

Reduction of Ploughshare Wear by Means of Carbide Overlay

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An intensive abrasive wear of agricultural machines and their parts occurs at the soil processing. An undesirable change of a tool surface occurs owing to the wear. Namely ploughshares of a plough are intensively abrasive worn. This undesirable change leads to a function loss. The paper deals with an evaluation of the ploughshare service life. The aim of the research was to evaluate the wear of the ploughshare with a layer of a carbide hardfacing OK Tubrodur 15.82 deposited on a bottom side of the ploughshare. The research was performed within a laboratory testing (a hardness HV30 and a wear) and field tests. Laboratory experiment results proved that the overlay material showed a significant increase of the wear resistance and the hardness. These conclusions of the laboratory testing were certified at the field tests. The research results certified this procedure as an efficient solution at the decreasing of the ploughshare wear at the ploughing.

Keywords: hardfacing, field tests, hardness, wear, SEM

1 Introduction

An engineering production fulfils requirements of single production areas in which its products are applied. An agriculture techniques are one of these areas in which many specifics have to be satisfied. Also the soil processing belongs among them. The significant abrasive wear of working tools of agricultural machines determined for the soil processing occurs at the soil processing [1, 2, 3]. The agricultural soil processing belongs to basic elements in a process of a crop production in which engineering products are utilized, i.e. namely plough bodies equipped with ploughshares which are considerably worn [4, 5]. The wear is a significant factor acting under production as well as user conditions [6, 7, 8].

Agricultural ploughs belong to the basic equipment of a farmer at the soil processing. Function complexes stop fulfilling their function owing to the abrasive wear. It is necessary to replace them. This replacement requires increased economic costs but mainly a shutdown of the machine caused by the replacement of parts. This replacement is very laborious and time demanding.

The interaction between the agricultural tillage equipment and the soil constitutes a complicated tribological problem. The mating surfaces of this tribosystem possess quite different properties, as the metallic tillage tool rubs on the soil [9]. The wear and the wear rate determination of tillage tools are necessary because the wear seriously affects a production planning, a tillage quality, an energy consumption (or power losses) for the tillage process each time performed and finally the production costs of agricultural products [9].

Implements for the primary tillage are mainly of three basic types: mouldboard ploughs, tined implements and disc implements [10]. Tillage tool wear in agricultural machinery used for soil processing is a consequence of a metal interaction with natural hard and sharp soil particles, which are continuously supplied, as the tool breaks the soil and has to overcome frictional forces [9]. This wear is characterized by a reduction of the tool volume and by a change of its shape which causes a decrease of

the work efficiency at the soil processing. This wear is characterized by a reduction a tool volume and by a change of its shape which causes a fall of the work efficiency at the soil processing. In order to elongate the service life of the soil processing tool, it is necessary to perform a research in an area of materials and their heat processing, prospectively to add a wear resistant material in a form of plates of sintered metals onto exposed sites or to perform overlays distinguished for increased wear resistance [11, 12]. This research has one aim and that is to increase a serviceability of given tool. There is a number of accesses how to increase the service life of those worn parts of machines. E.g. new materials, coatings, technical ceramics, hard-core overlaying etc. [13, 14, 15, 16]. An implementation of a preventive renovation, e.g. by means of the overlaying is one of possible ways how to keep the product under an operational condition [17]. Properties of a functional surface of tools and parts can be purposefully changed at keeping original properties under the surface [17]. The overlaying belongs among classical methods. It enables to decrease successfully the wear and connected frequency of an exchange of wearable parts which process the soil [17]. The wear of the ploughshare, at which a geometry change and mass losses of the material occur, is significant at the conventional soil processing. These pieces of knowledge from the wear process of the tools processing the soil are possible to use to defend, by means of the hard-core overlays, the exposed sites where the significant wear occurs. A different geometrical arrangement of an overlaying layer, i.e. a caterpillar can be used at the overlaying with the aim to copy a course of the processed soil outlet [16, 18]. This solution seemed to be effective. Horvát et al. ascertained in their research that it was possible to reach higher ploughing speed at the soil processing and smaller fuel consumption at the same time at the use of the hard-core overlaying materials, e.g. on the ploughshares [19].

According to Natsis et al., when a cutting edge of a mouldboard ploughshare thickness is increased from 1 to 6 mm, the fuel consumption is increased by 41% [20]. It is necessary to approach cautiously to the increase of the

ploughshare thickness from that reason [3, 11, 21]. The ploughshare is one of the most stressed parts of a ploughing body and considerable requirements are put on it. It has to fulfil namely a tenacity and the abrasive wear resistance [3, 11, 21]. Hard particles contained in the soil (siliceous sand, stones) which significantly abrasive act the working tool are the main causes of the increased ploughshare wear. A size, a shape and a hardness of soil particles, climatic conditions, a soil compaction and a soil moisture of course belong among basic factors affecting the abrasive wear intensity [3, 11, 21]. These basic factors act the change of the ploughshare geometry when also a reaction of a vertical force is changed which acts a ploughing the plough from a furrow [9, 20]. A deterioration of the plough quality, a deterioration of an ability to process plant residues, more difficult devotion etc. belong among negative consequences, difficult to assess economically [22]. A change of the ploughshare shape belongs among significant negatives at fulfilling its function [19]. The unsuitable shape leads to a stop of the work and a necessity to exchange it, so it contributes to high costs per ploughing [19]. An essential part of the force spent for the soil cultivation is changed into losses connected with the wear. As the soil cultivation is one of the most energy demanding operations, the tools wear represents an essential problem [23].

The wear resistance of the ploughshare is connected namely with the surface hardness. The wear speed is decreasing with increasing hardness [9]. The tools processing the soil are usually made from carbon and low-alloy steels and they provide an adequate abrasive wear resistance owing to their price [19]. A creation of an adequate overlay which does not increase significantly the tool price is one of possibilities how to increase the wear resistance of these tool [19]. It is obvious from the research results that a reinforcement of a front and a back part of the ploughshare is not sufficient for the wear resistance increase [18, 24]. Results of the change of the cutting edge height for fastening to shanks, the length from the bottom edge to the cutting edge top, the change of the ploughshare head length and the mass of the cutting edge did not explicitly prove the added value by performing the overlay on the upper site of the ploughshare [24]. The course of partial dependences was similar with minimum differences [24].

The aim of the research was to evaluate the wear of the ploughshare with a layer of the carbide hardfacing OK Tubrodur 15.82 deposited on the bottom site of the ploughshare. The research was performed within a laboratory testing (hardness HV30 and wear) and field tests. The paper deals with an evaluation of the service life of the ploughshare with welded carbide hardfacing OK Tubrodur 15.82. It is the overlay material determined for parts working under abrasive conditions with a combination of impacts at higher temperatures. The research focused on a reduction of the wear is essential not only from the economical point of view which is not always the primary aim but the main goal is to extend the time of machine working before the exchange of worn parts.

2 Material and Methods

Field tests with ploughshares at the ploughing were performed within the testing of the service life of tools under the field conditions, i.e. a change of the tools shape, a mass loss, a change of the edge shape were observed. The wear and the hardness were evaluated at the overlays on the ploughshare within the laboratory experiments. Results of the experimental part were completed with the results from a scanning electron microscopy (SEM).

A five-share mounted conventional plough Ross PH 1-435 trailed by a tractor Zetor 12045 was used for the field tests. Experiments were performed on a piece of land in a locality Nesperská Lhota near Benešov. The soil was sandy-clay cambisol with a high skeletalilty. This type of the soil shows a high abrasion of wearable parts of machine for the soil processing. The ploughing resistance was very high and the abrasive wear was above average compared to the normal. This piece of land was chosen purposely owing to the extreme wear at ploughing under these conditions. A total ploughed area within the experiment was 16 ha. Keeping approximately the same soil conditions within chosen piece of land was the reason. The measurements were performed on all five ploughshares from which three were overlaid (variants 1 till 3) and two were without the treatment (a standard ploughshare from a secondary production was the comparing standard).

The research within the field conditions was focused on the innovations of the ploughshare in the area of the conventional soil processing, namely on the increasing of the ploughshare service life by means of overlaying oblique deposited abrasive wear resistant overlaying material on the back side of the ploughshare. Keeping the optimum geometry of the ploughshare was the reason because the soil is leaving on the front side. Classical ways of overlaying, forming on the front functional side increase the ploughing resistance. A deviation from the optimum geometry occurs and inequalities come into being on the functional part draining the soil.

The carbide type of the hardfacing material OK Tubrodur 15.82 (PZ 6168) was the overlaying material. It is a tube wire from ESAB Company of a diameter 1.6 mm which is filled with a metal powder. It is suitable for overlaying the wear resistant layers. Its hardness ranges between 56 to 61 HRC and it is very abrasion resistant. A typical chemical composition stated by the producer is following: 4.5 % C, 0.7 % Si, 17.5 % Cr, 0.9 % Mn, 5 % Nb, 1 % V, 1 % W and the basis is created by Fe.

The overlaying material was deposited parallel to a ploughshare head, both in front part as well as in back part and bottom edge of the ploughshare cutting edge (fig. 1). The new surface was created by means of the overlaying which is presented in the fig. 2 - an automatic welding machine ESAB LAF 635 DC (an electric arc). The overlaying material was the tube wire of a mean 1.6 mm. Welding parameters are following: current 250 A, voltage 25 V, speed of overlaying 250 mm.min⁻¹. The weight of consumed hardfacing material OK Tubrodur 15.82 was 100 g at the variant 1, 170 g at the variant 2 and 300 g at the variant 3.

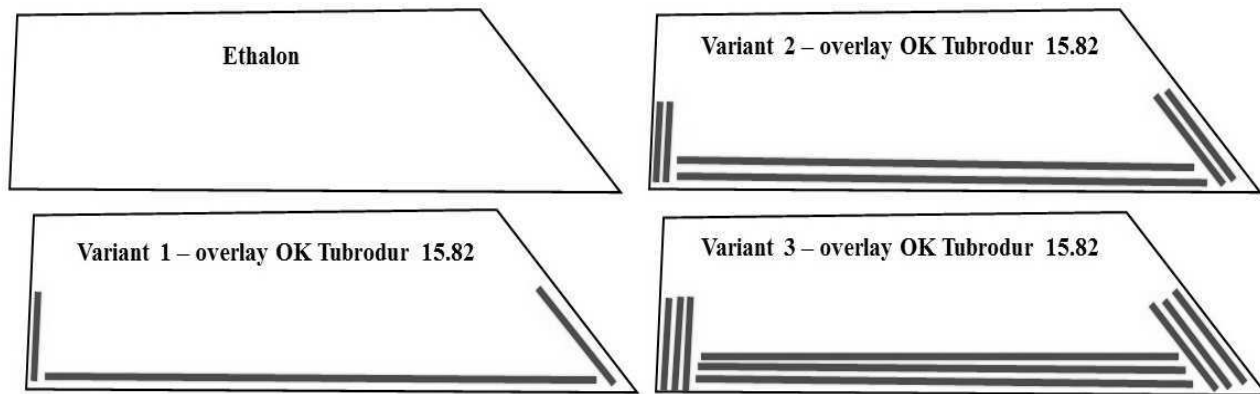


Fig. 1 Variants of experiment and location of overlaying material on ploughshare



Fig. 2 New surface created by means of overlaying – Automatic welding machine ESAB LAF 635 DC

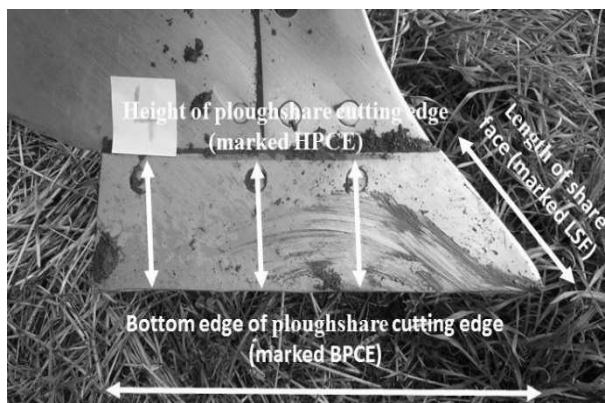


Fig. 3 Ploughshare with oblique overlay and position of measuring points

A method of a size and a mass analysis at field tests was chosen for measurements of the ploughshare service life. The location of the ploughshares on the plough changed after 2 ha. The measuring of the ploughshares was performed after 2 ha. Subsequently, the ploughshare was shifted of one position on the plough. This eliminated an uneven wear in particular places of the plough. Fig. 3 shows a schematic presentation of the geometric solution and a position of the measuring points. The places for measuring the change of dimensions passed through an axis of holes for fixing to a shank, i.e. the edge height in 1st hole for a screw, the edge height in 2nd hole for a screw, the edge height in 3rd hole for a screw (marked as

HPCE), a length of the bottom edge on the top of the ploughshare blade (marked as BPCE) and a length of the ploughshare face (marked as LSF).

The methodology of the overlay materials evaluation at the laboratory testing came from a mutual comparison of the wear resistance according to the standard ASTM G65 and the hardness HV. The hardfacing material OK Tubrodur 15.82 which had been overlaid on the ploughshare was subsequently grinded to a plane magnetic grinder with the aim to gain test samples corresponding by its shape and dimensions to requirements of the device with a rubber disc. The test samples were prepared with dimensions 51 x 25 x 7 mm. The abrasive wear resistance test was performed according to the standard ASTM G65, i.e. on the device with the dry rubber wheel.

The wear test principle is that the sand particles of a fractionally 0.2 to 0.315 mm fell between the test sample and the rubber wheel. The sample loading was 100 N. The rubber wheel diameter was 210 mm and the width was 12.5 mm. The test samples were cleaned with isopropyl alcohol in an ultrasonic bath and dried with a hot air before and after test. Mass losses were measured with a accuracy 0.1 mg on laboratory scales KERN ABS 120.

The hardness measuring of the overlay and the ploughshare (the comparing standard) was performed according to Vickers on the device Durajet G5 Rockwell Hardness tester enabling to measure the hardness also according to Vickers, namely in accordance with the standard CSN EN ISO 6507 – 1. The loading force was 294 N.

The worn surface of the ploughshare and the overlayed samples were evaluated on SEM TESCAN MIRA 3 GMX with a detector SE and BSE. The accelerating voltage was 25 kV. SEM analysis helps to understand the results of mechanical tests. Measured values were processed by means of statistical analysis methods (program STATISTICA). ANOVA was used for the statistical comparison of measured data. P-values were determined by means of ANOVA F-test. They enable to compare a difference of tested sets. The zero hypothesis H_0 indicates the state when there is no statistically significant difference among single compared sets of data in terms of their means: $p > 0.05$.

3 Results and Discussion

It was determined on the base of the laboratory tests,

i.e. the evaluation of the overlaying material and the comparing standard (the ploughshare) and their mutual comparison in the wear resistance according to the standard ASTM G65 and the hardness HV30 that the material overlaid on the basic material of the ploughshare showed considerably better wear resistance and the significant increase of the hardness at the same time. This material is

expected to increase the service life of the ploughshare also under the field conditions at the soil processing. The laboratory test results are visible in tab. 1. The ploughshare microstructure showed tempered martensite. The hardfacing OK Turbodor 15.82 microstructure includes austenite and chromium rich carbide eutectics plus niobium carbide particles.

Tab. 1 Laboratory test results

Experiment variant	Ploughshare	Hardfacing OK Turbodor 15.82
Mass losses – tests according to ASTM G65 (g)	0.0160 ± 0.0018	0.0051 ± 0.0018
HV30	266.0 ± 48.2	1103.3 ± 59.7

Results of mass losses, BPCE and LSF are presented in tab. 2. It is obvious from the result of BPCE parameter that the ploughshare with the overlay is less worn. The ploughshare without the overlaying material lost ca. 30 % of the length BPCE after 14 ha of the ploughing. Analogous behaviour showed also the parameter LSF. The fall of 55 to 60 % on average occurred at the overlaying material. The fall of LSF was more significant, namely in the

interval 66 to 69 % at the ploughshares without the overlay. Mass losses are stated only for orientation reasons. It was not possible to secure an exact determination of mass losses after 2 ha under the field conditions. Even so the ploughshares with the overlaying material showed smaller mass losses compared to original ploughshares marked as the comparing standard.

Tab. 2 Results of measured values after 14 ha of ploughing (average values from measuring data gained after 2 ha of ploughing)

Experiment variant	Comparing standard 1	Comparing standard 2	Overlay 1 layer	Overlay 2 layers	Overlay 3 layers
Mass losses – field tests (g)	372 ± 67	401 ± 85	291 ± 89	316 ± 56	359 ± 70
BPCE (mm)	487 ± 55	493 ± 52	509 ± 41	506 ± 38	506 ± 39
LSF (mm)	140 ± 42	148 ± 41	153 ± 38	155 ± 36	154 ± 39

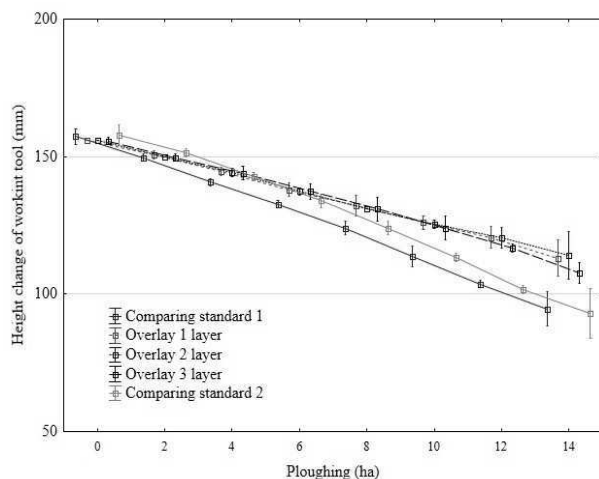


Fig. 4 Course of height change of working tool at soil processing

Results of field test are visible in fig. 4. The overlay on the bottom part of the ploughshare increased the wear resistance. This state lasted to a significant wear of the basic material of the ploughshare in the area of the overlay. Subsequently, this overlay was broken off. Used overlays considerably decreased the wear. This was manifested itself namely in the time when the cutting edge of the blade was identical with the location of the overlay in a longitudinal direction. The wear was reduced in this time. The wear was the same as at the comparing standard

without the overlay after the wear of the blade part where the overlay was placed. Designed solution of overlays has a potential for a practical application at one-component as well as divided plough blades. It was ascertained by a statistical comparison by means of ANOVA F-test that there is no statistical difference until 2 ha of the ploughing among five tested variants (the comparing standards and overlay variants according to a number of layers 1 to 3). Following sets show statistical differences. It is obvious from the statistical comparison of three overlay variants (1, 2 and 3 layers) that there is no significant statistical difference. The tested parameter p was in the interval 0.0550 to 0.5787. So it is obvious from the results that there is no significant difference among the wear of the ploughshare with one, two or three overlay layers.

If the overlay is placed on the upper side (front) of the ploughshare, it is worn flat above. This type of the overlays is used the most often. If the overlay is placed on the bottom side (back) the ploughshare is worn rather from side. An acting of forces in a direction of the ploughing is the reason. The wear process of the ploughshare is significant in the upper (front) side where it comes to faster wear of a relatively soft material of the ploughshare. The overlay placed on the bottom side of the ploughshare is not almost worn. At first it comes to the wear of the ploughshare material, i.e. the material over the overlay and occasionally first overlaying layers where the overlaying material was mixed with the basic material. The sharp edge is generated which is created by the overlaying layer which supports the soil cutting and it elongates the

service life of the ploughshare. It does not come to a significant change of the geometry. These conclusions were certified within the research and they are visible from fig. 4.

In case the overlaying material would be placed on the front (upper) side of the ploughshare the abrasive particles would wrap around the overlaying material at the soil processing. An increased wear of the basic material of the ploughshare would be probably happen behind the overlaying material.

Tab. 3 Equations of linear functions: y – tested parameter, x – ploughing (ha)

Description	Functional equations	R^2
Comparing standard 1	$y = -4.5139x + 158.64$	0.99
Comparing standard 2	$y = -4.759x + 160.5$	0.99
Overlay 1 layer	$y = -3.0516x + 156.53$	0.99
Overlay 2 layers	$y = -3.0099x + 155.86$	0.99
Overlay 3 layers	$y = -3.377x + 159.89$	0.99

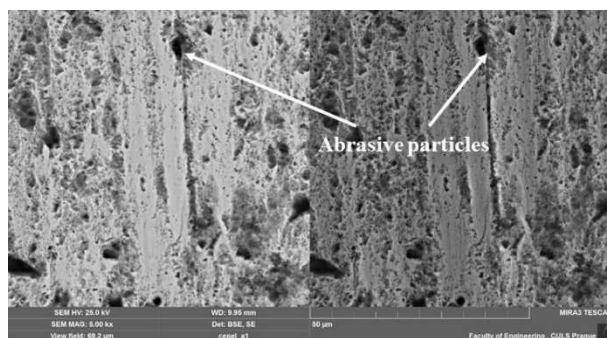


Fig. 5 SEM image of worn ploughshare (MAG 5.00 kx)

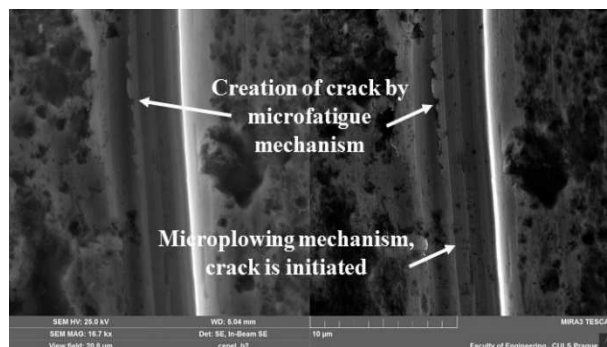


Fig. 6 SEM image of worn ploughshare (MAG 8.33 kx)

The worn surface of the ploughshare was tested by means of SEM analysis. The worn surface of the ploughshare without the overlaying material (i.e. the comparing standard) is showed in fig. 5 and 6. It is obvious from the results stated in tab. 1 that the ploughshare was of relative low hardness, i.e. ca. 266 HV30. This was also manifested itself by a wear way when abrasive particles were easy intended into the ploughshare surface (dark particles represent differently large particles of the abrasivum). A detail of a crack creation at a microfatigue mechanism at the ploughshare material wear is obvious from fig. 6. The microfatigue is connected with a mechanism of worn material removal at the abrasive wear called microplowing

For the correct evaluation it is also important to determine the determination index R^2 . It is the problem of the correlation analysis. The values of the determination index can be from 0 to 1. So far as R^2 equals to 1, there is a perfect correlation in this sample (so there is no difference between a calculation and real values). The functions presented in fig. 4 are determined by equations in table 3. A strong dependence is obvious from the values stated in tab. 3.

when a new abrasive particle acts the worn material after the groove creation and causes a new deformation in already deformed area of the plow (fig. 6). This wear principle results in a wall creation which is plastically deformed. Subsequently the worn material (a chip) is divided from the ploughshare surface. Places on the bottom of the plow caused by the wear process are also visible in fig. 6. The crack initiation is evident.

The worn surface of the ploughshare with the hardfacing material OK Tubrodur 15.82 is evident from fig. 7, 8 and 9. The niobium carbides were expelled in the overlaying material which stopped the abrasive particles (fig. 7 and 8). It is also obvious from fig. 8 that it came to the indentation of abrasive particles into softer overlay matrix.

Abrasive particles created plowes on the surface. The detail view on the plow is visible in fig. 8 and 9. The place where the abrasive particle disturbed the overlay at the wear by the microcutting process is evident in fig. 9. The microcutting leads directly to dividing of the worn material from the ploughshare surface, chips without a creation of lateral walls in the worn material are created and a total volume is taken.

The overlay material was worn by more mechanisms together, so the microfatigue with a small portion of the microcutting of the overlay matrix and the microcracking mechanism of niobium carbides went on. The microcracking shows itself namely at brittle materials.

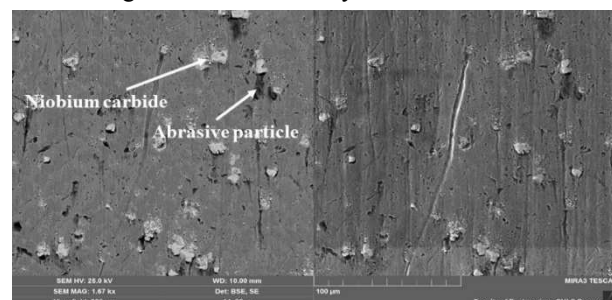


Fig. 7 SEM image of worn ploughshare with hardfacing OK Tubrodur 15.82 (MAG 1.67 kx)

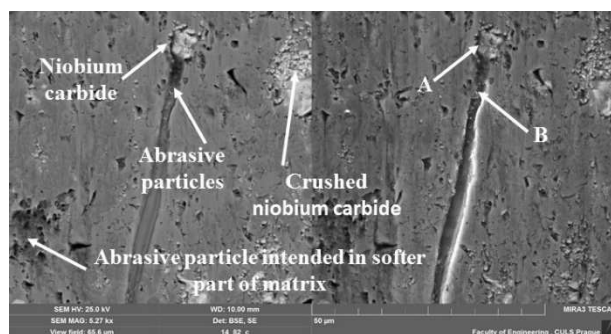


Fig. 8 SEM image of worn ploughshare with hardfacing OK Tubrodur 15.82 (MAG 5.27 kx)

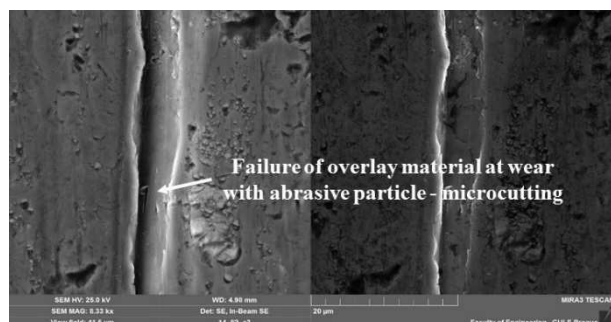


Fig. 9 SEM image of worn ploughshare with hardfacing OK Tubrodur 15.82 (MAG 8.33 kx)

Results of the research focused on the increase of the ploughshare service life by means of the overlaying material deposited by a minimization technology on the back part of the ploughshare confirmed conclusions of other studies dealing with a material and constructional research in the area of the soil processing [3, 5, 9, 11, 21].

The longer life of tillage tools enables greater productivity not only by a higher rate of work, but also through a reduction in changeover time of ploughshares [19]. Abrasive wear of ploughshares is the deterioration caused by hard soil particles because the share material is softer than the natural abrasives in the soil [25]. The wear causes due to highly abrasive soils the surface damage characterised by scoring, cutting, deep grooving and gouging, and micromachining, caused by soil constituents moving at a relative big velocity.

4 Conclusions

Results of the laboratory and field tests, i.e. the ploughshares determined for the ploughing are introduced in this paper. Properties of the ploughshare was improved by the hardfacing overlaying of the hardfacing OK Tubrodur 15.82 deposited on the bottom part of the ploughshare. Results of the laboratory experiments proved that the overlay material showed significant improve of the wear resistance and the hardness. These conclusions of the laboratory tests were confirmed by the field tests. The niobium carbides are the reason. The overlaid ploughshares showed better properties in all tested parameters – both length and weight, and also connected longer service life at the field tests. The difference between the ploughshare with the overlay and without the overlay was proved by the statistical analysis. However, the number of layers of the overlaying material had not

influence on the tested parameters. The statistical analysis did not prove it. SEM analysis proved the mechanisms of the abrasive wear on the ploughshare surface and in the overlaying material. The research results proved the elongation of the utilization time of the ploughshare before its exchange, with this type of the overlay and at keeping tested geometry, i.e. the overlay deposited on the bottom side.

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