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Evaluation of techniques for ploughshare lifetime increase

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Abstract

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Sustainability in a sphere of agricultural commodities production depends on soil processing. The soil is also a considerable abrasive medium which affects in a negative way tools processing the soil. The aim of the research is to increase the lifetime of a mould board by means of a constructional setting of an overlaid material. The lifetime increasing of the ploughshare by means of the overlaying is a much discussed topic. For this reason such strategy for the experiment was chosen which would enable to increase the lifetime at preserving low costs for ploughshare treatment. The research was focused on the ploughshare lifetime increasing by means of overlaying the abrasive wear with resistant material. The ploughshares of one of the leading world producers of the soil processing machines were chosen for the experiment. The aim of the work is to compare two commonly available overlaid materials in the combination with two overlaying techniques.

Keywords: ploughshare; soil; overlaid materials; agricultural machines; wear

Modern technological procedures enable faster motion of machines across a field which leads to requirements for more resistant tools for the soil processing (Čičo et al. 2012). The soil represents very aggressive environment for working parts of agricultural machines; the machine parts are exposed to dynamic load, chemical effect and namely to an intensive wear. All these factors cause a material loss and change of a part geometry which leads to an increase of operation costs, repair and renovation costs and does not last long enough.

The main problem connected with using the soil processing machines is their wear owing to particles embedded in the soil (Müller et al. 2013).

The abrasive wear can be decreased to an acceptable level by means of suitable technologies and of the material choice for production of the whole tool or its part in the area of the highest wear. The newest researches try to find and use such procedures in the ploughshare production which would secure a decrease of a friction between the working tool and soil. This would lead partly to increasing the lifetime of the most loaded parts and partly to decreasing the soil resistance which would save the fuel.

Recently, the ploughshare lifetime increase has become more topical. Creation of more perfect technologies for the soil processing would lead to considerable improvement of the economy of these machines operation. Bayhan (2006) states that the potential savings coming from the friction and wear decrease through improved tribology of agricultural tools would equal to almost 337 million dollars annually.

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There are a lot of approaches to the ploughshare lifetime increasing. Formerly, commonly used constructional and low-alloy steels are replaced by high-tensile wear resistant steel, forged or cast. The most common material worldwide for the ploughshare production is the boron steel. Another possible solution of the problem is a chemical heat processing of the high-quality carbon steel. Yazici (2011) dealt with the increase of the wear resistance by means of the carbonitridation in his research. Mass and dimension losses were essentially lower at the field tests compared with the conventionally heat-treated ploughshares. The mass wear decreased by 14.65% and the dimension by 26.47%. According to the results the carbonitridation seems to be the effective solution to decrease the wear (Yazici 2011).

Other research areas are surface treatments of parts. The most widespread method remains the hard faced overlaying, but recently less known treatments have been tested (Müller et al. 2011; Müller, Valášek 2011; Valášek, Müller 2012, 2013).

The ploughshare is one of the most loaded parts of the ploughing body and huge requirements are put on it. Partly it has to fulfill relatively high strength requirements (namely the impact strength) and partly high resistance to the soil abrasive wear (Müller, Hrabě 2013).

A significant problem is the change of the ploughshare geometry when also the reaction of a vertical force is changed, which affects deepening the plough from a furrow. The negative consequence (although it is difficult to evaluate) is the deterioration of ploughing quality, the deterioration of a possibility to process plant remains, more difficult sinking etc. (Legát et al. 2011).

During the tests carried out in Albania it was found out that the ploughshare thickness influences work speed of a tractor and fuel consumption. This parameter is essential at the overlaying technology application. The change of the ploughshare thickness from 1 to 6 mm caused the increase of the tractive force of more than 60%, the fuel consumption increase of 41% and the work speed decrease of 30% (Natsis et al. 1999).

The overlaying is primarily used for renovations of worn parts, often it is useful to use this technology in new production. So, own part can be produced from cheaper material and the surface properties are reached by overlaying the suitable metal or alloy (Müller, Hrabě 2013).

MATERIAL AND METHODS

The operation tests were carried out in the fields around Týn nad Vltavou, Czech Republic. The test took place on 87 ha of fields at deep ploughing by seven-share double-sided semi-attached plough Kverneland PW 100. A topsoil contained plant remains, the following plant was maize. The ploughing was carried out into the depth of about 30 cm (a deep ploughing) and the tractor speed ranged about 10 km/h. Soil granularity was evaluated by the Novak's method as the sand-clayey soil. Average soil moisture set from ten samples amounted to 19.53 ± 3.12%.

Preparation of tested shares. At first, the layer of a finishing coat was removed manually from shares. The shares were overlaid with the hard faced metal in a form of tube wires of a mean 1.6 mm by means of an automatic welding machine. It was the technique of the overlaying by an electric arc flashing by a continually passed electrode. Because of the semi-automatic way of the overlaying it can be stated all overlays reached the same quality. Materials 14.70 OK Tubrodur and 15.82 OK Tubrodur (ESAB, Vamberk, Czech Republic) were used for overlaying. The chemical composition of the overlaid material OK Tubrodur 14.70 is following: C 3.5%, Si 0.4%, Mn 0.9%, Cr 22%, Mo 3.5%, V 0.4% and that of OK Tubrodur 15.82: C 4.5%, Cr 17.5%, Mo 1%, W 1%, V 1%, Nb 5% (ESAB 2002).

Original shares Kverneland (Kverneland Group Czech s.r.o., Beroun, Czech Republic) were overlaid:

- by an oblique placing of the overlaid bead – the overlays placing was chosen with regard to the direction of abrasive particles affecting the share during its relative motion through the soil. According to the wear of the used share the approximate angle was set 45° towards the share cutting edge. Under this angle six overlays were carried out of a bead length 60 mm. A pitch among the beads amounted to 80 mm. Not only the lifetime increasing but also so called saw-tooth self-sharpening effect were expected at this solution.
- by a horizontal placing of the overlaid bead – the overlay placing in a parallel way with the share cutting is the most often used overlaying technique. Five beads of the length 50 mm were overlaid in two rows. Upper row is shifted towards the bottom one so the "blinded" space is created. The pitch among the beads in the row is 50 mm.

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Owing to this, it does not come to considerable heat influencing of the material and so the share preserves optimum mechanical qualities.

After each bead overlaying the share was cooled to the temperature approximately 60°C so that the basic material was not considerably heat influenced. The amount of deposited overlaid material at the oblique overlaying technique was 42.5 ± 1.5 g for OK Tubrodur 14.70 and 47.0 ± 1.0 g for OK Tubrodur 15.82. The amount of deposited overlaid material was at the horizontal overlaying technique 87.5 ± 0.5 g for OK Tubrodur 14.70 and 76.5 ± 2.5 g for OK Tubrodur 15.82. The overlaying parameters were: current 250 A, voltage 28 V, speed 20 cm/min and energy 21 kJ/cm^3.

The double-sided seven–share plough Kverneland was fitted with eight adjusted and six original shares. Both sides were fitted with the same shares in the same order.

"Oblique" and "horizontal" describe the overlaying technique. Numbers 14.70 and 15.82 show the mean type of the overlaid material OK Tubrodur. The shares order was chosen with regard to the operation loading of single shares.

It is generally known that the first and the last shares have different course of the wear. For this reason the investigated samples were fitted on the bodies 2, 3, 5 and 6. The middle fourth bodies were fitted with the original unadjusted share which served as the comparing standard.

A method of a dimension analysis was chosen for measuring the ploughshare lifetime. During the field test, single dimensions (A till D) of adjusted and standard ploughshares were measured after approximately each 3 ha of the ploughing. Places for measuring dimensions A, B and C passed through the axis of the holes for fitting to a frog, the dimension D was measured on the share heel.

RESULTS

Results of single measurements are visible in Fig. 1. 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. The beginning of the ploughing shows faster material loss which is observed until 9 ha. The reason for that is the constructional shape of the share which is more narrow in the bottom part.

Table 1. Equations of linear functions

Placing on plough – share characteristics	A	B	C	D
1	$y = -0.4575x + 138.59$	$y = -0.5904x + 138.3$	$y = -0.7069x + 138.93$	$y = -0.8877x + 141.89$
2 – obligue 14.70	$y = -0.5497x + 136.42$	$y = -0.7089x + 136.36$	$y = -0.8673x + 138.74$	$y = -1.0654x + 143.76$
3 – obligue 15.82	$y = -0.5197x + 137.27$	$y = -0.6614x + 137.22$	$y = -0.8126x + 139.98$	$y = -1.0012x + 144.19$
4 – comparing standard	$y = -0.5048x + 139.24$	$y = -0.606x + 139.01$	$y = -0.7324x + 140.64$	$y = -0.9198x + 144.61$
5 – horizontal 14.70	$y = -0.531x + 138.7$	$y = -0.6589x + 139.84$	$y = -0.7689x + 141.67$	$y = -0.9232x + 145.78$
6 – horizontal 15.82	$y = -0.4847x + 138.17$	$y = -0.5949x + 139.23$	$y = -0.694x + 142.16$	$y = -0.8061x + 145.84$
7	$y = -0.4663x + 139.39$	$y = -0.5408x + 139.03$	$y = -0.6209x + 140.3$	$y = -0.7623x + 144.13$

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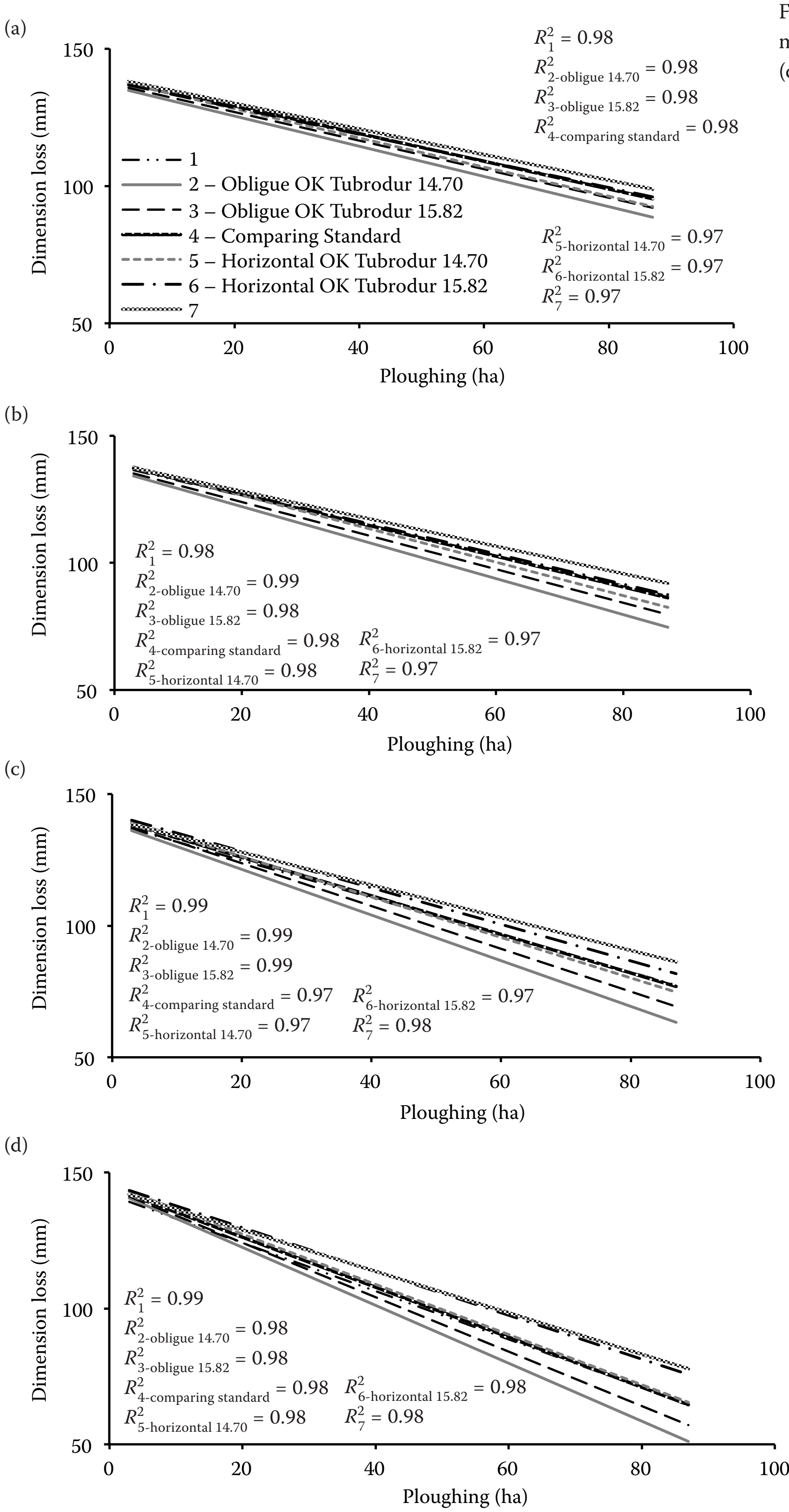

Fig. 1. Course of share wear – dimension parameters (a) A, (b) B, (c) C and (d) D

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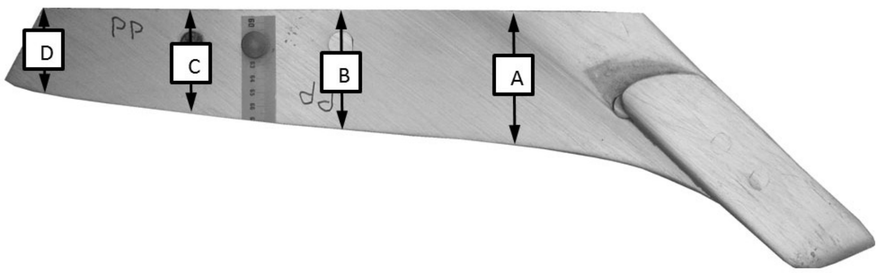

Fig. 2. Worn share (87 ha) with designated places of measurements A–D

The functions presented in Fig. 1 are determined by equations in Table 1.

The results prove that the wear of the ploughshare with exchangeable bit is increased towards the heel (Fig. 2). This fact is given by the constructional setting of the share because the wear of the share front part is taken over by the exchangeable bit from the great part. Because of the fact that the share is most worn from the heel it came to the loss of overlaid material namely from the back part of the share with increasing ploughed hectares. After ploughing 16 ha it came to the total wear of the first overlay.

The results graphical presentation was carried out by means of ANOVA by a least square method (Fig. 3). Tukey's HSD test was used for the statistical comparison of mean values. From the results of the Tukey's HSD test it was obvious that there are not statistically significant differences among data sets at the significance level α = 0.95; thus they belong among statistically homogeneous groups. From the wear point of view the testing variant 6 (that means the horizontal overlay, overlaid material OK Tubrodur 15.82) showed itself by reducing the difference among measured parameters A till D compared with other variants of the test. This conclusion is essential from keeping even shape of the share point of view.

It is true that overlays showed higher wear resistance, but on the contrary the material very close to the beads was worn a little bit faster compared with the rest. This was obviously caused by the tempering and subsequent softening of the material owing to the heat influencing the material near the overlay. Namely at the variant of the share with the oblique overlay the saw-tooth share was created (Fig. 4).

The total wear of the oblique overlays occurred approximately after 59 ha of the ploughing. At the horizontal overlays this state occurred after 87 ha

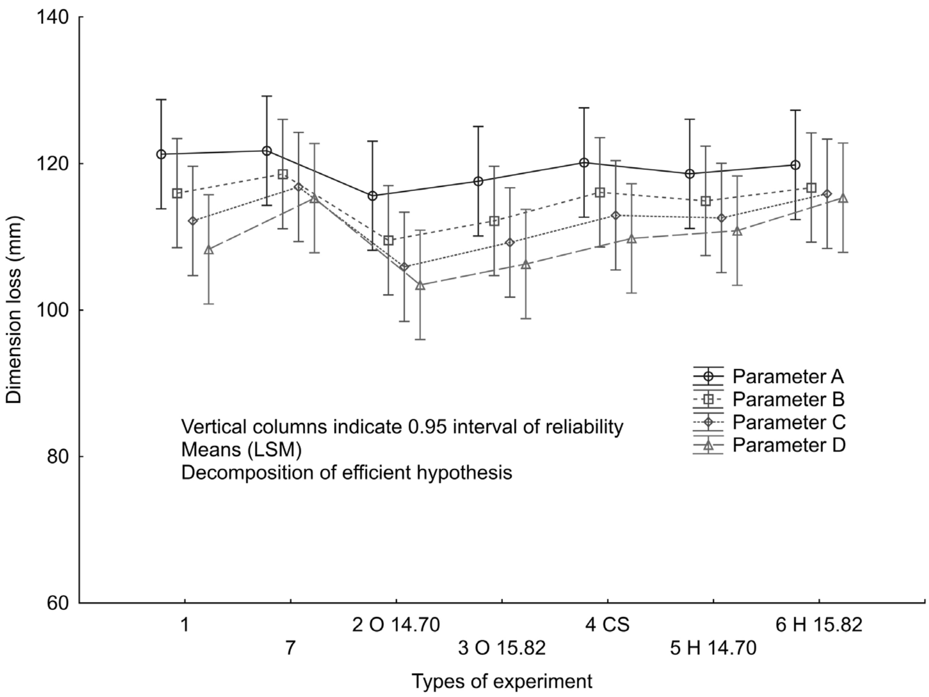

Fig. 3. Change of edge height depending on variant of experiment
O – oblique, CS – comparing standard, H – horizontal

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Fig. 4. Detailed view on wear course at oblique overlays after ploughing 18 ha, added material OK Tubrodur 14.70

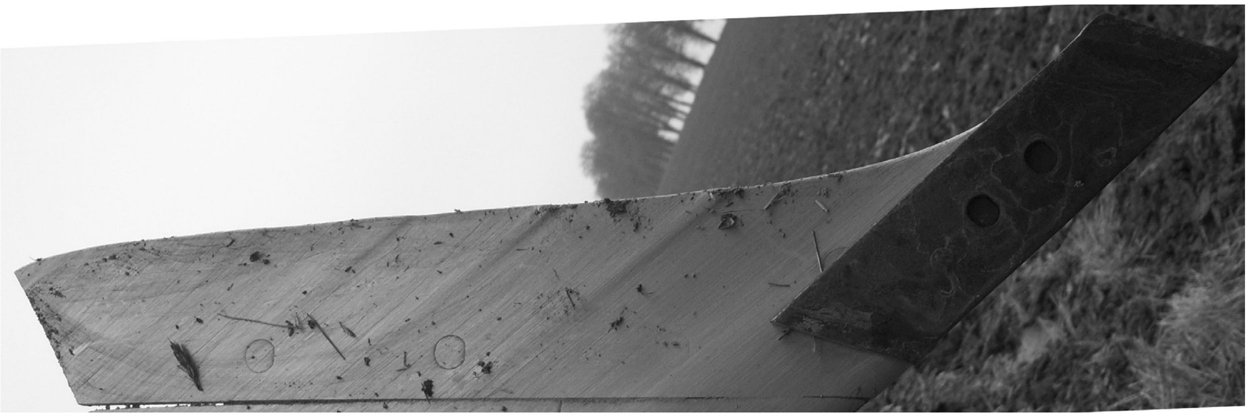

Fig. 5. Wear of ploughshare adjusted with horizontal overlay by material OK Tubrodur 15.82 after ploughing 59 ha

of the ploughing. After ploughing this area it came to the total wear of all horizontal overlays. Furthermore, the fuel consumption was increased considerably at the constant ploughing speed. Fig. 5 shows the wear of the ploughshare adjusted with the horizontal overlays by the material OK Tubrodur 15.82 after ploughing 59 ha.

From the detail of the horizontal overlay wear it is obvious that so called rising edge areas are created during the ploughing (Fig. 6). The rising edge areas are wedge-shaped orientated in the ploughing direction (direction of the wedge).

Fig. 6. Detail of horizontal overlay wear – added material OK Tubrodur 14.70

The horizontal overlays showed better qualities. The reason was the soil layer which "sticked down" free spaces bounded with single overlays. The material OK Tubrodur 14.70 overlaid in oblique as well as in horizontal way causes higher dimension losses. So, it decreases the share lifetime. The material OK Tubrodur 15.82 overlaid in oblique as well as in horizontal way causes smaller dimension losses. So, it increases the share lifetime. However, the optimum method is the horizontal overlaying. It reaches better results compared with the oblique overlays. This solution seems to be prospective from the next research point of view.

DISCUSSION

The wear is the essential point of view in the agricultural production owing to the loss of given part function caused by the change of the geometry which is significant in this segment of the soil processing. The ploughing technology can be mentioned as the sample in which the wear causes an increase of the fuel consumption, decrease of the labour effectivity, the outage time and so on (Natsis et al. 2008). The above-mentioned presumption

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defines definitely the priority of the research focusing on the possibilities of the abrasive wear resistance increase.

Horvat et al. (2008) came to conclusion during the operation tests focused on reducing the wear of a mouldboard ploughshare by means of overlaying that lower fuel consumption and higher rate of work in ploughing were achieved with hard-faced ploughshares compared to regular shares. From the results gained during the measurements we succeeded in proving mild optimum increase of the lifetime of the ploughshare with the horizontal overlay carried out by added material OK Tubrodur 15.82. Such adjusted share showed the wear decrease of 16.9% compared with the standard at the measured dimension D (the share heel) after ploughing 87 ha.

The results clearly show that the heel part of the share is worn much more intensively. The material modification by the overlaying seems to be ineffective for first third till a quarter of the share. In practice, this course of the wear is solved by the additional modification of already worn shares. This modification consists in welding on two worn shares below each other so the share is created which is able to keep processing the soil.

CONCLUSION

The experiment results show that the share modification by the oblique overlays did not bring the lifetime increase. On the contrary, owing to this modification technique it came to the share lifetime decrease. For the future experiments with the oblique overlays overlaying beads with smaller pitch can be recommended. The pitch 80 mm chosen for the experiment did not confirm the presumption of the creation of the saw-tooth self-sharpening effect. Second technique coming from the method of formerly investigated horizontal overlays reached better results. Such adjusted shares in combination with the overlaid material OK Tubrodur 15.82 show a decrease of the share dimension losses of 16%; however, costs put into this modification mean the increase of the basic share price of almost 20%. For this reason the material modification does not pay off from the economical point of view.

The test results comparing two overlaid materials confirm the presumptions of higher resistance of the material OK Tubrodur 15.82 compared with the material OK Tubrodur 14.70. Thus, the material OK Tubrodur 15.82 proved the potential for the applications increasing the lifetime and for modifications of parts working in contact with soil.

For increasing the lifetime of shares with the exchangeable bit, namely the modification of the share back part can be recommended.

As the front part of the share is constructionally protected by the exchangeable point bit, the overlaying of this part is less productive. Using overlays only in places with the largest wear can reduce costs connected with the share modification.

Further, work results confirm the rise of undesirable effect flowing from the overlays usage. Despite the higher resistance of the hard faced overlays the structure influencing the basic material during their overlaying has to be considered. It is true that in the place of the overlay hardness and resistance are increased but in surroundings the share qualities are worsen owing to the heat influence.

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