectures, video seminars, conferences using telecommunication equipment enables the teacher to have interactive contact with the audience. Digital learning technologies provide a real opportunity for a specialist to improve their professional level without leaving their place of work.

Modern communication technologies provide both quick access to the necessary digital resources and the interaction between various participants in objects of such a complex structure as digital art.

Tools for the implementation of digital art have their own characteristics. First of all, this is due to the creation and transmission without distortion of graphic, sound and video information. Since it is sound, color and light that have the greatest emotional impact on the audience, on end consumers.

Let's dwell on this in more detail. At present, for example, the concept of "CG artist" has become familiar and understandable, that is, a computer graphics artist is a specialist who creates digital images and various videos using computer technology. The works of a CG artist are indispensable in rendering films, developing video games, computer setting up lights and scenes, texturing objects, as well as in composing scenes, realizing the digital combination of captured frames with programmed objects, that is, when implementing the so-called VFX effects. When creating modern projects, the synchronization of light-sound-video with the help of digital technologies becomes significant; digital computer programs for working with sound, video, and light are used.

Currently, there are a number of sound programs aimed at specialists in the relevant field. The creation of computer sound processing programs can be carried out in various programming languages, for example, in the widely used C++, in Linux, as well as in specially designed environments. Sound programming is based on sound coding, that is, the creation of a digital signal as a result of the transformation of air vibrations, which is essentially the sound propagated in the form of elastic waves, into an electrical signal, air vibrations are converted into electric current vibrations of a particular frequency and amplitude. Of course, when digitizing sound, you cannot get an absolutely smooth line, we are dealing with one or another degree of sampling. When implemented on computer devices, the value of the amplitude of the analog signal is read by a digital converter at specified time

intervals; when reading, numerical coding is carried out, fixed in bytes, and it is recorded. The device that sets the recording and playback levels is called a mixer. Most sound cards are equipped with mixers. As a rule, the following generalized algorithm is at the heart of writing the code for sound digitization programs. The mixer is opened, microphone recording support is checked, microphone is set as the recording source (in the absence of a microphone, data can be recorded from an audio CD), the current recording level value is read, if necessary, increasing it, ... Currently, there are a large number of commercial and free audio editors. With their help, you can perform both basic functions (recording, editing audio files, "pulling" an audio track from a video, copying, adjusting the volume, trimming), as well as "advanced" processing, such as noise reduction, changing the tone, setting a frequency filter and spectrum, echo, audio effects and so on. For example, Sound Forge, Adobe Audition, Audacity, WaveLab, AudioMaster and others. The creators of electronic music (DJs) prefer, for example, such programs as Traktor Pro or Ableton. The German professional software Traktor Pro supports the iTunes library, and also allows you to use your own collection of sound files, music, which is done by specifying in the settings with the indication. The program analyzes tracks (audio tracks, possibly with text accompaniment) by tone, tempo, and other parameters, and makes it possible to build a rhythmic grid. The program provides the ability to create mixes, that is, play multiple files (MP3, WAV, AIFF, Audio CD) at the same time. Traktor Pro is equipped with a user-friendly and intuitive control panel. Ableton software, compared to Traktor, does not have such a convenient control panel, transport part, but a wider range of actions with plug-in effects and audio routing. Also, the creators of electronic music actively use such types of software as Serato, Rekordbox DJ, Virtual DJ.

When implementing digital art, one cannot underestimate such a software block as computer video processing, which allows not only to produce digital video recording, but also to edit files, perform color and tone correction of the image, create and overlay titles, use special effects, synchronize sound with the image and so on. This is a promising direction, currently there is a set of software of the corresponding direction. As an example, let's take such commonly used digital computer video processing programs as Adobe Premiere Pro and Adobe After Effects. Adobe Premiere Pro is designed for direct editing, gluing and applying special effects to video. Whether you're editing a social media video or shooting a movie, this program provides you with convenient intelligent tools. Many parameters of color correction, contrast, etc. allow you to achieve the required video quality.

Import and export of all projects in Adobe Premiere Pro is carried out in any format, which is important when fast or detailed and colorful video processing is required. Also, one of the advantages of Adobe Premiere Pro is full integration with other applications and services, including Adobe Photoshop, After Effects and Frame.io due to the fact that all Adobe applications are bundled into one Creative Cloud collection. Adobe Premiere Pro has the functionality of converting speech to text and automating the creation of subtitles, as well as a quick search for materials, which greatly speeds up the editing process. It should be noted that this program has support for the Russian language in its interface, which gives it an advantage over other programs whose main interface language, as a rule, is English. If we talk about the possibility of supporting audio files, then Adobe Premiere Pro provides convenient functions for working with them, as well as their simplest processing. The disadvantages of Adobe Premiere Pro include the demands on computer resources and some relative instability when working with large projects.

Adobe After Effects software is often compared to Adobe Premiere Pro due to their similar functionality, but Adobe After Effects provides deeper functionality for creating and applying effects to video. Here you can add both ready-made basic effects, and create your own, as well as download various plug-ins (compiled software modules that are dynamically connected to the base program in order to expand its capabilities) from the Internet to expand the

library of effects. This program can easily deal with dozens of 3D models, which can also apply effects, thanks to the use of a 3D design environment. It is worth noting that the latest versions of After Effects have significantly improved rendering algorithms, which has a very positive effect on speed. However, this software has a number of disadvantages. Firstly, this program is unstable, as it uses an excessively large amount of RAM resources. Another drawback of Adobe After Effects is incompatibility with some operating systems, such as Linux. Adobe Premiere Pro and Adobe After Effects are aimed at professionals who already have experience with editing, creating effects and other actions with video, and not at ordinary amateur users, so mastering them can cause some difficulties.[2]

We quickly appreciated the possibilities of digital achievements not only in the film and television industry, but also in show business. Partly because show business is a large and actively developing sector of the economy, capable of generating large incomes. That is, in this area there are both needs and means for the effective use of modern digital technologies. An additional incentive is a serious competition in show business. Here, as in no other area of art projects, the object of art acts as a commodity, and the viewer as a consumer.

The technologies under consideration are also an effective tool for creating stage projects that are not usually classified as show business, at their various stages - from an idea, a sketch, a layout to the creation of scenery. As we have already shown, one should not underestimate the opportunities that digital technologies provide us with for the successful organization of space - one of the important components of the success of staging projects. Modern technologies can significantly expand the range of means to achieve the artistic expression of the performance. About digital control of light and sound, as well as computer artists, it was mentioned above. Currently, there is a set of computer programs for creating visual sketches in "projection" scenography. Scenographers use various technical, interactive means of expression when creating scenery, which often makes the scenery an independent work of art. When implementing the projects under consideration, modern projection devices, sound systems, video images, and so on can be used.

As already mentioned, talking about digital art as a kind of a single integral concept provides an opportunity for digital communication technologies that ensure the integrity of the interaction of individual components, uniting them into a single system. Communication technologies is a dynamically developing area with active development of digital communication channels and programming methods used. As we have shown, digital audio and video information, as well as its correct transmission over communication channels, is essential in digital art. The difficulty of transmitting such information over communication channels lies in the fact that delays in the transmission of packets, in case of exceeding the maximum set size into which the transmitted information is divided, can lead to distortion of it in the final communication nodes. That is, audio and video digital information is very sensitive to delays in the transmission of initial data packets. To solve this problem, in particular, corresponding sets of data exchange rules are developed, which are programmatically implemented in the form of protocols at various levels. There is a MOSPF (Multicast Open Shortest Path First Protocol), a Sparse-mode PIM protocol that defines the shortest routes between the media server and workstations. With the help of RTCP (Real Time Transport Control Protocol), specialists apply methods to compensate for distortions in case of shortcomings in the real-time quality of the functioning of multimedia applications. Resource Reservation Protocol - Resource Reservation Protocol makes it possible to optimize bandwidth and resort to other resources. In order to transfer the required information to network routers between clients that are members of multicast groups, the IGMP group management protocol is used.

It should be noted that in modern conditions for the implementation of communication channels, virtual private networks (VPNs) are of particular importance, some abstractions that work on the basis of

routing through a virtual server that transmit traffic from a given workstation through a virtual (third-party) server. In other words, a VPN is an abstract network implemented on top of another network. Through the use of encryption methods, information exchange channels are created that are closed from outsiders. VPN provides data protection, protection from hackers and malware. As we understand, security and, in some cases, ensuring data confidentiality is an important factor both for the application developer and for other participants in the creation, implementation and consumption of art projects implemented through digital communication channels. Through tunneling technology, packets of transmitted messages are transmitted over a public network as if over a traditional point-to-point connection, while a secure logical connection, the so-called tunnel, is established between the sender and the recipient, making it possible to encapsulate the data of one protocol in another protocol. The components of a tunnel include an initiator, a routed network, a tunnel switch, and a tunnel terminator. Tunneling, encryption, and authentication are at the heart of VPN development. Tunneling hides the source and destination of the rendered data from the network infrastructure that lies in between. Problems that may arise when trying to intercept data are solved by methods of cryptographic information protection. There is currently a set of VPNs such as NordVPN, ExpressVPN, CyberGhost, Turbo VPN, Free VPN, Windscribe, and more. [2] In principle, a programmer can write a VPN for himself, for example, in Ubuntu, by choosing connection protocols, one of them is IPsec IKEv2 and OpenVPN, specifying the server

part used, programmatically creating access certificates, providing configuration of network parameters using code, including forwarding packages.

Conclusions

Modern communication technologies make it possible to securely unite networks, nodes and users, to correctly transmit information of various types. This direction continues to develop actively, quickly responding to changes taking place in the real world. Digital communication technologies, modern computer software of various types make it possible to implement a holistic approach to such a non-trivial concept as digital art, with a prompt response to changes that arise in the world around us.

Literature

1. Соловьева О.М. Цифровое искусство и современные коммуникационные технологии. Умная цифровая экономика. 2022. Т.2, №1, с. 12-17.
2. Соловьева О.М., Иванов В.А. Некоторые особенности реализации цифрового искусства. Современные технологии. Умная цифровая экономика. 2022. Т.2, №2, с. 6-12

Hybrid technologies for joining dissimilar materials

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Abstract: This paper presents an overview of hybrid technologies for joining dissimilar materials in automotive applications. CMT welding/brazing technology has been experimentally verified for the purpose of joining dissimilar steels or steels and aluminium alloy. Two types of filler material were used, one based on Cu and the other based on Al. When joining dissimilar steels, a true brazed joint was formed, while when joining steels and aluminium, a hybrid - welded/brazed joint was formed. Subsequently, metallographic analysis of the joints and testing of their load carrying capacity was carried out.

Keywords: JOINING, DISSIMILAR MATERIALS, CMT WELDING, HYBRID JOINT, METALLOGRAPHY, LOAD-BEARING CAPACITY

1. Introduction

The combination of dissimilar materials within a specific structural subgroup in the automotive industry is a consequence of the desire to save material resources, to create tailored structures with locally reinforced parts, to create zones with increased absorption of deformation work, to reduce the weight of the final product by saving material by locally reducing the thickness, etc. Combining materials in a "tailored" way also requires mastering their joining together in a way that does not interfere with the continuity of force transfer and meets the requirements for joint safety. For joining thin-walled materials in automotive applications, welding (spot resistance, laser, CMT MIG, FSW) or mechanical joining (clenching, flowdrill, riveting and their many variations with or without a fastener) are most commonly used. The problem with fusion welding of dissimilar materials is their different melting temperatures and different chemical compositions, which affect their weldability to each other. Some material combinations have low or no solubility of major elements, which makes it impossible to form a joint. Some material combinations form brittle intermetallic phases in the fusion zone which crack at low joint loads. These problems can be solved by using interlayers which mitigate the differences in the chemical composition of the materials to be joined and are at least partially soluble in both, or by modifying the technological parameters of the welding process, in particular by ensuring low heat input (e.g. CMT welding, laser welding, etc.), which limits the formation of IMCs [1-6].

Mechanical joining of dissimilar materials, in turn, encounters problems with different formability of the materials being joined and different physical properties, which negatively affect the strength of the joints. Welded and mechanically formed joints can also be combined with adhesive bonding, which increases the load carrying capacity of the joint, spreads the stresses in the joint over a larger area, increases the seal and corrosion resistance of the joint, reduces the risk of crevice corrosion, and reduces the ability to absorb energy under load on the joint.

The aim of the experimental work presented in this paper was to validate the CMT welding technology for the formation of joints of dissimilar materials based on steels and aluminium alloy.

2. Materials and Methods

The following materials were used to create the joints:

TL 1550-220+Z - structural high-strength HSLA steel with fine microstructure and enhanced cold formability. It is hot-dip galvanized with a Zn layer thickness of 100g/m². Hereinafter TL.

DC04 - unalloyed, uncoated, deep-drawn cold-rolled steel for cold forming of the most complex profiles with high deformation capability. Weldable by various technologies. Hereinafter DC.

EN AW-6082 T6 (AlSi1MgMn) - precipitation-hardened Al alloy, well weldable by all common aluminium welding technologies (especially MIG and TIG). Hereinafter Al.

The chemical composition and mechanical properties of the materials are given in Tab. 1 and 2.

Table 1: Chemical composition of the materials used, wt. %

steel	C	Mn	Si	P	S	Al	Ti	Nb	Fe
DC	0.04	0.25	-	0.009	0.008	-	-	-	Bal.
TL	0.10	1.00	0.50	0.08	0.03	0.015	0.15	0.1	Bal.
Al alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al	1.0	0.4	0.06	0.44	0.7	0.02	0.08	0.03	Bal.

Table 2: Mechanical properties of the materials used

Material	Re Min (MPa)	Re Max (MPa)	Rm Min (MPa)	Rm Max (MPa)	A80 Min (%)	Zn (g/m ²)
DC		210	270	350	38	-
TL	220	310	320	420	28	100
Al	289	298	339	346	14	-

The materials were cut into 100×200 mm plates overlapped by the longer side with an overlap size of 12 mm and joined by CMT welding/soldering. Subsequently, the welded plates were waterjet cut into test specimens, Fig. 1.

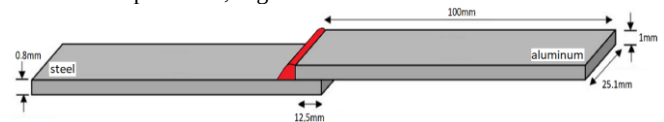


Fig. 1 Dimensions of test specimens

Two brazed filler metals were used for joining: for steels - CuSi3 and for combinations with Al alloy - AlMg5. Welding equipment used: Fronius VR 7000 CMT, welding parameters: welding speed 7.5 m/min, wire feed speed 4 m/min, current 82 A, voltage 17 V. The material combinations created, the solder used and the successful connections made are summarised in Tab. 3.

Table 3: Positions of materials in the joint, solder used (bright grey - CuSi3, dark grey - AlMg5) and successfully formed joints (OK – successful joint, NOK – failed joint)

Position	Upper sheet			
	material	DC	TL	Al
Lower sheet	DC	OK	OK	NOK
	TL	OK	OK	OK
	Al	NOK	OK	OK

The joints were tested in tension at a speed of 10 mm/min with continuous force and displacement recording on a universal tensile test machine TIRATEST 2300. The maximum force at failure of the joint was recorded and the location of the failure was monitored. The metallurgical interface was assessed on transverse metallographic sections.

3. Results

The appearance of the surface of the formed joints is shown in Fig. 2.

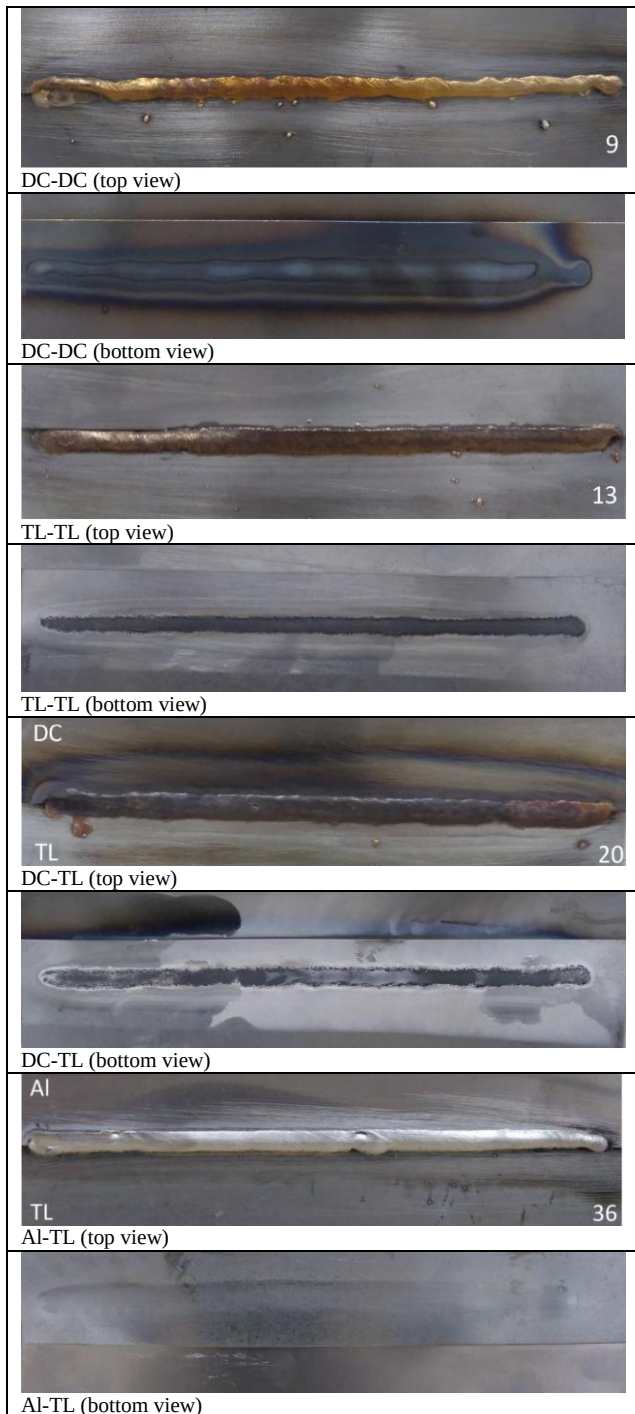


Fig. 2 Appearance of the joints

From Fig. 2, a pattern of weld beads can be seen, with a slight spatter on the top plate. If galvanized steel is in the bottom position, when CuSi3 solder (with a melting temperature of 980°C) is used, evaporation of the Zn layer is visible, indicating a weakening of the corrosion resistance of the joint. In the case of AlMg5 solder, which has a lower melting temperature (575-633°C), no damage of protective Zn layer on the TL sheet in the hybrid joint occurred.

The metallographic sections of the formed joints are summarized in Fig. 3. In the metallographic sections, it is necessary to note the wettability of the surfaces by the solder, i.e. the angle between the surface of the sheet and the solder. A wetting angle <15° indicates perfect wetting, good surface wettability is up to an angle of 75°.

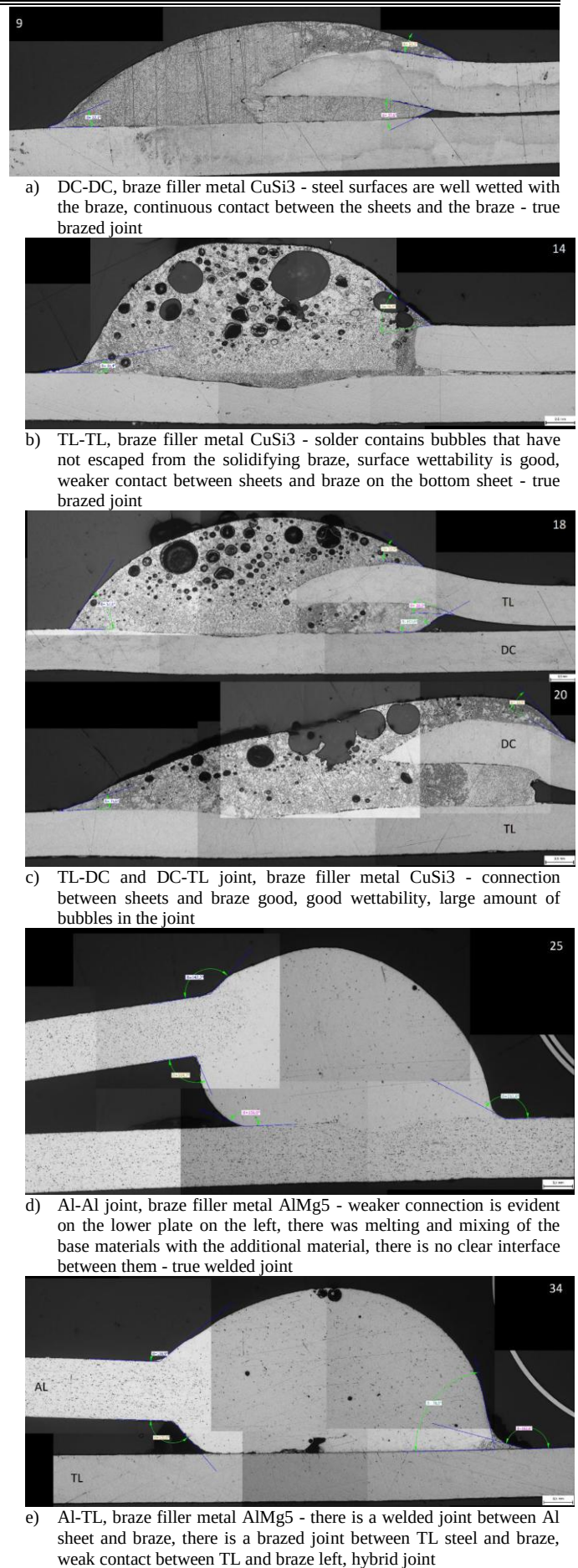


Fig. 3 Metallographic cross-sections of joints

Fig. 3 shows that the braze filler metal must be selected with respect to the melting temperature of the materials to be joined, and the melting temperature of the braze filler metal must not exceed the melting temperature of the base material with the lower melting point. Thus, in CMT welding/brazing of dissimilar materials, a weld-brazed hybrid joint is formed. The load capacity of the formed joints is shown in Fig. 4.

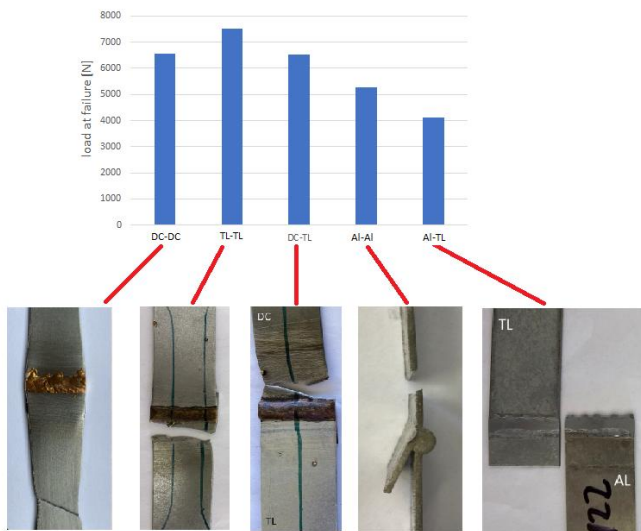


Fig. 4 Load-carrying capacity of joints and indication of the place and mode of their failure

The highest load carrying capacity are steel-steel solder joints, either similar or dissimilar, using CuSi3 braze. Failure occurred either well outside the joint or in the heat-affected zone near the joint. Aluminum-steel and aluminum-aluminum joints with AlMg5 braze exhibited lower load carrying capacity. The Al-Al welded joint failed in the HAZ, and in the hybrid welded-brazed joint Al-TL, the brazed joint - i.e. the joint between the braze and the TL steel - failed.

4. Conclusion

The paper presents the original research results of experimental work on joining dissimilar materials by CMT technology. For joining steels, a braze filler metal based on Cu-CuSi3 alloy, which has a lower melting temperature than the materials to be joined, is suitable. The braze has good wetting properties for both galvanized and non-galvanized steel materials. However, care must be taken to optimise the brazing process to eliminate significant porosity in the joint. When joining dissimilar aluminium-steel alloy materials, it is recommended to select an additional material with a lower melting temperature so that the lower fusible material of the joining pair does not burn through. This results in a hybrid brazed-welded joint. For a hybrid joint, the limiting factor will always be the load carrying capacity of the brazed part of the joint.

References

1. B. Mezrag, F. Deschaux-Beaume, L. Sabatier, B. Wattrisse, M. Benachour. Microstructure and properties of steel-aluminum Cold Metal Transfer joints. [cit. 2022-04-02]. Available for the internet: <https://hal.archives-ouvertes.fr/hal-03345667/document>
2. H. Lei, Y. Li, B.E. Carlson, Z. Lin. Microstructure and Mechanical Performance of Cold Metal Transfer Spot Joints of AA6061-T6 to Galvanized DP590 Using Edge Plug Welding Mode, J. Manuf. Sci. Eng. 2016, 138(7): 071009, <https://doi.org/10.1115/1.4032082>
3. D. Saha, Y.D. Park. A Review on Al-Al/Al-Steel Resistance Spot Welding Technologies for Light Weight Vehicles. Journal of Welding and Joining 29:35-40, 2011, <https://doi.org/10.5781/KWJS.2011.29.4.397>
4. D. Varanasi, D. Koncz-Horvath, A. Sycheva, P. Baumli, G. Kaptay. Cracking of Copper Brazed Steel Joints Due to Precipitation of MnS upon Cooling. Journal of Materials Engineering and Performance 29, (2020), 8183–8193, <https://doi.org/10.1007/s11665-020-05293-9>
5. M. Peng, H. Liu, Y. Liang, W. Xu, Y. Zhao, S. Chen, J. Weng, J. Yang. CMT welding-brazing of al/steel dissimilar materials using cycle-step mode. Journal of Materials Research and Technology, 18, (2022), 1267-1280, <https://doi.org/10.1016/j.jmrt.2022.03.043>
6. S. Selvi, A. Vishvakshnan, E. Rajasekar. Cold metal transfer (CMT) technology - An overview. Defence Technology, 14:1, (2018), 28-44, <https://doi.org/10.1016/j.dt.2017.08.002>

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Influence of mechanically activated particles on the activity of polymer engineering materials and compositions based on them

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Abstract: *The article presents the results of studies on the study of the physical and mechanical characteristics of polymeric materials modified with mechanically activated particles. It is shown that the use of mechanically activated nanosized particles makes it possible to achieve a significant effect of increasing operational characteristics at relatively low degrees of modification of 0.05% wt. – 3% wt. The use of modifiers at such concentrations in polymer matrices makes it possible to preserve the basic technology for the processing of polymeric materials and equipment in the manufacture of composite materials on a polymer matrix.*

KEYWORDS: POLYMER, VISCOSITY, STRENGTH, MECHANICAL ACTIVATION, STRUCTURE.

1. Introduction

The formation of functional composite materials based on thermoplastic and thermoplastic polymers is in most cases achieved by extensive modification of matrices with powders, fibers, agglomerates, clusters, etc. varying degrees of dispersion. The use of nanocomposite materials based on polymers is a promising trend in the development of modern mechanical engineering. To modify regular and irregular high-molecular compounds, various types of low-sized particles are used: micas, metals, metal oxides, clays, graphenes, sialons, graphite, etc. The geometric parameters of individual crystals of low-sized particles are in the range of 1-5 nm. The conducted studies on the study of the activity of nanoscale objects showed high values of the specific surface area, residual charge, which indicates a high modifying ability of these objects.

The energy state of nanosized particles essentially depends on the habitus of the nanomaterial, its composition, and the formation technology. The influence of these parameters has a significant effect on the structure of the surface layers of the particles of the resulting composite material, which determines the force interaction within the volume of the composite.

The influence of the force field of nanoparticles leads to a change in the predominant orientation of the modified polymer molecules in space, which makes it possible to obtain nanophases in the bulk of the material with a higher degree of orientation compared to other phases of the composite material. The main disadvantage of these materials is the loss of activity over time. In this regard, various technological methods are proposed for the activation of low-dimensional systems or the creation of systems of nanomodifiers with a prolonged lifetime of the active state.

Thus, the establishment of the mechanism of influence and interaction of mechanically activated particles with an uncompensated charge on the structure and properties of structural thermoplastics is of both theoretical and practical interest. The creation of these modifiers will make it possible to obtain composite materials with enhanced functional characteristics. As modifiers of polymeric materials, organic and inorganic dispersed particles of various kinds and origins are widely used. One of the current trends in purposeful changes in the structure and properties of polymeric materials is the use of nanodispersed particles with a high specific surface area, which contributes to a higher activity when interacting with a polymer matrix [1-4]. Nanodispersed particles of diamond-containing compounds obtained by blasting technology with a negative oxygen balance have found the widest application in industry.

The technology for obtaining such compounds has been developed at a sufficiently high level, and the structure and properties of diamond-containing nanoparticles have been well studied [1]. The disadvantage of this class of nanomaterials is the high cost of the final product (diamond nanoparticles), which ranges from \$0.5 per carat and more. An alternative for obtaining low-dimensional active modifiers using existing technologies is the use of the mechanical activation (MA) method. Mechanical activation of organic compounds or mixtures of organic compounds and inorganic substances makes it possible to obtain composite nanosized, nanophase particles that meet the criteria of

environmental friendliness, ergonomics, resource saving, financial savings. This technology makes it possible to carry out the reactions of high-molecular compounds of an ordered structure with surface layers of inert materials.

In the course of mechanochemical activation, the destruction of polymer molecules occurs with the formation of active radical groups, which can interact with hydroxyl groups of silicates to form composite particles of various dispersed compositions, including those in the nanometer range. The structure of these particles is a layered composite, in which the radical groups of polymeric materials are chemically bonded at the molecular level to the carrier metal ions of silicate. A number of works have previously shown the interaction of polymeric materials with layered silicates, including during mechanical activation, in which it is assumed that there is a relationship between the shape (habitus) of a particle and the charge activity of the obtained nanocomposite particles. The purpose of this work was to study the physical and mechanical characteristics of polyamide modified with composite mechanically activated particles.

A widely used polymeric material in mechanical engineering, in particular in the production of automotive and tractor equipment, is polyamide.

2. Preconditions and means for resolving the problem

At present, polyamide 11 is widely used in the automotive industry. This material is used as a block product and coatings in automotive units manufactured by leading companies in the world, including. Mercedes Benz, Wabco, Comatsu, Ford, etc. Target additives are introduced into polyamide 11 (Rilsan) - antioxidants, dyes, dry lubricants, which are graphite, molybdenum disulfide, aliphatic amines. Polyamide 11, used for coating, is produced in the form of a powder with a particle size of 80-10 microns. To ensure a stable level of adhesive strength of the coating with a substrate of carbon steels, an undercoat ("primer") of Rilprim based on an epoxy resin oligomer is used. The sublayer is applied in the form of a solution by spraying or dipping on a thoroughly cleaned surface of a metal part, after which it is dried and heat treated in the temperature range of 290-340 °C for 5-20 minutes. A Rilsan coating is applied to the metal part prepared in this way from a fluidized bed, which is melted to form a layer with a thickness of 100-500 microns. After cooling, the coatings are processed to size using special tools, such as broaches.

The disadvantages of this material for domestic manufacturers are due to the fact that: the lack of large-tonnage domestic production of polyamide 11 in the Union State, which does not allow mastering the industrial production of the powder component, which is the basis for the coating; insufficient adhesion of the coating to metal products and substrates without special preparation; the need to apply a special sublayer ("primer") to the metal surface, which provides the necessary adhesive strength of the coating and substrate; complex coating technology, involving high energy costs; the need to use special methods for cleaning the environment due to the fact that during the application, heat

treatment of the sublayer (Rilprim), a large amount of environmentally harmful components in the gaseous state are released. A replacement for an imported analogue can be found by using different dispersions of polyamide 6, modified with a mechanically activated mixture of polyamide 6 - kaolinite, with a content of nanometer-sized particles of 20-50 nm. Figure 1 shows the rheological characteristics of polyamide 6 modified with mechanically activated particles.

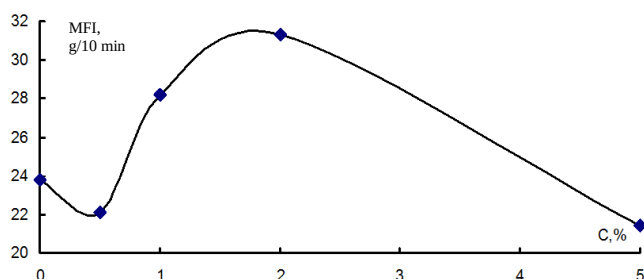


Figure 1 - Rheological characteristics of polyamide 6 modified with mechanically activated particles polyamide 6-kaolinite

The introduction of mechanically activated particles at low concentrations leads to an increase in the viscosity characteristics of the composite material. A further increase in the content of the modifier in the composition leads to a decrease in the values of the viscosity characteristics. The maximum increase in the fluidity of the modified polymer is observed at 2% wt. modifier content. Increasing the content of the modifier to 5% wt. increases the values of viscosity characteristics.

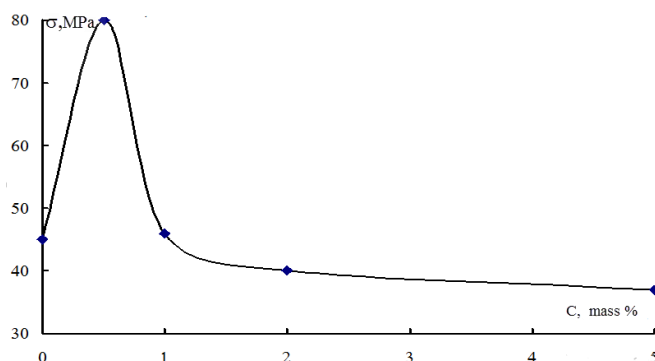


Figure 2 - Dependence of the tensile strength of polyamide 6 modified with a mixture of mechanically activated particles of polyamide 6-kaolinite on the concentration of the modifier.

The increase in viscosity with the content of the modifier at 0.5% wt. is explained by the formation of a labile network of physical bonds formed as a result of the interaction of electric charges of mechanically activated particles and dipole charges of polar polyamide 6 molecules. and plastic deformation of the surface layers of the polymer matrix both in the process of friction and in the process of mechanical destruction. Increase in the fluidity of the composite material at 2% wt. is explained by an increase in the concentration of particles in the bulk of the polymer, as a result of which these particles begin to interact with each other with the formation of agglomerates capable of breaking down at low tangential shear stresses. A further increase in the concentration of the modifier, leading to an increase in the viscosity characteristics, is explained by classical concepts associated with the modification of polyamide materials with various types of modifiers. The introduction of mechanically activated particles into the polyamide matrix leads to a change in the strength characteristics of the composite material.

In the area of modifier concentration of 0.5 wt.%, an increase in strength characteristics up to 80 MPa is observed. A further increase in the concentration of the modifier in the polymer matrix leads to a decrease in the values of the ultimate tensile strength. This is due to the interaction between charge clusters, the

formation of large agglomerates of mechanically activated particles with low cohesive strength in the bulk of the polyamide matrix, which leads to a decrease in strength characteristics.

Table 1 shows the physical and mechanical characteristics of polyamide 6 modified with a mechanically activated mixture of PA6-kaolinite.

Table 1 - Physical and mechanical characteristics of polyamide 6 modified with mechanically activated particles "PA6-kaolinite"

Options	raw material	0,5 %	2 %	5 %
Physical yield strength, MPa	30,6	49,5	28,3	16,2
Deformation at physical yield strength, %	19,85	6,9	4,2	4,9
Strength at maximum force, MPa	48,6	77,6	30,2	37,6
Deformation at maximum force, %	133,4	81,6	5,6	9,2
Breaking strength, MPa	48,6	77,6	30,2	37,6
Deformation at failure, %	133,4	81,6	5,6	9,16

The use of mechanically activated nanosized particles makes it possible to achieve a significant effect of increasing performance at relatively low degrees of modification of 0.05 wt. – 3% wt. The use of modifiers at such concentrations in polymer matrices makes it possible to preserve the basic technology for the processing of polymeric materials and equipment in the manufacture of composite materials on a polymer matrix.

The main effect explaining the increase in the physico-mechanical characteristics of polymer nanocomposites upon modification with nanosized mechanically activated particles is the formation of a spatial network of labile physical bonds of the adsorption type in the polymer layer, as well as the influence of the modifier on the kinetics of the formation of the polymer layer from the liquid phase with the formation of supramolecular and pseudocrystalline ordered structures.

The conducted studies on the study of the structure of particles obtained using mechanical activation showed that the formed particles of both organic and inorganic structures differ significantly from each other depending on the technological processing modes and on the initial semi-finished products used.

Studies on the study of the structure of mechanically activated silicate particles with polymeric materials showed that with an increase in the time and modes of mechanical activation, amorphization of the structure of the resulting composite silicate-polymeric materials occurs, and the habitus of microparticles changes. In the course of mechanoactivation, the values of parameters corresponding to an increase in the activity of the resulting composite particles increase.

The developed compositions of composite materials based on polyamide 6 belong to the field of polymer materials science and can be used in mechanical engineering for the manufacture of coated friction parts used in automotive units such as a shock absorber, driveline, brake chamber, etc.

3. References:

- 1.Khaibullin I.B. [et al.] Ion synthesis in viscous organic // Nuclear Instruments and Methods in Physics Research B. – 1997. –Vol. 127/128. – P. 665 – 690.
- 2.Grigorieva T.F. [et al.]. Solid-state interaction of kaolinite and acids during joint mechanical activation. // J. Mater. Synth. and Proc. – 1996. – Vol. 4, 5. – P. 299 – 305.
- 3.Yiu-Wing Mai, Zhong-Zhen Yu Polymer nanocomposites – Cambridge, Woodhead Publishing Limited, 2006 – 594 p.
4. Physicomechanical characteristics of composite materials modified with mechanically activated particles/ Y. Auchynnikau [et. al.] // Fundamental bases of mechanochemical technologies : The book of abstracts of the V International Conference "Fundamental bases of mechanochemical technologies". 25-28 June 2018, Novosibirsk, Russia.- Novosibirsk : IPC NSU, 2018. - P.167