Research of overlays influence on ploughshare lifetime

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Abstract

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The aim of this study was to research the impact of the overlaying to increase the resistance to the abrasive wear of the ploughshare using three types of welding tubular wire electrodes. These tubular wire electrodes are used to increase the active parts of machines and equipments processing the soil. The experiment was performed on the six ploughshare plough, where the first and last share was without the overlay. Overlaid shares were compared with non-overlaid shares as standards. From evaluation, it is clear that the best overlaying materials are FILARC PZ 6159, OK Tubrodur 14.70 and OK Tubrodur 15.82. The results proved that the wear of the ploughshare is increased towards the heel. The study determined the weight loss during the ploughing and ploughshares dimensional width. The research results did not confirm the benefit of the overlaying with regard to the ploughshare lifetime.

Keywords: ploughing; soil; abrasive wear; overlaying; field tests

Working tools of agricultural machines for processing the soil are exposed to a dynamic loading, an intense abrasive wear and a chemical influence by environment. The rapid loss of a material and the change of the shape of the working tool edge require higher operating costs and costs for renovation of equipments (Kotus et al. 2011; Müller et al. 2011). The abrasive wear can be reduced to an acceptable level by selecting appropriate technologies and materials for the manufacture of the tool or part in the areas of the greatest wear. When evaluating the wear resistance or to determine the causes of the low durability and reliability of machines a complex cooperation between the material specialist, designer, technologist and the user is necessary (Natsis et al. 1999).

A typical example of a working body of agricultural machinery for ploughing causing the very topical problem of the intense abrasive wear is the ploughshare. The current methodology to examine this problem is still based on finding suitable materials and suitable tool shape for soil types, with links to optimizing the exchange of worn shares operating in abrasive environments. Long-term experiments are focused on plough tools, because the quality of the share has a significant influence on the overall ploughing economy. This evaluation usually leads to two basic positions. Either it negatively evaluates the low-life share with regard to all the resulting consequences, or high input costs. Sub-indicators will be reflected in unit costs of ploughing and these costs are influenced by ploughing conditions. The share ploughing resistance is significantly influenced by the share that overcomes the resistance of soil against the cutting, the frictional force on the working area of the share and weight that results from raising the mould in its movement after the share (Guul-Simonsen et al. 2002).

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Table 1. Soil analysis results

Soil	I. cat. (%)	II. cat. (%)	III. cat. (%)	IV. cat. (%)	Clay (%)	Dust (%)	Sand (%)
Fraction (mm)	< 0.001	0.01–0.05	0.05–0.1	0.1–2	< 0.002	0.002–0.05	0.05–2
DRY	22.7	17.18	12.12	47.98	15.33	24.57	60.1
WET	18.49	20.49	9.66	51.34	7.19	31.81	61

	Soil type by Novak	Soil type by triangle	Bulk density of soil parts (g/cm)
DRY	sandy loam	sandy loam	2.10
WET	loamy sand	loamy sand	2.25

DRY – soil humidity 10%; WET – soil humidity 23%; cat. – category

The character and the intensity of wear on metal parts of the plough are the function of the nature, the mechanical properties of soil particles, ploughing conditions and mechanical properties of tool material, typically alloys (Kufel, Wierzcholski 1993). Factors for determining the ploughing with regard to the wear are dependent on the soil type and soil moisture content in time and depth of processing, as well as the pressure and the hardness of ploughing tools and the soil. Wear on parts of the mould board depends on (Guul-Simonsen et al. 2002):

- wear resistance of plough parts depends on their heat treatment and shape,
- conditions for cultivation, the speed and depth of the ploughing,
- normal forces between the soil and the surface of plough parts,
- share, hardness, sharpness and shape of soil particles,
- soil moisture content,
- density and mechanical soil properties (hardness, shear strength and brittleness),
- impact of environment and weather changes.

All these factors relate primarily to the soil conditions and to the plough design. The soil conditions have a significant influence on the wear of the share. One of the ways to increase the life of the ploughshares is overlaying (Kulshwaha et al. 1990).

The greatest advantage of the overlaying is that it is a relatively quick way to increase the wear resistance. It is usually applied where we cannot achieve the required surface quality by any of the commonly used methods of heat or chemical-heat treatment owing to the difficult working conditions.

In many cases only this solution keeps the equipment in the operation without an expensive reconstruction or without a loss of performance (Bayhan 2006). Parts fitted with overlays, tend to have so great life that the choice of this expensive metallurgical surface treatment pays off repeatedly.

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

The research aims to select overlaid materials suitable to increase the durability of the ploughshare and to determine the influence of the soil moisture on the course of wear.

MATERIALS AND METHODS

The research was conducted at a farm in the south of the Czech Republic (Stanislav Muška, Velký Bor, Czech Republic). The ploughing was carried out into the depth of about 20 cm and the tractor speed ranged about 11 km/h.

The soil type was sandy-clayey according to the soil analysis (Table 1). The penetration resistance was measured in 70 places. The measurement was carried out by means of the penetrometer developed by Šařec et al. (2009). The average value of the soil penetration resistance is 2.62 ± 1.62 MPa.

Ploughshares which were used for the research were left in their original factory conditions. Sixteen new ploughshares (cast airon; VPH-METAZ, Týnec nad Sázavou, Czech Republic) were overlaid

Table 2. Chemical composition of ploughshares

Element	C	Si	Mn	Fe
(% wt)	0.54	0.13	0.72	98.61

Table 3. Chemical composition of the overlaying tubular wire electrodes (% wt)

Overlaying tubular wire electrode mark	C	Si	Mn	Mo	Cr	V	W	Nb	Co	N	Fe
OK Tubrodur 14.70	3.5	0.4	0.9	3.5	22.0	0.4	–	–	–	–	rest
OK Tubrodur 15.82	4.5	0.7	0.7	0.9	17.5	1.0	1.0	5.0	–	–	rest
FILARC PZ 6159	0.4	1.1	1.1	0.4	1.8	0.4	8.0	–	2.0	0.31	rest

with three different overlaid materials. Chemical composition of the ploughshares which was determined by the method GDOS is described in Table 2. Chemical composition of the overlaid materials (FILARC PZ 6159, OK Tubrodur 14.70 and OK Tubrodur 15.82; ESAB Vamberk, Vamberk, Czech Republic) is described in Table 3. The overlaid material was in the form of a tubular wire electrode of a diameter 1.6 mm. In the tubular wire electrode there is a flax which serves as a shielding atmosphere.

Overlaid materials are recommended by manufacturers for overlaying machine parts which are highly prone to the abrasive wear. The overlays were made on the cutting edge and on the forehead of the ploughshare (Fig. 1). The overlays were overlaid by the methodology in the Table 4.

Overlaying parameters were chosen in a range recommended by the producer. Partial properties of the overlaying parameters of single materials stated in the Table 4 differ. The reason for that is a different behaviour of single overlaid materials and a necessity to keep a uniform geometry of the bead. Overlaying parameters stated in the Table 4 were in accordance with the recommendation of the producer and with the experimental knowledge of given problems at the same time. The overlay methodology comes out from the utility pattern CZ21776 (Brožek 2011).

Fig. 2 shows the example of the overlaid ploughshare according to the specification M4 (Table 4).

Six-share plough was used for the experiment (Fig. 3). The first and the last ploughshares were without overlaying and these shares were used as the comparing standard, the second one was placed according to the specification M1, the third one according to the specification M2, the fourth one according to the specification M3 and the penultimate ploughshare according to the specification M4 (Table 4).

Four ploughshares were prepared according to each specification from the Table 4. Two were used in the field of moisture 10% and the remaining two on the field of about 23% humidity. Humidity at 10% is in the graphs labelled as DRY and humidity at 23% is marked as WET. The humidity was set ac-

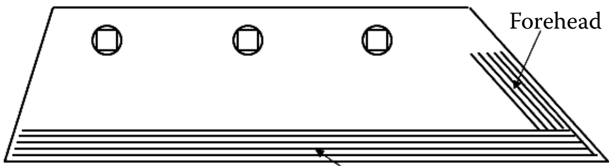


Fig. 1. Diagrammatic presentation of application of overlaid materials – overlaid share forehead and cutting edge (Brožek 2011)

Table 4. Bead position on the ploughshare, overlaying parameters

Specification	Overlaid material	No. of the beads		Overlaying parameters		
		cutting edge	forehead	I (A)	U (V)	v (cm/min)
M1	OK Tubrodur 14.70	5	3	400	36	100
M2	OK Tubrodur 15.82	7	3	350	27	160
M3	FILARC PZ 6159	8	5	200	27	50
M4	FILARC PZ 6159	5	–	200	27	50
M0	Ploughshare without overlaying					

I – arc current; U – circuit voltage; v – welding speed

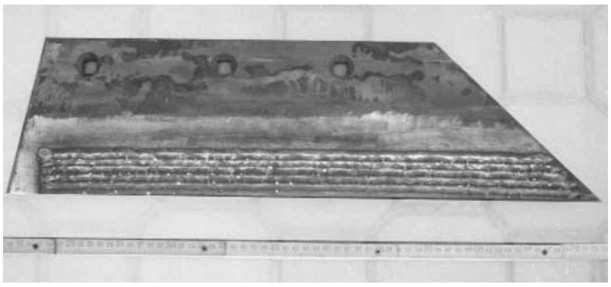


Fig. 2. Overlaid ploughshare (specification M4)

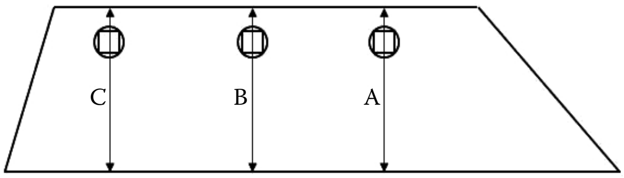


Fig. 4. Diagrammatic presentation of the width measurement
A, B, C – measuring in line

cording to the gravimetric method, so it is the relative humidity. The soil moisture was determined by weighing the sample before and after drying in a special furnace.

A method of a mass analysis and a dimension analysis was chosen for measuring the ploughshares lifetime.

During the experiment the weight of the ploughshare was measured after ploughing approximately four hectares. Weighing was conducted after proper cleaning and with the precision on 100 g. The measurement was terminated after ploughing 40 ha in both dry and wet soil when some ploughshare was completely worn.

Also the width of the ploughshare was evaluated because the width changed with the increasing number of ploughed hectares (Fig. 4). Places for measuring the width A, B and C passed through the axis of the holes for fitting to a frog. The initial width of all ploughshares was the same (136 mm).

RESULTS AND DISCUSSION

There were noticeable differences between the dry and wet soil types. Different values were also reached among single overlay specifications and the comparing standard. Fig. 5 shows the experiment results. Larger mass losses were achieved in all overlaid specifications (M1–M4) and the comparing standard (ploughshare without overlaying) in the dry soil than in the wet one.

From the results it is visible that the overlay specifications M1 and M4 are not suitable. They reach higher mass losses than the original ploughshare (the comparing standard M0).

Ploughshares surface which was hardened by using the overlay recorded less wear of the spike than the standard (ploughshares without overlaying). In comparison, the mass loss in the dry soil was 127.55 ± 19.28 g/ha and in the wet soil it was 100.06 ± 12.85 g/ha. According to Bayhan (2006), the wear of the ploughshares is an average of 90 to 210 g/ha.

In Fig. 6 the width change of the ploughshares is shown. The smallest drop of the width was found at the specification M2 – ploughshares overlaid with the material OK Tubrodur 15.82. The overlay was carried out on the cutting edge and on the forehead.

The width of the shares prepared according to the specifications M1 and M4 decreased of approximately the same value as the share without the overlay (the comparing standard M0).

Longer life for ploughing tools enables a greater productivity for high speed, but also a reduction in

Fig. 3. Six-share plough with overlaid ploughshares

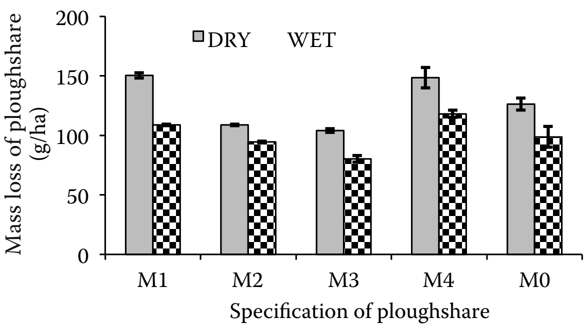
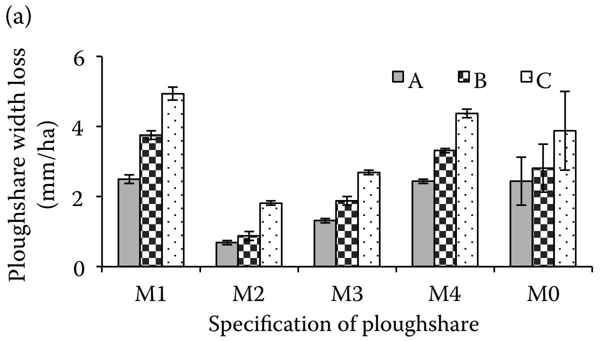


Fig. 5. Mass loss depending on the type of ploughshare
For M0–M1 specifications see Table 4



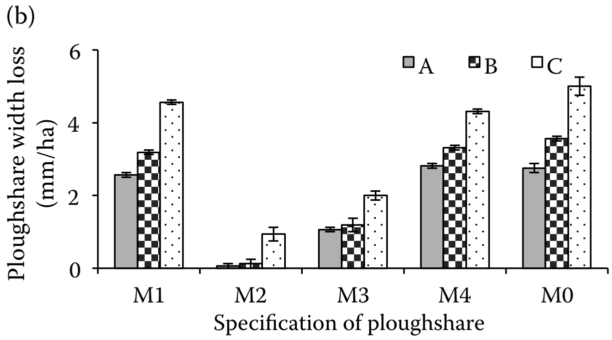


Fig. 6. Width change depending on ploughshare specification (a) dry soil and (b) wet soil
For M0–M1 specifications description see Table 4; A, B, C – measuring in line

the exchange time of ploughshares (Ferguson et al. 1998), which was confirmed in this experiment (the specifications M2 and M3). The economic efficiency of the overlays is low because of the high costs for the overlaid material etc. Fig. 7 shows the comparison of the overlaid material consumption and costs.

The wear is the essential point of view in the agricultural production owing to the loss of 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 increase of the fuel consumption, decrease of the labour efficiency, the outage time etc. (Natsis et al. 2008).

From the results gained during the measurements we succeeded in proving mild lifetime increase of ploughshare of the specification M2 (overlaid material OK Tubrodur 15.82) and M3 (overlaid material FILARC PZ 6159).

The results clearly showed the heel part of the share is worn much more intensively.

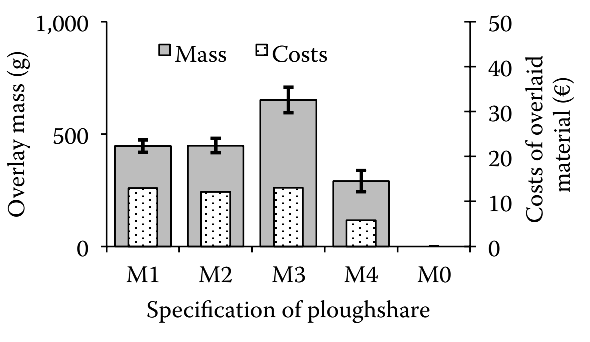


Fig. 7. Comparison of overlaid material consumption and costs for preparation of new functional surface of one ploughshare
For M0–M1 specifications see Table 4

In the wet soil the wear decreased by 19% at the specification M3 compared with the comparing standard M0. Yazici (2011) found out similar results during the chemical – heat treatment (carbonitridation).

CONCLUSION

This research provides evidence on the effects of overlaying ploughshares to increase their lifetime. The overlaid materials were selected according to recommendations of the manufacturer as suitable for use under very intensive abrasive wear conditions.

The research focused on the weight loss during the ploughing and the change of the ploughshare width.

The results from the research revealed that the largest change of ploughshares width and mass losses were in the dry soil. The results also clearly showed the heel part of the share is worn much more intensively.

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