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Research into the influence of test parameters on the resistance of weld deposits to abrasive wear

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ABSTRACT
The article investigates how welding speed affects the properties of hardmetal layers, with a particular focus on evaluating the abrasive wear of coatings produced by tubular wire welding technology. The layers were deposited using Fluxofil 54, a flux-cored wire supplied by ESAB. During sample fabrication, two different welding speeds were applied — 125 m/min and 18 m/min. The study then aimed to determine how abrasive wear depends on the hardness of different abrasive materials.Two types of abrasives were used in the experiments: silicon dioxide (SiO_2, silica) and aluminum oxide (Al_2O_3, alumina or corundum). Abrasive wear resistance was assessed by measuring the mass loss of the specimens before testing and after sliding distances of 420 m and 716 m. Sample preparation followed the ASTM G65-16 standard. Surface degradation after wear testing was analyzed using a Neophot 21 optical metallographic microscope. The substrate material used was S355J0 (designation 11 523), a structural non-alloy steel characterized by specified mechanical properties and controlled contents of carbon, sulfur, and phosphorus.

KEYWORDS; Abrasive wear, weld, resistance

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I. INTRODUCTION

The service life of mechanical systems in operation is influenced by numerous factors, including design, manufacturing quality, material selection, the effects of the working medium, and operating conditions. Surface treatments enable the development of new technical and technological solutions by modifying the properties of the contact surfaces at specific locations and in precisely defined amounts and qualities. The base material is typically chosen to meet structural and strength requirements, while the applied coating provides the desired tribological or other functional properties.To enhance the durability of mechanical assemblies, various surface treatment methods are employed to produce surface layers or coatings with high wear resistance. These treatments encompass a broad spectrum of surface layers and coatings produced through different technological processes. A wide range of techniques is now available for creating surface finishes that improve the reliability and lifespan of tools and machine components [1.2].

Surface treatments aimed at improving the tribological properties of metallic materials can generally be divided into three main groups: surface coatings, coatings, and duplex coatings.

In surface coatings, the chemical composition and structure of the surface and subsurface layers are modified. This results in a gradual gradient of physico-mechanical and chemical properties extending toward the core, without a distinct interface between the surface layer and the substrate [3,4].

In contrast, coatings involve the deposition of a material with chemical and structural characteristics different from those of the substrate. This process creates a distinct interface marked by abrupt changes in both chemical and physico-mechanical properties [5,6].

Duplex coatings combine surface modification with the application of a coating. In this case, the transition in physico-mechanical and chemical properties from the surface to the core is eliminated. However, duplex processes require multiple technological steps, making them more complex and costly [7,8].

High hardness in the surface layer or coating improves resistance to erosive, abrasive, cavitation, fatigue, and vibration wear [9,10,11]. Conversely, soft and ductile surface layers or coatings are advantageous for applications involving friction and wear, as they provide a positive gradient of physico-mechanical properties. In such cases, shear deformation and failure occur within a thin, highly plastic surface layer, while the stronger subsurface region modifies the stress–strain field, limiting the development of plastic deformation and delaying material failure. These types of surface treatments are particularly effective in combating adhesive and vibratory wear [12,13,14].

II. MATERIALS AND METHODS

The experimental specimens were prepared by depositing the coating material onto a steel substrate of grade 11 523 (S355J0). The coatings were applied to test plates measuring 780 mm × 360 mm × 17.5 mm. From these plates, individual test specimens were subsequently cut to dimensions of 70 mm × 22 mm × 6 mm, suitable for mounting in the tribometer used for wear testing.

Prior to testing, the surface of each specimen was milled and ground see Figs. 2 in sequential operations to achieve a surface roughness of Ra = 0.2 μm (primary surface profile). This ensured consistent surface quality and minimized the influence of surface irregularities on tribological performance.

The friction system, or friction triplet, used in the tribological tests consisted of three main components:

- the coated test specimen,
- a rotating disc with a rubber lining, and
- abrasive particles dispensed from a hopper.

The abrasive particles used in the experiments varied in hardness, allowing the study of wear behavior under different abrasive conditions see Fig. 1.

The primary objective of the experiments was to evaluate how welding speed influences the tribological properties of the deposited layers under a normal load of 1000 N, simulating the real operating conditions of welded components subjected to abrasive wear. Additionally, the study examined the impact of abrasive particle size on the wear resistance of the coatings by analyzing changes in both the coefficient of friction and the mass loss (wear rate) after completion of the sliding path.

Table 1 summarizes the parameters used for the plate cladding process on the 780 mm × 360 mm × 17.5 mm steel plates. The filler material employed was Fluxofil 54, a tubular wire with a diameter of Ø 1.2 mm, designed for welding tough and abrasion-resistant layers used in applications such as conveyor components, crusher jaws, and similar parts exposed to severe wear.

The welded layers exhibited no visible cracks or porosity, indicating good metallurgical bonding and process stability. The cladding was applied in two layers, with the upper layer characterized by a columnar crystalline microstructure, which typically enhances wear resistance due to its directional grain growth.

According to the manufacturer's specification, the chemical composition of the Fluxofil 54 coating is as follows:C = 0.45 %, Si = 0.6 %, Mn = 1.6 %, Cr = 5.5 %, and Mo = 0.6 %.

The deposition of the filler material onto the base metal was carried out using the MAG (Metal Active Gas) welding process with CO_2 shielding gas and a melting electrode, ensuring stable arc conditions and uniform coating deposition.experiment was conducted are recorded in Table 1.

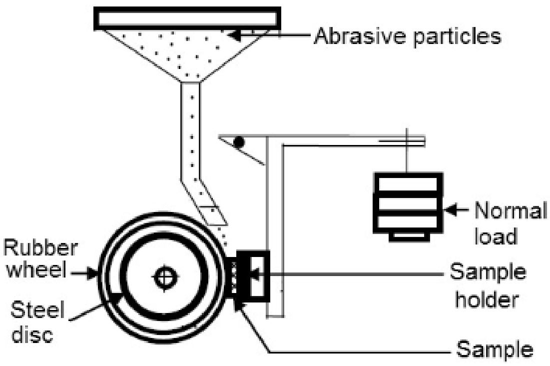


Figure 1 Schematic Diagram of Test Apparatus

Table 1Conditions for rolling experimental samples

Samples of series 2	Samples of series 3
Fluxofil 54	Fluxofil 54
Thickness 39mm	Thickness 40mm
Backing material sheet thickness 30 mm	Stainless steel base material 10mm
U= 28V, I= 282A	U= 23V, I= 200A
V= 18m/min	V=125m/min

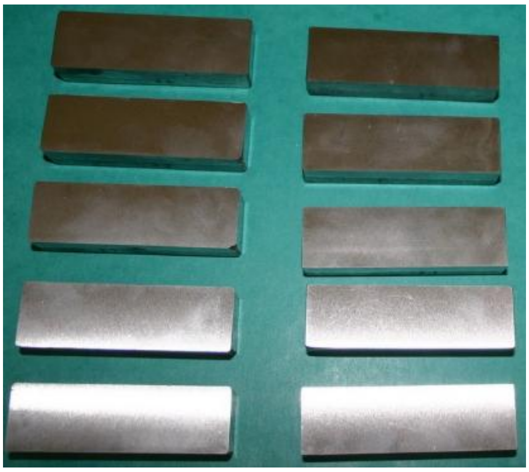


Figure 2 Schematic Diagram of Test Apparatus

In the operation of industrial machines, working surfaces often come into contact with natural abrasive materials, the hardest component of these materials being silicon dioxide (SiO_2) with a hardness of approximately 1000 HV. For this reason, in the range of 50–770 HV, the hardness of the abrasive wear resistance suffers and the devices are resistant to mechanical stress.

However, laboratory tests have shown that even steel with a high proportion of hard complex carbides does not achieve stable, constant resistance to abrasive wear. The variability of the tribological behavior of these materials is mainly due to differences in microstructure, chemical composition, as well as in the interaction between the material surface and abrasive parts during experimental friction.

Table 2 Comparison of different types of hardness of abrasives

Material	Hardness (HV)	Metal material	Hardness (HV)
Limestone	110	Armco iron	90
glass	500	Stinging steel	100 - 250
feldspar	600 - 750	perlite steel	230 - 350
Quartz	900 - 1280	steel for rolling bearings	700 - 950
WC	1900	tool steels	700 - 1000
Korund	2000	cemented steel	900
TiC	2450	nitrided steel	900 - 1250
SiC	2500	WC+Co	1400 - 1800
Limestone	110	Armco iron	90
glass	500	Stinging steel	100 - 250
feldspar	600 - 750	perlite steel	230 - 350

Based on the dependence of the mineralogical properties of the abrasives, where hardness and grain shape (macro and microgeometry) are important (Table 2), two types of abrasives were used for the experimental tests:

- quartz - SiO_2
- corundum - A_{l2} O_3

The following abrasive dimensions were used in the tests: 0.2 – 0.315 mm.

According to the ASTM series see tab.3, the recommended rotational speed of a 229 mm diameter disc is between 10 and 350 rpm and the load per specimen is in the range of 20 to 350 N. The specimens should be 25mm x 58mm x 6-16 mm in size. The double layer welds were carried out on S355J0 metal plates. The thickness of the specimens after welding exceeded the recommended values, which was beyond the capability of the testing equipment, and therefore the base material was machined by milling and the specimens had a final thickness of 20mm. Another reason for surface modification of the specimens was to ensure that the rubberised disc would sit full flat on the surface to be tested during the test, to avoid measurement errors based on variations in the size of the test areas when testing individual specimens, as the surface finish throws off the convexity and concavity of the surface and to make the surface flatness of the surface to be tested uniform, the surface needs to be further machined by milling and grinding. At the same time, a new specimen holder has been manufactured to allow different specimen thicknesses to be tested, so that the prescribed position of the specimen relative to the axis of the wheel is always ensured.

Table 3 Parameters of test ASTM G65/16

Disc diameter	229mm
Disc material	Rubber disc
Revolutions	287 RPM
Dimensions of the sample	70mm x 22mm x18mm
Load	1000N
Abrasive	Silica sand, white corundum
Glide path	420m, 716m

III. MEASUREMENT RESULTS

Experimental tests at constant load with 420 and 716 m runways. Wear was determined based on the mass loss after traversing the 420m runway and traversing the 716m runway. Figure 3 shows the surfacing samples after testing for abrasive wear.

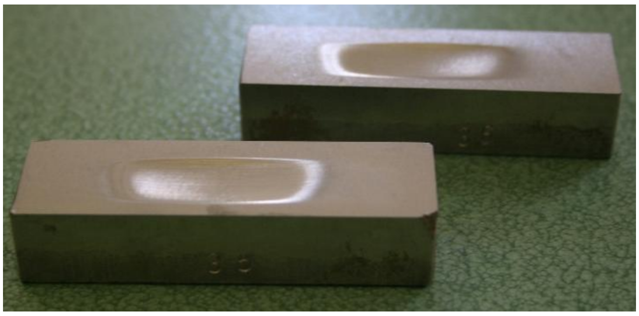


Figure 3 Appearance of samples after the test

The test samples were weighed before and after the tests on KERN precision balances with an accuracy of four decimal places to ensure high accuracy of weight measurement and the possibility of detecting even small changes. However, the test was interrupted after a sliding distance of 420 m, when a temperature of 80 °C was reached in the contact area between the sample and the rubber disc. The increased temperature caused changes in the conditions in the contact area, namely a reduction in the gap between the sample and the disc, which includes the contact conditions.

To achieve stable conditions in the contact area at a load of 1000 N, it was necessary to constantly hold and again to stabilize the temperature and mechanical conditions. This procedure ensured that further measurements were satisfactory and that the influence of temperature on the results was minimized.

Individual test results for Fluxofil 54 at a speed of 8 m/min and using SiO_2 abrasive with a fraction of 0.2 – 0.315 mm are presented in Tab. 3 and Tab. 4, which document the consumption values and changes of the samples at different stages of the tests. These data are key for evaluating the tribological behavior of the material and its wear resistance under defined conditions.

Table 3Mass loss versus path for Fluxofil 54, v= 18m/min and abrasive used $Si0_2$ on average 0.2 - 0.315 mm

Marking of test samples	420[m]-Mass loss [g]	716[m]-Mass loss [g]	Mass losses [g/m]
S. 2.6	0.0996	0.1639	0.00021 g/m
S. 2.3	0.0858	0.1456	
S. 2.0	0.0880	0.1450	
Average value	0.09113	0.1515	

Table 4 Mass loss versus path for Fluxofil 54, v= 125 m/min and abrasive used $Si0_2$ on average 0.2 - 0.315 mm

Marking of test samples	420[m]- Mass loss [g]	716[m]- Mass loss [g]	Mass losses [g/m]
S.3.1	0.0947	0.1672	0.000 23 g/m
S.3.2	0.1004	0.1648	
S. 3.0	0.0998	0.1678	
Avg. value	0.0983	0.1666	

Fig.4 shows the dependence of the mass loss on the winding speed for the SiO2 abrasive used. The winding speeds in this case were 18 m/min and 125 m/min. Where the pink color is used to graphically indicate the dependencies of the mass loss on the winding speed for a sliding distance of 420m. The column marked in white indicates the mass loss dependencies on the winding speed for the 716 m sliding path.

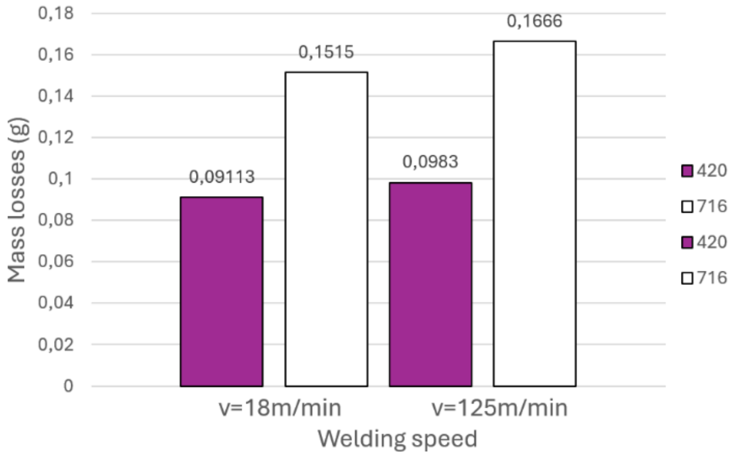


Figure 4Mass loss in abrasive wear when using abrasives SiO_2 for layers wound at different speeds

Individual test results for Fluxofil 54 at 18m/min and using abrasive Al_2O_3 with a diameter of 0,36 mm are given in Tab.5 and Tab.6.

Table 5.Mass loss versus path for Fluxofil 54, v= 18 m/min and abrasive used Al_2O_3 about the average 0.36 mm

Marking of test samples	420[m]- Mass loss [g]	716[m]- Mass loss [g]	Mass losses [g/m]
S. 2.5	1.0801	1.7493	0.000 23 g/m
S. 2.8	0.9818	1.6590	
S. 2.9	1.0202	1.6554	
Average value	1.0279	1.6879	

Table 6. Turbidity losses as a function of path for Fluxofil 54, v= 125 m/min and abrasive used Al_2O_3 on average 0.36 mm

Marking of test samples	420[m]- Mass loss [g]	716[m]- Mass loss [g]	Mass losses [g/m]
S. 3.5	1.0784	1.7041	0.000 24 g/m
S. 3.6	1.0686	1.7204	
S. 3.0	1.0695	1.7519	
Average value	1.07216	1.7255	

Fig.5 shows the dependence of the mass loss on the winding speed for the Al2O3 abrasive used. The winding speeds in this case were 18 m/min and 125 m/min. Where the pink colour is used to graphically indicate the dependencies of the mass loss on the winding speed for a sliding distance of 420m. The column marked in white indicates the mass loss dependencies on the winding speed for a 716 m sliding path.

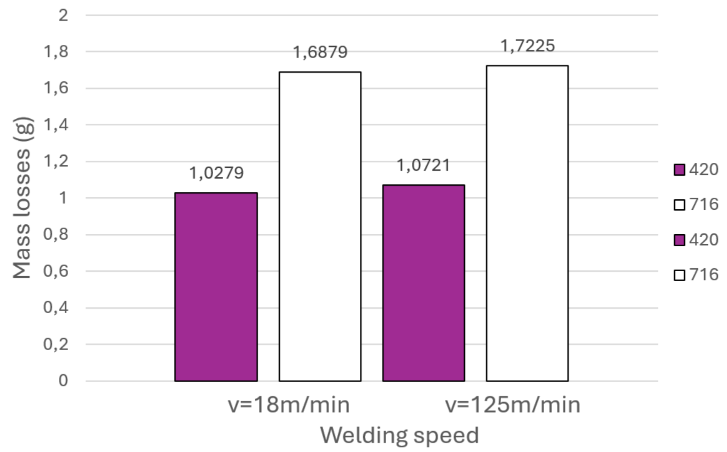
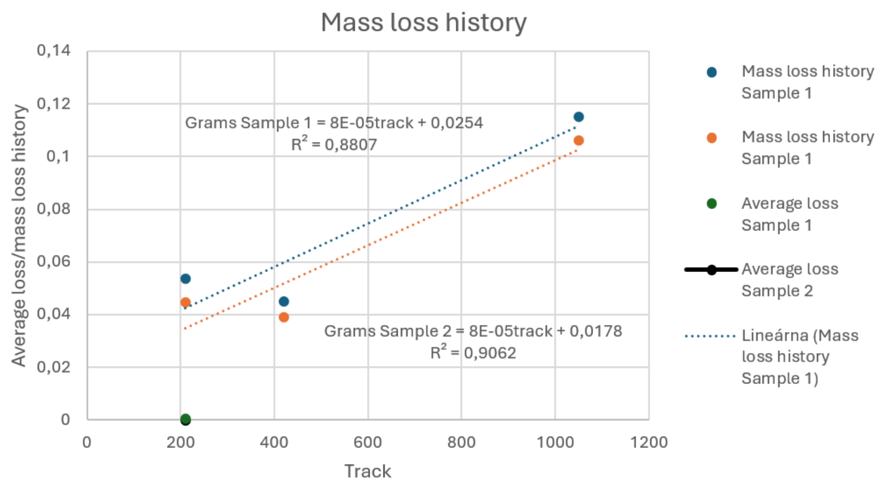


Figure 5 Dependence of abrasive wear mass loss when using abrasives Al_2O_3 for layers wound at different speeds

In order to compare the parameters and measurement agreement of the experimental equipment, tests were performed on the rubber disc equipment for test specimens 1 and 2 as well as for the 210m runway as a supplementary measurement. The results are correlated for wear with the layers seeTab. 4, Tab. 5 for the abrasives Si02 o priemere 0,2 - 0,315mm. Also, the regression analysis see fig. 6 documents a relatively high degree of adequacy of the mathematical model in the setting of the experiment itself.



	Grams			Gram per metre of track
Track	210	420	1050	Average loss
Sample 1	0,05360	0,04520	0,11520	0,00020
Sample 2	0,04420	0,03910	0,10580	0,00017

Figure 6 Mass loss and abrasive wear history when using abrasives SiO_2Fluxofil 54, v= 18 m/min in the upper part and table of used values in the lower part

IV. RESULTS AND DISCUSSION

The evaluation of layers applied at different speeds showed that the wear rate increases with increasing winding speed. An increase in welding speed results in a decrease in wear resistance and is observed for abrasive particle wear SiO_2 as well as Al_2O_3. From the point of view of experimental tests in laboratories, it can be stated that the results used in friction and wear research can be applied to practical possibilities of investigating surface and subsurface indentations or thick surfacing layers as in this case. The measured experimental results show that hard and sharp particles Al_2O_3 create a micro-cutting effect on the surface. Most of the particles interfere with the tribocontact, which increases the surface wear associated with the striations of the material.

The results show a significant effect of abrasive hardness on the wear of materials. Very intense wear occurs if the abrasive used is harder (Al_2O_3) whereby the particles more intensively etch the surface of the material. The presence of a relatively softer abrasive (SiO_2) results in low shear deformation of the surface layers under the applied particle, i.e. less wear (approx. 0.00023 g/m) compared to wear with abrasive particles Al_2O_3 (approximately 10 times higher i.e. 0,00024g/m).

The silica sand and corundum used in the abrasive wear experiment showed that, as well as the surface characteristics of the layers, the type of abrasive itself is a significant factor affecting wear, and hence the conditions and type of particles acting on the surface of the material are another important evaluation criterion for the use of the abrasive in practice.

The results of laboratory tests depend on their ability to simulate the conditions in the tribosystem and in obtaining the necessary data for making decisions on the choice of materials or surface treatment. The benefit of our facility is the testing of a variety of materials and consequently more realistic testing on fewer samples under conditions closer to those of real-world operation.

V. CONCLUSION

Testing for resistance to abrasive wear is a fundamental method for assessing the performance and longevity of materials and surface coatings in practical applications. In the initial stage of the study, technical modifications were implemented on the test rig to enhance its ability to realistically simulate the behavior of coating surface layers under abrasive wear conditions. These modifications were critical to ensuring that the experimental results accurately reflect the real-world performance of the materials being tested.

Subsequently, experimentalmeasurementswereconducted to assessthewearresistance of variousmaterials, with a focus on surfacecoatings. The study alsoexaminedtheinfluence of surfacingparameters on wearbehavior, includingthedetermination of theoptimalsurfacingspeed limit. Itisworthnotingthatthewelding and surfacingtechnologyemployed in this study isstillevolving. Despiteitsdevelopmental status, itcanbeappliedrelativelyquickly and efficiently in practicalindustrialsettings, offeringpotentialadvantages in terms of operationalfeasibility and cost-effectiveness.

In thefollowingphase, a series of experimentaltestswerecarriedout on multiplesets of headers. Foreachseries, theslidingdistancerangedfrom 420 m to 716 m, under a constantload of 1000 N and a rubberdiscrotationspeed of 287 rpm. Thedurability of individualcomponents and theprogression of wear are closelylinked to themaintenance and refurbishment of workingmachineryparts. Onepotentialrefurbishmentmethodiswinding. Analysis of theresultsindicatedthatincreasingthewindingspeeddoesnotnecessarilyimprovethewearresistance of theappliedlayer. Thisobservationhighlightstheunderstandingthatwearresistanceisnotsolelydetermined by hardness; rather, itisprimarilyinfluenced by technologicalparametersthatdictatetheresultingmicrostructure of thecoating.

Thehighestresistance to abrasivewearwasachievedusing a two-step surfacingtechnology, NP50WC45, whichisattributed to thehighcontent of hardcarbideparticlesembeddedwithinthecobaltmatrix. Thisfindingunderscorestheimportance of coatingcomposition and microstructuralcharacteristics in determiningperformanceunderabrasiveconditions.

Theexperimental study alsoinvestigatedtheeffect of abrasivehardness on thewearresistance of weldedlayers. Evaluation of coatingsapplied at differentsurfacingspeedsrevealed a clear trend: wear rate increases as windingspeedincreases. Thiscorrelationissupported by boththemeasureddata and thegraphicalrepresentation of massloss as a function of windingspeed. Theresultsdemonstratethathigherwindingspeedscanlead to a reduction in wearresistance, emphasizingthecritical role of processparameters in optimizingcoatingperformance.

Overall, thefindings of this study providevaluableinsightsintotheinterplaybetweensurfacingparameters, microstructure, and abrasivewearresistance, offeringpracticalguidancefortheapplication of advancedweldingtechnologies in industrialmaintenance and componentlongevity.

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REFERENCE

[1]. Zdravecká, E. – Slota J.: echanical and Microstructural Investigations of the Laser Welding of Different Zinc-Coated Steels – 2019. In: 2019. In: Metals. - Basel (Švajčiarsko): MDPI Roč. 9, č. 1 (2019), s. 1-13 [online]. - ISSN 2075-4701 (online)

[2]. Slota, J,.Kubit, A., Gajdoš, I.Trzepiecinski, T., Kaščák, Ľ.: A comparative study of hardfacing deposits using a modified tribological testing strategy. - 2022. In: Lubricants. - Bazilej (Švajčiarsko): Multidisciplinary Digital Publishing Institute Roč. 10, č. 8 (2022), s. [1-20] [online]. - ISSN 2075-4442 (online)

[3]. Kaščák, Ľuboš - Spišák, Emil.: The Analysis of Plastic Strain of Single and Double Reduced Tinplates. Conference: 2016. In: The International Journal of Engineering and Science. Vol. 5, no. 12 (2016), p. 32-37. - ISSN 2319-1805

[4]. Brezinová, J. - Džupon, M. et.al: Evaluation of the influence of the welding current on the surface quality of spot welds. - 2019. In: Metals. - Basel (Švajčiarsko): Multidisciplinary Digital Publishing Institute Roč. 9, č. 11 (2019), s. [1-23] [online]. - ISSN 2075-4701 (online)

[5]. Sundstrom, A.; Rendnón, J.; Olsson, M. Wear behaviour of some low alloyed steels under combined impact/abrasion contact conditions. Wear 2001, 250, 744–754.

[6]. Buchanan, V.E.; Shipway, P.H.; McCartney, D.G. Microstructure and abrasive wear behaviour of shielded metal arc welding hardfacings used in the sugarcane industry. Wear 2007, 263, 99–110.

[7]. Rendón, J.; Olsson, M. Abrasive wear resistance of some commercial abrasion resistant steels evaluated by laboratory test methods. Wear 2009, 267, 2055–2061.

[8]. Budinski, K.G.; Budinski, S.T. On replacing three-body abrasion testing with three-body abrasion testing. Wear 2017, 376–377, 1859–1865.

[9]. Wu, C. S. - Hu, Z. K. - Zhang, Y. M..: Suppression of weld-bead defects and increase in the critical welding speed during high-speed arc welding - 2009. In: Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. Volume 223 Issue 6, June 2009sciences: https://doi.org/10.3390/app110102622016; 2020.

[10]. Linghui, S.W.; Linghui, S.; Qiao, S.Y.; Min, M. Effect of Carbide Orientation on Impact-Abrasive Wear Resistance of High-Cr Iron Used in Shot Blast Machine. Tribol. Lett. 2013, 50, 439–448.

[11]. Chotěborský, R. Effect of heat treatment on the microstructure, hardness and abrasive wear resistance of high chromium hardfacing. Res. Agric. Eng. 2013, 59, 23–28.

[12]. Venkatesh, B.; Sriker, K.; Kumar, M.A. Wear characteristics of multi layerhardfacing alloys. AIP Conf. Proc. 2020, 2259, 020020.

[13]. Xu, X.; van der Zwaag, S.; Xu, W. Nový viacprechodovýdvojvložkovýpoškriabací test naodhalenietvorbypoškodeniaoderom v konštrukčnýchoceliach. Opotrebenie2015 , 322–323 , 51–60.

[14]. Fraiwan, M., Faouri, E., Khasawneh, N. Multiclass Classification of Grape Diseases Using Deep Artificial Intelligence. Agri-culture, 2022, Vol. 12, pp. 1542. doi.org/10.3390/agriculture12101542.

[15]. Gu, J., et al. Recent advances in convolutional neural networks. Pattern Recognition, 2018, Vol. 77, pp. 354-377. doi.org/10.1016/j.patcog.2017.10.013.

[16]. Halawa, H., Abdelhafez, H.A., Boktor, A., Ripeanu, M. NVIDIA Jetson Platform Characterization. In: Euro-Par 2017: Parallel Pro-cessing: 23rd Int. Conf. on Parallel and Distributed Computing. Springer Int. Publishing, Santiago de Compostela, 2017, pp. 92-105.