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Research of a material and structural solution in the area of conventional soil processing

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Abstract. Sustainability in the area of agricultural commodities production depends on soil processing. Ploughshare is one of the most strained parts of a ploughing body and huge requirements are put on it. It has to meet relatively high strength requirements on one hand and high wear resistance on the other hand.
The aim of the research is to increase the service life of the ploughing body by means a structural and material solution. Increasing the service life of a ploughshare by means of overlaying is a much discussed topic. The types of overlay materials of carbides (Soudokay A43-0, OK Tubrodur 14.70, OK Tubrodur 15.82) and martensitic (Filarc PZ 6159) were used. Further, new a functional surface was distinguished for reinforcement of the ploughshare cutting edge. A method of size and mass analysis in field tests was chosen for measurements of the ploughshares service life.

Key words: functional surface, overlays, ploughshare, service life, wear.

INTRODUCTION

The main problem connected with using soil processing machines is their wear owing to the particles embedded in the soil (Chotěborský et al., 2008; Doubek & Filípek, 2011; Hrabě & Müller, 2013; Kejval & Müller, 2013; Müller et al., 2013).

The abrasive wear can be decreased to an acceptable level by means of suitable technologies and choice of material for the production of the whole tool or its part in the area of the highest wear (Horvát et al., 2008; Hrabě & Müller, 2013; Valášek & Müller, 2013). The newest researches try to find and use such procedures in ploughshare production which would ensure decreasing of the friction between the working tool and the soil (Votava et al., 2007; Horvát et al., 2008; Chotěborský et al., 2008; Doubek & Filípek, 2011; Hrabě & Müller, 2013; Kejval & Müller, 2013). This would lead partly to increasing the service lives of the parts under the heaviest load and partly to decreasing soil resistance which would save fuel (Müller & Valášek, 2012).

There are a lot of approaches to increasing the ploughshare service life (Müller & Hrabě, 2013). A significant problem is changing the ploughshare geometry when the reaction of the vertical force is also changed which affects the depth of the plough in the furrow (Hrabě & Müller, 2013).

The properties of the functional surface of the tools and parts are can be usefully changed at keeping original properties below the surface. One of the effective solutions is increasing the wear resistances of the tools processing the soil by means of overlays while creating a new functional surface with an aim to improve the current properties (Chotěborský et al., 2009).

It is possible not only to create a wear resistant surface, but also to use various geometric settings of the overlaying layer (that means the bead) at the same time with the aim to copy the course of draining off of processed soil and to create a serrated cutting edge. An example of a serrated cutting edge is combined shares of tactical knives. A significant benefit of this solution is a possibility to divide the material in an effective way and to sink. These elements taken over from observing the nature enable to process the soil in an effective way and simultaneously decrease the tool wear at the application on the ploughshares.

Recently, creation of a new functional surface or renovation of a relatively large area have been preferred (Natis et al., 2008). A negative of this solution is the change of the geometry, increasing of the cross-section and the related energetic demands and significantly increasing the price of the tool (Natis et al., 1999).

Soil is a considerably abrasive medium which affects the tools processing the soil in a negative way. The aim of the research is to increase the service life of the ploughing body by means of a structural and material solution.

MATERIALS AND METHODS

The solution is based on creation of a new functional surface. The research was focused on increasing the service life of ploughshares by overlaying oblique deposited overlay material which is abrasive wear resistant. Increasing the ploughshare service life by means of overlaying is a much discussed topic. Further, a new functional surface was distinguished for reinforcement of the ploughshare cutting edge. A method of size and mass analysis in field tests was chosen for measurements of the service life of ploughshares.

A change to the tool’s shape, a mass loss and changes to the cutting edge shape were observed within testing the tool’s service life under field conditions. A five-share plough was used for the field tests. The experiments took place on a piece of land in the settlement Neperská Lhota near Benešov and mainly gravelly soil was found on this piece of land. The ploughing resistance was very high and the abrasive wear was above the average. This soil was chosen on purpose owing to the extreme wear at ploughing under these conditions. Changes to the sizes, the mass and the geometry were observed after each 2 ha of ploughing. The entire ploughed area within the experiment was 18 ha. The reason for that was keeping approximately the same soil conditions within the chosen piece of the land. Measurements were performed at all five ploughshares, of which four were overlaid and one had not been treated (a comparing etalon). The comparing etalon was a standardized share from the final manufacturing.

Overlay materials of types carbides (Soudokay A43-0 (described as M4), OK Tubrodur 14.70 (described as M1), OK Tubrodur 15.82 (described as M2)) and a martensitic one (Filarc PZ 6159 (described as M3)) were used.

A new functional profile was created by means of overlaying electrodes on a conventional tool in such a way that the draining off of the processed soil was respected (that means oblique overlays). The oblique depositing of the overlaying bead, i.e. locating of the overlays was chosen with respect to the direction of the action of abrasive particles on the share at its relative motion through the soil. An angle cca 45° to the share cutting edge was set according to the wear of the used share. The necessity to reinforce the peak and the end of the cutting edge was obvious from previous experiments. In addition to increasing the service life, a serrated self-sharpening effect was also expected with this solution. Fig. 1 shows a schematic presentation of the geometrical solution.

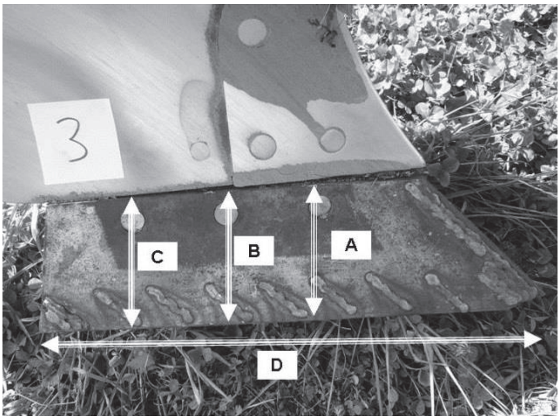

Figure 1. Ploughshare with oblique overlay and positions of the measurement points.

A method of a dimension and mass analysis was chosen for measuring the ploughshare service life. During the field test, single dimensions (marked A to C) of adjusted and standard ploughshares were measured after approximately each 2 ha of ploughing. The places for measuring the dimensions passed through the axis of the holes for fitting to the frog.

Further, the bottom edge of the ploughshare cutting edge (marked D) and the length of the share face (marked F) were measured.

At first, the layer of the finishing coat was removed manually from the shares. The shares were overlaid with hard faced metal in the form of tube wires of a mean 1.6 mm by means of an automatic welding machine. It was a technique of overlaying by an electric arc flashing by a continually passed electrode. Because of the semi-automatic way of the overlaying, it can be stated that all overlays reached the same quality.

After each bead overlaying, the share was cooled to the temperature of approximately 60°C so that the basic material was not considerably heat influenced.

RESULTS AND DISCUSSION

The amount of deposited overlaid material with the oblique overlaying technique was 0.1 kg (share mass increased of 2%) for OK TUBRODUR 14.70 (M1), 0.05 kg (share mass increased of 1.02%) for OK TUBRODUR 15.82 (M2), 0.15 kg (share mass increase of 2.86%) for Filarc PZ 6159 (M3), and 0.1 kg (share mass increase of 1.90%) for Soudokay A43-0 (M4).

The results of single measurements are visible in Figs. 2 to 6. For 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 range from 0 to 1.

The functions presented in Figs. 2 to 6 are determined by the equations in Table 1.

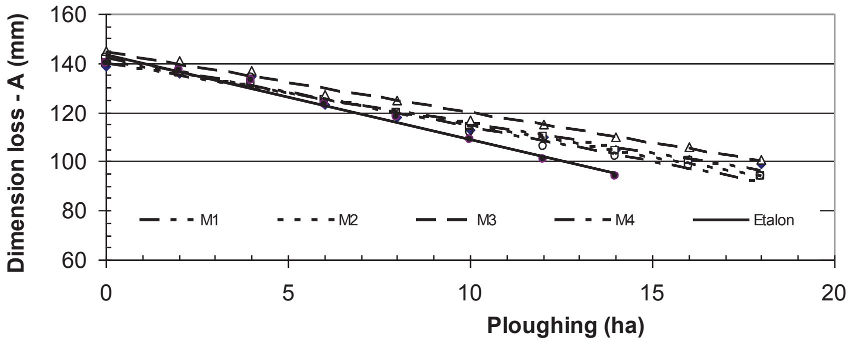

Figure 2. Course of share wear – dimension parameter A.

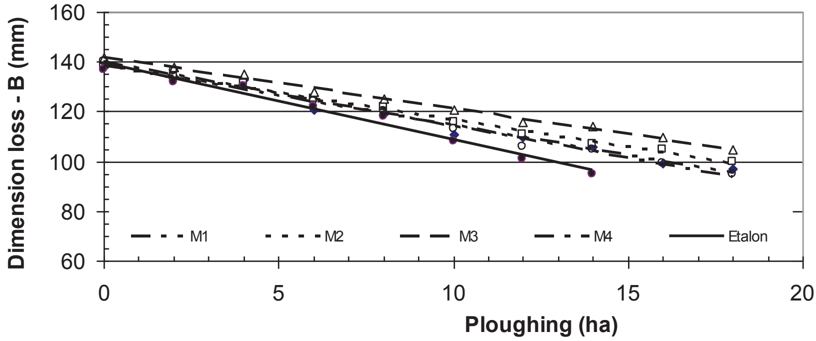

Figure 3. Course of share wear – dimension parameter B.

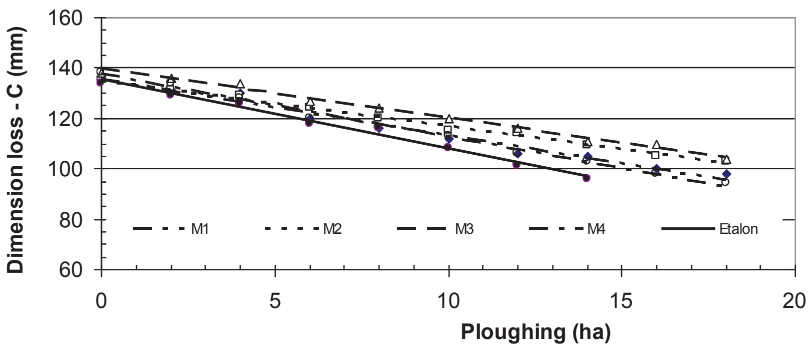

Figure 4. Course of share wear – dimension parameter C.

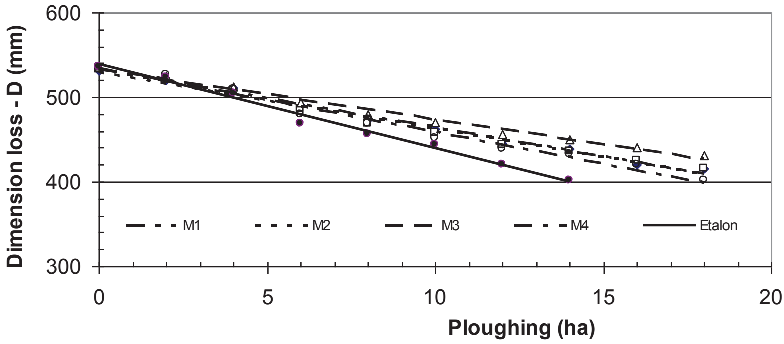

Figure 5. Course of share wear – dimension parameter D.

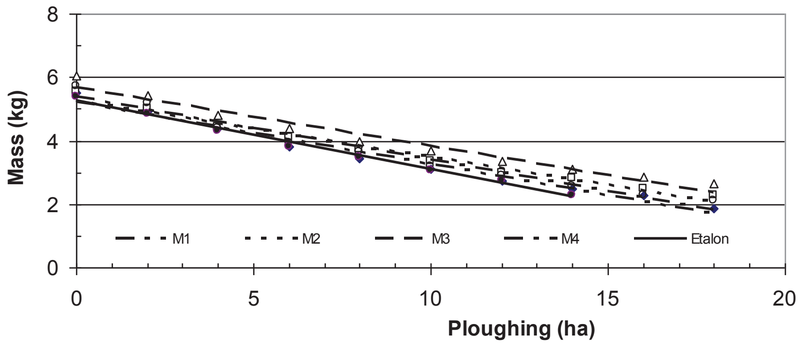

Figure 6. Course of share wear – mass.

Table 1. Equations of linear functions

Description	Functional equations	R^2	Description	Functional equations	R^2
M1 / A	y = -2.4212x + 139.69	0.97	M1 / C	y = -2.2121x + 135.31	0.98
M2 / A	y = -2.597x + 140.87	0.99	M2 / C	y = -1.8333x + 135	0.99
M3 / A	y = -2.4848x + 144.76	0.99	M3 / C	y = -1.9394x + 139.45	0.99
M4 / A	y = -2.8091x + 142.18	0.99	M4 / C	y = -2.4788x + 137.31	0.99
Etalon / A	y = -3.4464x + 143.5	0.99	Etalon / C	y = -2.75x + 135.25	0.99
M1 / B	y = -2.3939x + 138.35	0.98	M1 / D	y = -6.8242x + 532.22	0.99
M2 / B	y = -2.1606x + 138.35	0.99	M2 / D	y = -6.7121x + 529.91	0.99
M3 / B	y = -2.0424x + 141.78	0.99	M3 / D	y = -5.9212x + 532.89	0.99
M4 / B	y = -2.5758x + 139.98	0.99	M4 / D	y = -7.503x + 533.93	0.98
Etalon / B	y = -3.0893x + 139.5	0.98	Etalon /D	y = -9.8333x + 538.33	0.99
M1 / mass	y = -0.1952x + 5.22	0.98	M4 / mass	y = -0.1986x + 5.3827	0.97
M2 / mass	y = -0.1779x + 5.28	0.98	Etalon / mass	y = -0.2158x + 5.2542	0.99
M3 / mass	y = -0.1841x + 5,69	0.98	ploughshare type / place of measuring		

The graphical presentation of the results was performed by means of ANOVA by the least square method (Fig. 7). Tukey's HSD test was used for statistical comparison of the mean values. From the results of Tukey's HSD test, it was obvious that there were not statistically significant differences between the data sets at the significance level $\alpha = 0.95$. From the wear point of view, the comparing etalon already stopped being functional after 14 ha. This conclusion is essential from the perspective of keeping even shape of the share.

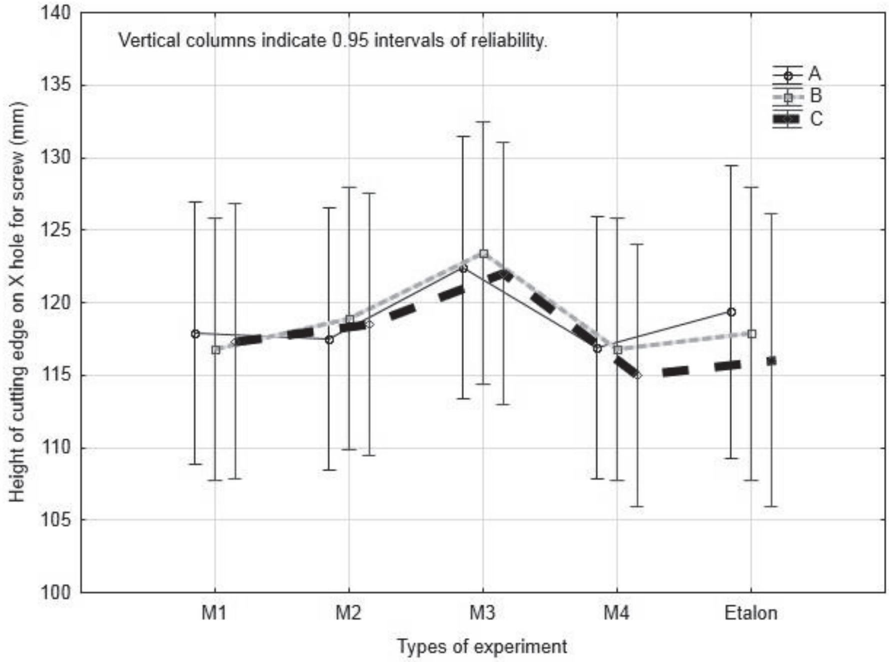

Figure 7. Change of cutting edge height depending on variant of the experiment.

Table 2 shows the particular means of statistically homogeneous groups, i.e. the cutting edge mass, the length of the bottom edge to the peak of the cutting edge and the change of the length of the share face. It is obvious from the results that no statistically significant differences exist between the data sets at the significance level $\alpha = 0.95$ within the evaluated variants of the experiment.

Table 2. Statistical comparison of mean values – Tukey's HSD test (H – homogeneity)

Tested variant of ploughshare	Mass (g)	H	Length of bottom edge to peak of cutting edge (mm)	H	Length of share face (mm)	H
M1	3.46	*	477.00	*	139.67	*
M4	3.60	*	469.50	*	130.70	*
M2	3.68	*	469.50	*	129.00	*
etalon	3.74	*	469.50	*	136.00	*
M3	4.04	*	479.60	*	140.20	*

Figs. 8 to 11 show the wear of the ploughshare.

Figure 8. Wear of ploughshare (M1) after ploughing 12 ha.

Figure 9. Wear of ploughshare (etalon) after ploughing 12 ha.

Figure 10. Wear of ploughshare (M1) after ploughing 14 ha.

Figure 11. Wear of ploughshare (M1) after ploughing 18 ha.

The research results confirmed the conclusions about the necessity of material and structural research in the area of soil processing (Doubek & Filípek, 2011; Chotěborský et al., 2008; Hrabě & Müller, 2013; Kejval & Müller, 2013; Müller et al., 2013; Natis et al., 1999; Natis et al., 2008).

CONCLUSIONS

The research in field conditions was focused on innovations of the ploughshare in the area of the conventional soil processing. The essence of the technical solution consists of using a direction and slope copying the draining off of processed soil; however, keeping the peak of the ploughshare and the possibility of effective production also have to be taken into regard.

It is possible to determine the following conclusions from the research result:

- Ploughing efficiency (that means the speed, fuel consumption, quality, etc.) is the most important from the practical user's perspective. This was definitely confirmed by the efficiency of the creation of the serrated ploughshare owing to the gradual wear. These conclusions can be made on the basis of the cutting conditions of the ´toothed cutting edge´.

- It is possible not only to create a wear resistant surface (overlays, forming) but also to use various geometrical setting of the overlaid layer (the bead) at the same time with the aim to copy the course of draining off of the processed soil. A ploughshare with the functional surface created this way is worn unevenly at ploughing.
- Increasing of the service life owing to the structural solution was proved. The service life increased by more than 20% on average. The ploughshare also preserved a suitable geometrical shape after finishing the field tests.
- The significant benefit is the fact that the suggested structural solution minimized the wear of the share face.

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