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THE COMPARISON OF EFFECTS OF THERMAL SPRAYING EUTALLOY 10112 AND LASER ALLOYING WITH SILICON NITRIDE OF CAST IRON OUTMOST DISK COULTER

Summary

The aim of this research was to evaluate an effect of surface layer condition of machine parts working in sand on abrasive wear intensity, and particularly comparison of two surface treatments - thermal spraying and laser alloying. The outmost disk coulters of 'Poznaniak' seeder were tested. Special laboratory tester called 'rotated bowl' used in wear research in sand was used. The research showed, that by applied surface treatments it is possible to change the microstructure of outmost disk coulter surface layer and in this way increase their hardness and wear resistance. By laser alloying 2,5-times and after thermal spraying 3-times hardness increase was achieved in comparison to untreated outmost disk coulter. Part of modified area after laser alloying was considerably smaller than after thermal spraying. Wear of outmost disk coulter after laser alloying was 5-times and after thermal spraying was 6-times smaller than wear of outmost disk coulter without treatment. Both treatments allowed to considerably decrease wear of tested elements, but taking into account size of modified areas, laser alloying could be more effective treatment than thermal spraying.
***Key words**: thermal spraying, laser alloying, outmost disk coulter, abrasive wear*

PORÓWNANIE EFEKTÓW NATRYSKIWANIA CIEPLNEGO STOPEM EUTALLOY 10112 ORAZ STOPOWANIA LASEROWEGO AZOTKIEM KRZEMU FRAGMENTÓW ŻELIWNYCH STOPEK REDLIC SIEWNIKA

Streszczenie

Celem badań była ocena wpływu stanu warstwy powierzchniowej elementów maszyn pracujących w ośrodku piaszczystym na intensywność zużywania ściernego, a w szczególności porównanie efektów dwóch obróbek powierzchniowych natryskiwanie cieplnego i stopowania laserowego. Badaniu poddano redlice siewnika mechanicznego typu Poznaniak i przeprowadzono je na specjalnie do tego celu zbudowanym stanowisku laboratoryjnym typu „wirująca misa", służącym do wykonywania testów zużyciowych w ośrodku piaszczystym. Badania wykazały, że za pomocą zastosowanych obróbek można zmienić mikrostrukturę warstw powierzchniowych stopek redlic, a przez to zwiększyć ich twardość oraz odporność na zużywanie. Za pomocą stopowania laserowego uzyskano 2,5-krotne zwiększenie twardości, a po natryskiwaniu 3-krotne w porównaniu do stopek redlic w stanie wyjściowym. Część zmodyfikowanego obszaru warstwy powierzchniowej w przypadku stopowania laserowego była o wiele mniejsza niż po natryskiwaniu cieplnym. Zużycie redlic było 5-krotnie, a po natryskiwaniu cieplnym 6-krotnie mniejsze w porównaniu do stopek redlic w stanie wyjściowym. Obie zastosowane metody obróbki powierzchniowej pozwoliły istotnie zmniejszyć zużycie badanych elementów, przy czym biorąc pod uwagę wielkość zmodyfikowanego obszaru po obu rodzajach obróbek, stopowanie laserowe może być obróbką efektywniejszą niż natryskiwanie cieplne.
***Słowa kluczowe**: natryskiwanie cieplne, stopowanie laserowe, stopki redlic, zużycie ścierne*

1. Introduction

Studies on the impact abrasive medium stream where wear abrasive process occurs, relatively are carried out at reduced frequency. In that case equipment machinery is exposed to very high mechanical, abrasive and corrosive wear process. Determination of the effects of physical and chemical properties of soil on the this process is very difficult as well as of capturing of the rules governing wear process. Despite of the development of computer simulations and several attempts made on mathematical descriptions, laboratory and regular tests remain the main tool [2].

Detailed analysis of the literature, both domestic and foreign has shown that up to now has not been completely explained the mechanism of the abrasive wear process concerning machines equipment using for soil cultivation and mining. The published results [3-7] has obtained by individual researchers are not in a simple and clear way comparable. Incomplete state of knowledge on the issues of consumption means there is no coherent theory of wear elements working in the soil, resulting in ambiguity in determining the impact basic operating parameters , soil conditions and characteristics of the tools on the wear process.

A suitable preparation and modification of surface layer can reduce the wear parts of machinery made of similar materials and working in similar conditions and thus can help to improve durability and tool replacement intervals.

The aim of this research was to evaluate an influence of surface layer condition of machine parts working in sand on abrasive wear intensity.

Relatively common methods of modification of the surface layer enabled for increasing resistance to wear is flame spraying. It is pursued by coating the objects (usually metal) layers of the air spraying fine particles of coating material in the flame (gas, electric arc, plasma). This will ensure a kinetic energy and exert pressure on the surface layer which creates good adhesion of the sprayed coating to the substrate while heating the substrate to a low temperature (150°C). As the coating materials usually is used steel alloy, zinc, aluminium and its alloys, copper, tin, lead,

nickel, brass, cadmium, bismuth, cobalt, chromium, tungsten or titanium. The thickness of the layer is from 50 up to 1000 microns. Thermally sprayed coatings are mainly used to protect equipment and steel structures against atmospheric and gas corrosion [1] but this method is relatively expensive. As an example we can mention thermal spray powders like Ni, Cr, B, Si tungsten carbide that are applied to shoulder and snails, mixers, skids, conveyor chains and other objects exposed to abrasive wear.

One of the surface treatment which allows to achieve changes in surface layer is laser heat treatment (LHT). Remelted surface layer achieve in nodular iron by this method could characterize by hardness increase comparing to the bulk material [11]. Cast iron after laser remelting or alloying (i.e. with boron) is characterized by better wear resistance, as well [12]. LHT allows to modify locally only those parts of machine elements which are exposed to intensive wear (by friction or corrosion) mostly. The microstructure is very fine and homogenous.

2. Methodology of research object, surface treatments, and techniques of their assessment

2.1. Research object

Foot outmost disk coulter of "Poznaniak" mechanical seed drill produced by the "Famrol" company was used as the research sample (Fig. 1). Seeder co-operates with tractor and width of sowing is 3.0, 2.7, or 2.5 m. It is designed for row sowing oilseeds, cereal, legumes, root crops and some others, and uses Siedersleben system seeding.

The outmost disk coulters is designed as easily exchangeable parts, are attached to the drill by screws. In practice, however, users often do not pay due attention to the quality of sowing and allow for the serviceability limit state of wear without replacement. The outmost disk coulters is flat on one edge formed in the shape of the blade passing a spherical surface with a medium-sized width: 18mm, length: 240 mm, height: 55 mm. Each outmost disk coulter has four mounting holes, and the weight is in the range from 1100 to 1250g. Coulter is made of grey cast iron and surface layer of blade is chilled.

Source: own work / Źródło: opracowanie własne

Fig. 1. Outmost disk coulter of „Poznaniak" seeder
Rys. 1. Stopka redlicy siewnika „Poznaniak"

2.2. Surface layer modifications

Two methods of surface treatments were performed to change the properties of surface layer of outmost disk coulter presser feet:

In the first method - thermal spraying with powder Eutalloy 10112 (Ni-Cr-B-Si with hard carbide phases) using the temperature of the flame 950-1000°C.

In the second method - laser alloying with silicon nitride using the molecular CO_2 laser with 2600W output power and TEM_{01} mode located in the Laboratory of Laser Technology at the Poznan University of Technology (laser beam power was 1000 W and the velocity of its movement relative to the work surface was nearly to 2 mm/s).

2.3. Wear test

Outmost disk coulter has been tested by extensive wear in "rotating bowl". The choice of this method has contributed to the fact that the nature of the relative motion between the sample and the abrasive medium is similar to the movement of agricultural or machinery equipment tools during operation. The test stand allows to conduct research in specified soil compactness and humidity. The device is equipped with an engine with inverter and the rotational speed can be set in the range of 0 to 27 rpm, which translates into a linear speed in the range from 0 to 8 km/h at the periphery of the bowl.

The test stand has been also equipped with regulating system which allows displacement of tested samples relative to the bowl in both horizontal and vertical directions.

Moreover, the soil compactness can be changed by the roller which moves in guides. The roller clamping force is applied and controlled by screw. Another piece of equipment is the soil conditioner which can regulate soil compactness or can be completely disconnected from test stand. The moisture of abrasive medium can be regulated by the irrigation system.

As an abrasive medium was selected river sand. It was caused by a high proportion of very hard quartz particles in relation to other soils ensuring perfect abrasive conditions. Investigation of the mechanical composition of the soil was performed during the experiment. It was caused by objective evidence from other studies that it could have big impact on the intensity of wear [10].

Sieve analysis of the abrasive medium has enabled screening 1000 g of soil and allowed for determination of particle size distribution curve. The curve analysis was concluded that sand was optimal granulation with a very small share of gravel and dust fraction (less than 3%).

During the experiment the temperature was in the range 20-23ºC, and the humidity of the abrasive medium within 7-13%.

For the experiment up to 6 pieces of outmost disk coulter were selected and properly prepared from all variants of surface treatment. Each outmost disk coulter before placing on the test, has been thoroughly cleaned using ultrasonic cleaner and then weighed. Distance of abrasive way was in average 100 km ± 3km, which corresponds to approximately 35 hectares sowing field, assuming that width drill is 3.5 m [1].

All samples were tested under the same conditions, which allowed to compare the results. Loss in weight before and after test was checked and the calculation of the intensity of wear results was presented in tabular and graphical form. It could determine the effect of surface treatment on the abrasive resistance of the tested outmost disk coulter.

Due to the difference in linear velocities occurring at different distances from the axis of rotation of the bowl, each sample was inverted while the direction of rotation position. This action allowed for all three mounted samples cover the same distance.

To obtain correct wear parameters for tested samples was set to in fitted distance of approximately 12 cm one from each other. It does not influence on flow around stream of ground. Linear velocity for the three samples mounted at different distances from the axis of the rotating bowl amounted to 6.4 km/h 5.4 km/h and 4.3 km/h. As a result of this changes within the individual coulter from the axis of rotation managed to get an equal way of friction for all the outmost disk coulters, regardless of their distance from the axis of rotation. The diameter of bowl was 1600 mm and the linear speed along the circumference was 7.2 km/h.

The working depth of outmost disk coulter was set to 4 cm. The conditions set up are corresponding with one of the most popular cereal seeder and outmost disk coulter.

During the tests the following parameters were measured: the linear velocity, distance travelled, humidity, abrasive medium and temperature. The studied parameters were the values value of wear intensity per travelled distance.

2.4. The way of the surface layer and wear tests assessing

The studies consisted of macro- and microscopic research carried out on the cross section to the wear surface using Epiquant Zeiss light microscope and 3212 ZWICK hardness Vickers tester was used to assess the result of the surface modification. During hardness measurement 100G load were used.

The wear tests were assessed using weight measurement of outmost disk coulter presser feet before and after wear tests using weight Radwag model PS 1000/Y with 0,001 g precision.

3. Results and disscusion

The initial examination of outmost disk coulter intended for surface modification and wear test showed large imprecision of the dimensions like oscillations of the main line dimensions, imprecisions in case of implementation and deployment of the mounting holes, variations in thickness and weight of the particular outmost disk coulter were characterized by a high roughness and small dents.

Macroscopic research of outmost disk coulter surface after modifications showed that, after thermal spraying (in opposite to laser alloying) quite large modified areas were obtained – approx. ¼ of the whole surface of the outmost disk coulter (fig. 2). The surface of created coat was characterized by reduced roughness in comparison to the rest cast. But, some imperfections like gas blisters and incompletely melted powder particles were observed. After laser alloying the width of the modified area was relatively small and was about 4mm (Fig. 2). One side track with a length of only 50mm at the edge of the outmost disk coulter was obtained. The edge of the outmost disk coulter was rounded and smoothed as a result of laser remelting.

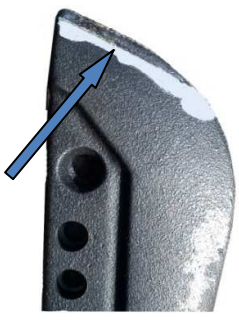
It was observed that, after wear test surfaces of the sides of all outmost disk coulter cooperating with the ground soil were wiping, and the blade edges have been rounded. As a result of intense friction outmost disk coulter without additional modification have been smoothed out and gained polished. The side surfaces could be seen also small grooves in accordance with the direction of movement of abrasive particles. The side surface view and the edge outmost disk coulter without any additional modification after the wear test was shown in fig. 3.

Source: own work / Źródło: opracowanie własne

Fig. 3. The side surface view and the edge of outmost disk coulter without any additional modification after the wear test

Rys. 3. Widok powierzchni bocznej i krawędzi stopki redlicy w stanie wyjściowym po eksperymencie

Outmost disk coulter feet after thermal spraying were characterized by matt surface with the lack of signs of grooves. But small exfoliation of the coating was observed. It was also noticed, that their impact strength was lower than before the experiment. In case of outmost disk coulters after laser alloying their surfaces were characterized by high roughness than surfaces of outmost disk coulters with absent additional surface modification but their edges rounded up less.

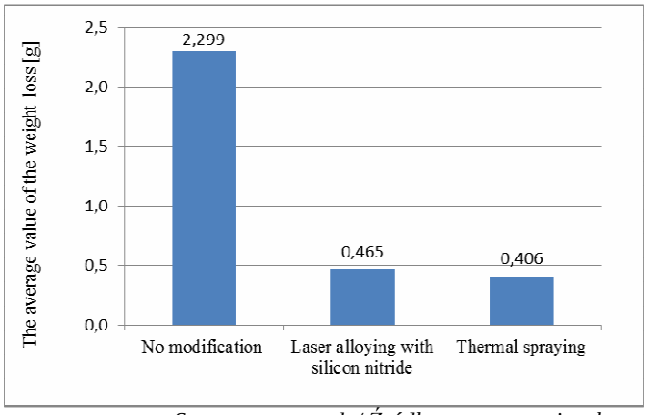
Variant	I	II	III
Treatment	No modification	Thermal spraying	Laser alloying with silicon nitride
The view of the edge of the outmost disk coulter			

Source: own work / Źródło: opracowanie własne

Fig. 2. The surfaces of the edge of the outmost disk coulter before wear test (with marked modified areas)

Rys. 2. Powierzchnia czubów redlic przed testem zużyciowym z zaznaczonymi strzałką obszarami zmodyfikowanymi

The results of weight loss of the outmost disk coulter feet with absent additional surface modification were characterized by the largest wear loss deviation rates (50%). Though 50% deviation rate is relatively high value, it should be taken into account results obtained by other researchers [3,5] this value is within the normal limits. The differences in material of outmost disk coulter foot could be the reason of this effect. It can be expected that the manufacturing process and whitening of gray cast irons is not completely stabilized and does not provide dimensional repetition. Therefore, similar state of the surface layer is probably not provided. In case of outmost disk coulter after thermal spraying and laser alloying wear loss deviation rates are smaller. It may be the result of modifications performed in technology which allows to stabilize the machining parameters better. The weight loss of the outmost disk coulter values are shown in fig. 4.



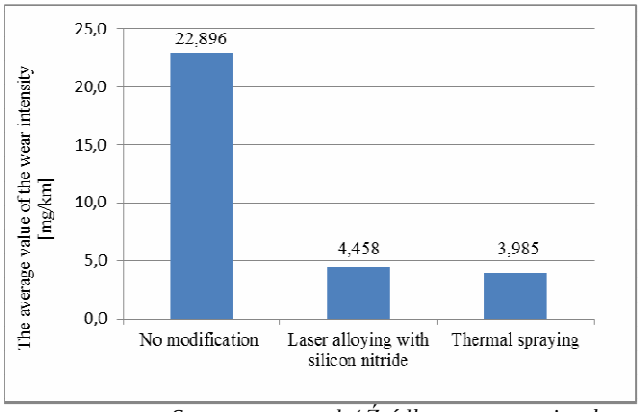
Source: own work / Źródło: opracowanie własne

Fig. 4. The values of the weight loss of outmost disk coulter
Rys. 4. Średnie zużycie wagowe stopek redlic

The highest values were obtained for the outmost disk coulter without additional surface modification. After laser alloying with silicon nitride the average value of the weight loss was 5-times lower and after thermal spraying was 6-times lower in comparison to weight loss of outmost disk coulter without additional surface modification. The average values of the wear intensity (the weight loss value calculated per working distance [µg/km]) are presented in fig. 5. The outmost disk coulter without additional surface modification were characterized by average value of the wear intensity of 23 µg/km. These values, calculated per kilometer, might not seem to be large. But it should be taken into account that particular working element has to cross about 285 km if 100 h of filed needs to be sow.

Consequently, the obtained results confirmed that the modification of the surface layer of outmost disk coulter feet significantly affects the abrasive wear intensity in sandy soil.

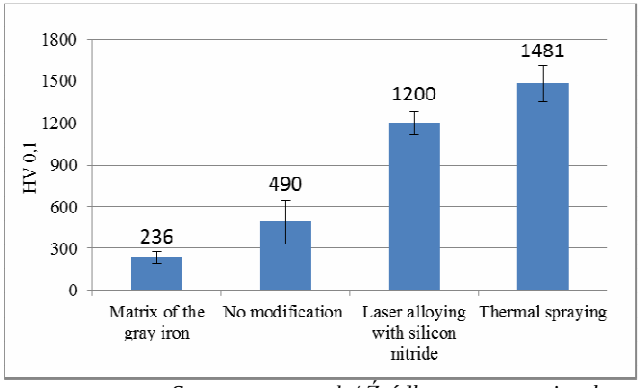
The microstructural studies have shown that the outmost disk coulter after thermal spraying received a coating heaving 0.05 mm thickness with microstructure-rich carbides. The surface layer obtained by laser alloying was characterized by dendritic microstructure, similar to hardened white cast iron. The thickness of alloyed layer was approx. 0.20 mm. The microstructure of the layer after laser alloying was very fine and homogenous, especially in comparison to typical white cast iron. This microstructure was additionally enriched with silicon nitride. The average hardness of coat after thermal spraying was 1500 HV0.1.



Source: own work / Źródło: opracowanie własne

Fig. 5. The values of the wear intensity of outmost disk coulter [µg/km]
Rys. 5. Intensywności zużywania dla różnych wariantów obróbki powierzchni stopek redlic [µg/km]

The surface layer after laser alloying with silicon nitride was characterized by lower value of average hardness – approx. 1200 HV0.1. Taking into account that white cast iron (occurring at the edge of outmost disk coulter without any additional surface treatment) is characterized by average hardness of about 500 HV0.1 2,5-times hardness increased could be stated after performed surface treatments. In comparison to the matrix of gray iron (230HV1.0) 5-times increased of hardness occurred in surface layer after performed surface treatments (fig. 6).



Source: own work / Źródło: opracowanie własne

Fig. 6. The average hardness of the edge of the outmost disk coulter with and without additional surface treatments and the average hardness of the matrix of gray iron
Rys. 6. Średnie twardości warstw powierzchniowych ostrzy redlic bez i po obróbkach wraz ze średnią twardością osnowy żeliwa szarego płatkowego

4. Conclusions

The study confirmed that there are technological possibilities of increasing wear resistance of agriculture tools (or equipment for earthmoving equipment), especially those made of widespread cast iron. Longer lifetime operation, before reaching the serviceability limit state of wear brings quantifiable economic outcomes. In this way can reduce the intensity of equipment wear working in the soil. Obtained results have great importance in the context of the annual crop of more than 14 million hectares of land in Poland.

The performed research showed, that by applied surface treatments it is possible to change the microstructure of outmost disk coulter surface layer and in this way increase

their hardness and wear resistance. By laser alloying 2,5-times and after thermal spraying 3-times hardness increase was achieved in comparison to untreated outmost disk coulter. Part of modified area after laser alloying was considerably smaller than after thermal spraying. Wear of outmost disk coulter after laser alloying was 5-times and after thermal spraying was 6-times smaller than wear of outmost disk coulter without treatment.

Both treatments allowed to considerably decrease wear of tested elements, but taking into account size of modified areas, laser alloying could be more effective treatment than thermal spraying.

The study discussed in this paper allows one to conclude that, it seems reasonable to continue research on the effect of various surface modifications and anti-wear coatings on the wear process in an abrasive medium.

Currently, laser treatment and coating by flame spraying are not used on a mass scale, either in manufacturing or in refurbishment of machine parts working in soil.

The problem of excessive wear affects many working elements of construction and farming equipment. The study showed that there exist ready-to-use technologies for improving operational performance and delaying terminal wear.

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