A Study of the Wear Resistance of Weld Overlay Coatings Produced By Using Flux Shielding In an Abrasive Environment

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Abstract: *The article studies the wear resistance of weld overlaid coatings produced by using flux shielding of components from agricultural, transport, construction and forestry machinery which are used in an abrasive environment. The obtained results reveal that the coatings obtained through weld overlaying with DUR 600 electrode wire and FBTT flux possess the highest wear resistance in a dry and wet abrasive environment. The gradual change in the magnitude of wear of these coatings allows for the prediction of changes in the technical condition of restored components.*

Keywords*: abrasive wear, submerged arc welding and overlaying*

INTRODUCTION

Wear resistance of restored components of contemporary agricultural, transport, forestry and construction machinery is largely determined by their wear resistance in an actual working environment. This type of equipment functions in abrasive environments, which accelerate considerably the wear of machine components. With reference to this, the aim of researchers and technical experts is to reduce components' wear and increase durability of machinery.

Increasing the wear resistance of agricultural, transport, forestry and construction machinery components after repairs is achieved through weld overlaying of wear resistant layers on worn components. One of the main methods for restoring running gear components of tracked machines is weld overlaying using flux shielding. The occurrence, development and intensity of the wear process are determined by the properties of the restorative coatings, their quality and the external conditions and influences.

The purpose of this article is to determine the wear resistance of large – sized components of tracked tractors, which were restored by flux - shielded weld overlaying and which work in an abrasive environment.

MATERIAL AND METHODS

The methodology for the study of wear resistance of flux - shielded weld overlay coatings was developed according to current understanding of scientific research in this field [3, 7].

The input factors of the cybernetic research model are as follows: **Tp** is the vector of the abrasive media's parameters (type and condition of the abrasive media; interaction of the abrasive media and the sample); **Pp** is the vector of the friction mode (weight/force applied, velocity of movement, temperature mode, length of experiments, etc.) and **Kp** is the vector of the coating's parameters (type of the coating and its quality characteristics) (see Fig. 1).

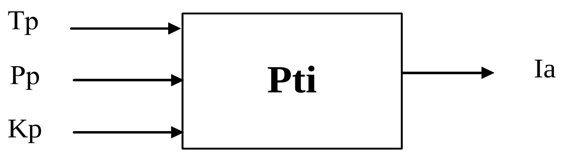

Fig. 1 Model for testing friction and wear in an abrasion - free environment:
Tp – vector of the abrasive environment's parameters; Pp – vector of the friction mode;
Kp – vector of the coating's parameters; Ia – vector of the samples' wear.

The output parameter, characterizing the process of friction and wear of samples in an abrasive environment, is the vector of abrasive wear of the samples obtained during laboratory testing **Ia** (size, dynamics, intensity of wear and wear resistance).

The methodology for studying the wear resistance of weld overlaid coatings uses the CT - 1 stand for friction and wear in a free abrasive environment, which was specially designed and produced by our research team . The stand permits the wearing of the friction surface during sliding.

When selecting the abrasive environment, we followed the principle of achieving maximum similarity between laboratory and real conditions of friction and wear. For the tests we used abrasive material molding mixture type K16 with grain size of 0,016 mm. Molding mixture type K16 is used in metal casting for molds. With its specifications, this molding mixture is very close to the environment in which agricultural, transport, construction and forestry machinery functions.

The study was conducted at two moisture levels of the abrasive environment, i.e. “dry” (with moisture W 10% of the moisture holding capacity limit) and “wet” (with moisture W 90% of the moisture holding capacity limit). The hydro-abrasive environment is obtained by using a special attachment to the CT – 1 device for tribological wear. To achieve the constant moisture level of the abrasive environment, we pour water in a special tank. The water flows with particular water flow to the abrasive environment. The level of abrasive dust before the test must cover the samples, mounted on the disk.

The scheme of interaction between the test sample and the abrasive environment, reproduced by the CT – 1 device, could feature lower and upper abrasive. Under the “lower abrasive” test scheme, force is applied between the samples and the abrasive environment. This is accompanied by intensive friction, higher degrees of wear and overall heating of the work environment. Under the “upper abrasive” test scheme, the samples raise the abrasive mixture, which is under them. The applied force and the resulting friction and wear are considerably lower.

The choice of a particular test scheme depends on the conditions in which the tested components function and has to recreate these conditions as closely as possible. The test for determining the wear resistance of flux – shielded weld overlay coatings was conducted by using the “lower abrasive” test scheme. According to this scheme the samples are flat and cleaned after being treated

The rotational speed of the samples is 80 min^{-1}. It is a constant value and does not change during the experiment. The rotational radius of the samples is 120 mm. The temperature of the process during the tests corresponds to the temperature of the natural environment. The samples are mounted on the disk at an angle of 30°, to permit intensive friction between the abrasive and the tested sample. The feeding of the dust abrasive as well as the mounting and dismounting of the disk is done by removing the cover.

With reference to chosen methodology, the overall tests length in an environment, made up of the type K16 molding mixture, was 48 hours (2880 min). These minutes were distributed in 6 experiments of 8 hours (480 min) for the samples in each group. When the overall duration expires, the abrasive environment is replaced with a new one. The number of experiments is determined by the requirements of mathematical statistics and the theory of probability.

Based on the modal and average values of the statistical distribution of the worn components, for the experiment we selected the “model” component, which corresponds to the agricultural and transport machinery components. A considerable number of the oversized components, subjected to abrasive wear, rotate. Therefore, for the purposes of the study the weld overlaid samples used were also rotating.

Table 1 *Parameters of the multilayer weld overlay mode of the rotating samples*

Indicators	Value
Arc voltage, V Of the first layer Of the second layer	 33 28
Magnitude of current, A	180-200
Type of current	Direct
Weld overlay speed, m\min	1,26
Spacing between weld overlay seams, mm\ min-1 Of the first layer Of the second layer	 3 3
Speed of feeding the electrode wire, m\min Of the first layer Of the second layer	 0,9 0,9
Diameter of the electrode wire, mm	1,2
Stick – out of the electrode wire, mm	15
Total thickness of the weld overlay layer, mm	3,6 – 6,8

The selected “model” has the following characteristics: material – St 45, hardness of the base metal – 200-220 HB, diameter - 100 mm, length - 200 mm and weight - 12 kg, thickness of weld overlaid coating - 10 mm [5, 6]. The coating is produced by weld overlaying with an intermediary layer due to its better formation properties and the need of smaller amounts of filler metal for further mechanical treatment [2]. The parameters of the flux shielded weld overlay process are outlined in Table 1.

The samples used are cut from the weld overlaid components and these samples are used for the study of friction and wear in an abrasive environment. The parameters of the samples are as follows: length L = 50 mm, width B = 35 mm, thickness b = 5 mm, weight of the base G = 70-80 g [1].

The running gear components of tracked machines function in conditions causing heavy abrasive wear which is also accompanied by considerable shock loads. These components can be considerably worn. However, this can be compensated by the weld overlaying of several layers of seams. The last layer must be wear resistant while the intermediary ones have other functions.

In addition, multilayer weld overlaying is a suitable solution because the last layer can be made by using an expensive, wear resistant, filler material, which meets the requirements for reliability of the restored components, while the other layers could function as a base. To a great extent, these requirements can also be met by applying several layers of the same filler material because the last layer contains a smaller amount of the base material and a bigger amount of the filler material, which increases the hardness of the coating. When the first layer is applied, the hard alloy is inevitably mixed with the base metal of the component and its amount is bigger than that of the alloy. Therefore, the wear resistance and hardness of the first weld overlaid layer are lower. The percentage of the hard alloy increases with the application of the other layers.

Multilayer weld overlaying helps to reduce the cooling rate of the weld overlaid surface. It is recommended that each successive layer is applied before the restored component is completely cooled. What is more, the lower layer is reheated by the upper layer. As a result, the ductility and toughness of the multilayer seams are increased. Another advantage of multilayer weld overlaying is that the evenness of the coating increases with each successive layer deposited.

The studied weld overlay coatings are obtained by flux shielded, multilayer weld overlaying on rotating components. The coatings consist of two layers made of identical materials and fluxes (table 2). The weld overlay samples are organized in groups according to the filler material and flux used. In each group there are six samples.

The selected electrode wires refer to the stainless and heat resistant steels. Their chemical composition of these wires is close to that of the base metal used for the production of most of the oversized components. The filler material has a diameter of 1,2 mm. The selected protective OK 1096 flux, produced by ESAB, has good metallurgical properties. The CS 350 and FBTT fluxes have good alloy properties with reference to improving the wear resistance of weld - overlaid working surfaces.

***Table 2** Materials used for the flux – shielded multilayer weld overlaying of the rotating samples*

№	Electrode material	Flux
1	Sv 08G2S	CS 350
2	Sv 08G2S	OK 1096
3	Np 30HGSA	FBTT
4	Np 18 HGSA	FBTT

The wear magnitude of the weld overlaid coatings is determined by measuring the samples weight at the beginning and end of each experiment with an accuracy of 0,1 mg by using an analytical balance, type WA 33 PRLTA 13/1. The changes in the samples' weight at the end of each experiment provide data for preparing the dynamics of change in wear resistance in the process of abrasive wear. The wear dynamics and wear intensity of the "standard" sample and the weld - overlaid samples are determined according to the methodology, outlined in ГОСТ 23.208 – 79 [1].

RESULTS AND DISCUSSION

The dynamics of the change in the overall wear magnitude of the "standard" sample and the samples with the restorative coatings is shown on Figures 2 and 3.

The weld – overlaid samples (see Fig.2) have considerably lower wear compared to the wear of the "standard" sample in a dry abrasive environment. For the "standard" sample and all the groups with weld – overlaid samples, there is a considerately gradual and even increase in the loss of material during the experiment. This property is beneficial during exploitation because it does not permit sharp fluctuations in the size of components subjected to wear. This also permits predictions concerning changes in the size of components and the related maintenance and repair activities.

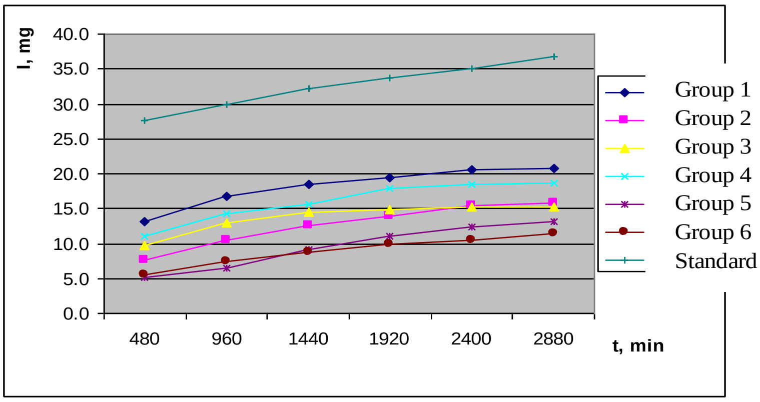

Fig. 2 Dynamics of the wear magnitude of the "standard" sample and the samples with two identical weld overlaid layers in a dry abrasive environment, made of the K16 moulding mixture

According to Fig. 2, the samples from groups 2, 5 and 6 have wear values of 10…15 mg at the end of the experiment while at the end of the cycle the overall lost material is approximately 20 mg for the other samples and 37 mg for the “standard” sample.
The samples from group 1 have the highest overall wear. At the end of the experiment it reaches a value of 20,5 mg. Groups 6 and 5 have the lowest overall wear. It is 11 mg and 13 mg respectively at the end of the cycle. This wear is nearly twice lower, compared to the wear of the samples from group 1. For group 5 the magnitude of wear after the first experiment has increased only by 5 mg.
In the study of wear resistance in a wet abrasive environment, the samples make considerable efforts to overcome the compacted abrasive material compared to the efforts they make in a dry abrasive environment. Therefore, in this case the wear is higher, compared to the one in a dry environment.

The changes in the overall wear in a wet abrasive environment are analogical to the ones in a dry abrasive environment. However, the wet abrasive increases the overall wear of the samples by 2 to 8 mg (see Fig. 3). During the experiment, the samples from groups 2, 5 and 6 have the lowest overall wear values. At the end of the cycle, they are 16 mg, 15,5 mg, and 15 mg respectively.

The samples from groups 1, 3, and 4 have the highest overall wear values in a wet abrasive environment. This trend is identical with the trend, recorded during the experiment in a dry abrasive environment. However, the obtained values are higher.

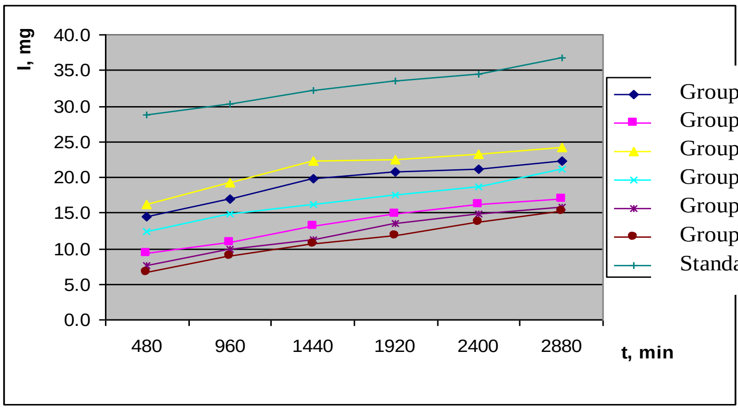

Fig. 3 Dynamics of the wear magnitude of the “standard” sample and the samples with two identical weld overlaid layers in a wet abrasive environment, made of the K16 molding mixture

The wear of the samples from group 6 is the lowest overall wear recorded for the dry and wet abrasive environment. The increase in wear after the first experiment is within the range of 6 cm, which is approximately 30% of the overall sum wear. This gradual increase in wear permits specialists to predict the wear of oversized components and forecast changes in their resources.

***Table 3** Wear resistance and relative wear resistance of samples, weld overlaid with two identical layers*

Samples	Wear resistance		Relative wear resistance	
	Dry	Wet	Dry	Wet
Group 1	0,08	0,07	2	1,75
Group 2	0,12	0,14	3	3,5
Group 3	0,11	0,07	2,75	1,75
Group 4	0,10	0,10	2, 5	2,5
Group 5	0,18	0,16	4,5	4
Group 6	0,18	0,16	4,5	4
Standard	0,04	0,04	1	1

In addition to wear magnitude, the intensity of wear, as one of the main tribological properties, is also of significant importance for assessing the changes in the size of friction surfaces. Intensity of wear permits the comparison of wear of restored components made of different materials. It also provides information about the loss of material with reference to the distance, covered by the studied surface subject to wear, as well as the thickness of the material, used for the production of the same surface. One of the main requirements to the weld overlay material is its sufficient wear resistance under the given working conditions, which are characterized by the wear intensity.

According to Fig. 4, the intensity of wear decreases rapidly during the first 24 hours. After that, it remains nearly constant and on the graphs, there is a smooth transition from the steep to the shallow section of the curve. This can be explained by the lower hardness of moulding mixture type K16. Naturally, the “standard” samples have a higher intensity of wear compared with the test samples.

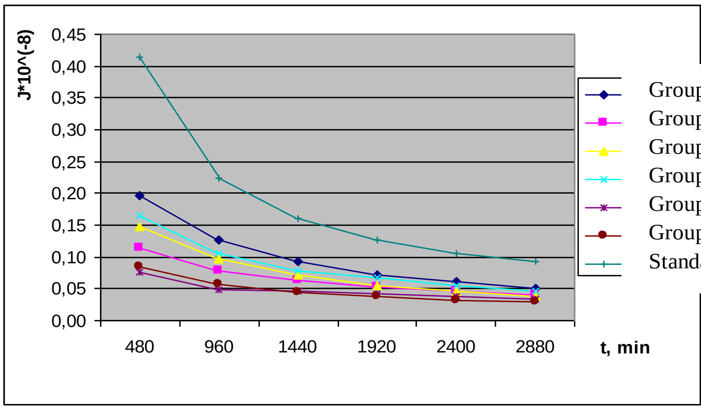

Fig. 4 Wear intensity of the “standard” sample and the samples with two identical weld overlaid layers in a dry abrasive environment, made of the K16 molding mixture

The samples from groups 5 and 6 have the lowest wear intensity (see Fig. 4). The intensity of wear is the highest for groups 1, 3 and 4. This reveals that the restorative coatings from groups 5 and 6 have higher durability.

According to Fig. 5, the intensity of wear of the samples, tested in a wet abrasive environment, is higher than the intensity of wear of the samples tested in a dry abrasive environment. This is also proved by the results in [4]. The samples from groups 5 and 6, tested in an environment made up of moulding mixture type K16, have the lowest intensity of wear compared to the samples from the other groups.

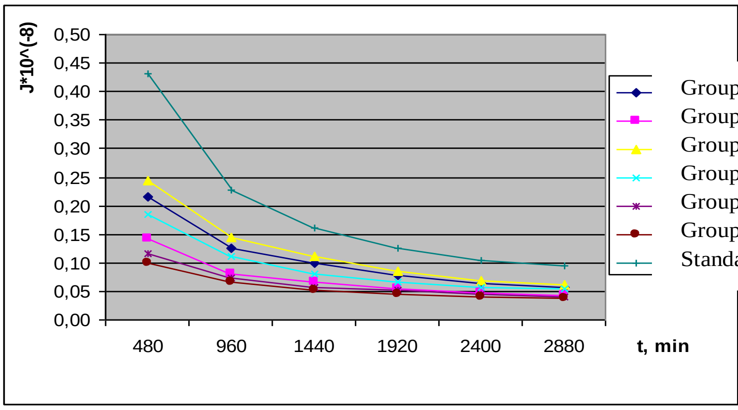

Fig. 5 Wear intensity of the “standard” sample and the samples with two identical weld overlaid layers in a wet abrasive environment, made of the K16 molding mixture

The “standard” samples have the highest intensity of wear in a wet abrasive environment. The samples from groups 1, 3 and 4 have the second highest intensity of wear.

The wear resistance of the oversized components weld overlaid by using flux shielding is a complex property and depends on a number of factors such as the percentage of carbon and alloying elements, the obtained hardened structures, and the toughness and fragility of the weld overlaid metal. By increasing the toughness of the weld overlaid metal we, by rule, increase the wear resistance of the components working in an abrasive environment.

The results concerning the wear resistance and the relative wear resistance of the weld – overlaid samples produced by using flux shielding are shown in Table 3. The relative wear resistance is determined according to the “standard” sample.

The data in Table 3 shows that the weld – overlaid samples from group 5 and 6 have the highest wear resistance in a dry and wet abrasive environments. For the dry abrasive environment the wear resistance is 1,5 times higher compared to the one of the other groups and 2,5 times higher than the wear resistance of the “standard” sample. This is also confirmed by the results for the wear of the samples from this group which are shown on Fig. 2. The weld overlaid coatings from group 1, 3 and 4 have the lowest wear resistance.

The results from the tribological studies of the flux – shielded weld overlaid coatings on running gear components of agricultural, construction and forestry machinery, working in an abrasive environment, show that the lowest wear and the highest wear resistance is recorded for the coatings from group 6.

CONCLUSIONS

1. Restorative coatings are characterized by a gradual increase in overall wear. This allows users to make predictions concerning wear of running gear components from agricultural, transport, construction and forestry machinery, functioning in conditions of abrasive wear. This also permits forecasts concerning the replacement of worn components.

2. At the end of the tests conducted, flux – cored weld overlay coatings, produced with DUR 600 electrode wire and FBTT flux possess the smallest values of overall wear in dry and wet abrasive environments, namely 11 - 15mg.

3. The lowest wear intensity of flux – cored weld overlay coatings is recorded for electrode wires DUR 600 and DUR 500. This proves the high durability of these coatings under conditions of abrasive wear.

4. The highest wear resistance under conditions of abrasive wear in dry and wet environments is possessed by the flux – cored, weld overlay coatings from group 5 and 6.

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