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Application of overlaying material on surface of ploughshare for increasing its service life and abrasive wear resistance

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Abstract. Soil processing is one of the most basic operations in vegetable production. This research project focuses on extending the service life of ploughshares by covering the tools with an oblique deposited overlaying material which is resistant to abrasive wear. The overlaying material was put in place parallel to the ploughshare's head, both to the front part as well as the back. The new functional profile of the conventional tool was created with overlaying electrodes so that the processed soil could drop from the tool. Carbide type (Soudokay A43-0, OK Tubrodur 14.70, OK Tubrodur 15.82) and martensitic type (Filarc PZ 6159) materials were used. Tested variants (overlays OK Tubrodur 15.82 and Filarc PZ 6159 above all) proved that the service life of the area at the top of the ploughshare's cutting edge was prolonged. This parameter is essential for effective ploughing.

Key words: soil processing, extending service life, functional profile.

INTRODUCTION

Agricultural soil processing is a basic element in the process of crop production (Červinka & Fajman, 2013). Material type, thermal treatment and the geometry of exchangeable wear parts are essential characteristics for soil processing tools. The main problem connected with using soil processing devices is their wear owing to the components being embedded in soil (Doubek & Filípek, 2011; Müller & Hrabě, 2013; Müller et al., 2013).

Abrasive wear can be decreased to an acceptable level with suitable technologies and choosing the right material for the production of the whole tool or its part in the area of the highest wear (Votava et al., 2007; Liška & Filípek, 2012; Bednár et al., 2013). The ploughshare is one of the most stressed parts of the plough body (Müller & Hrabě, 2013). There are a lot of approaches to extending the service life of a ploughshare.

The most widespread method is hard faced overlaying but less known treatments have been increasingly tested in recent times (Legát et al., 2011; Müller et al., 2011). A significant problem is modifying the share geometry which also changes the impact of vertical force, enabling the plough to hollow furrows out from the soil (Müller et al., 2014). The functional surface properties of tools and parts can be purposefully changed, while keeping the original properties under the surface. An effective solution is increasing the wear resistance of tools that process soil with overlays (Novák et al., 2014). The aim is to improve the properties of a ploughshare.

MATERIALS AND METHODS

Field research focused on the innovations connected to ploughshares in the area of conventional soil processing, namely on extending a ploughshare's service life by covering it with an oblique deposited abrasive wear resistant overlaying material. The overlaying material was put in place in parallel to the ploughshare head, both to the front part as well as the back. The new functional profile of the conventional tool was created with overlaying electrodes so that the processed soil could drop from the tool. The oblique depositing of the overlaying bead, i.e., the location of the overlays, was chosen in view of the direction of the abrasive particles' impact on the ploughshare during its relative motion through the soil.

Carbide type (Soudokay A43-0 (marked 1), OK Tubrodur 14.70 (marked 2), OK Tubrodur 15.82 (marked 3)) and martensitic type (Filarc PZ 6159 (marked 4)) overlaying materials were used. The etalon was marked with the number 5.

The new coating was created with overlaying, which is presented in Fig. 1 (an automatic welding machine ESAB, i.e.,an electric arc). Overlaying material was tube wire with the mean diameter of 1.6 mm. Welding parameters were the following: current 300 A, voltage 25 V, speed of overlaying 150 m min^{-1}.

The hardness of the coating layer was HV 751.46 ± 20.27 for Soudokay A43-0, HV 580.39 ± 15.65 for OK Tubrodur 14.70, HV 581.97 ± 3.08 for OK Tubrodur 18.82, HV 546.95 ± 15.82 for Filarc PZ 6159. The hardness of the basic material was HV 522.94 ± 8.13.

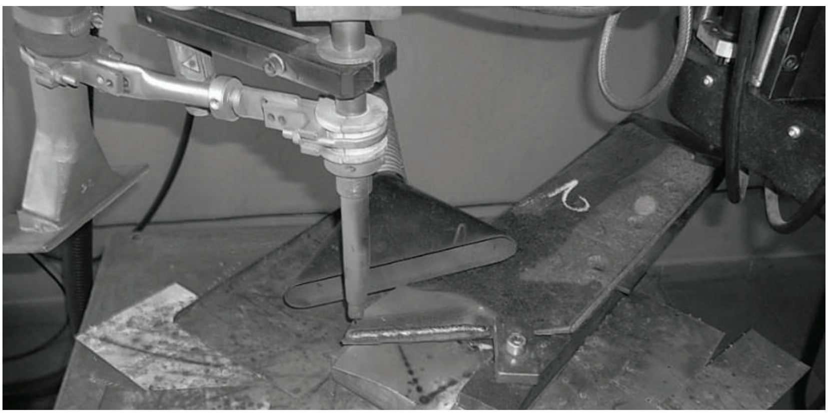

Figure 1. New surface created with overlaying. Automatic welding machine ESAB.

About 0.11 to 0.12 kg of the overlaying material was deposited on the plough surface. The new functional surface had a reinforced cutting edge and back part. The method of size and mass analysis was chosen for measuring the ploughshare's service life in field tests.

The location of the ploughshares on the plough was changed after 2 ha. The ploughshares were measured after 2 ha. Subsequently, the ploughshare was shifted to another position on the plough. This eliminated the factor of uneven wear in particular areas of the plough.

Fig. 2 shows a schematic presentation of the geometric solution and position of the measuring points.

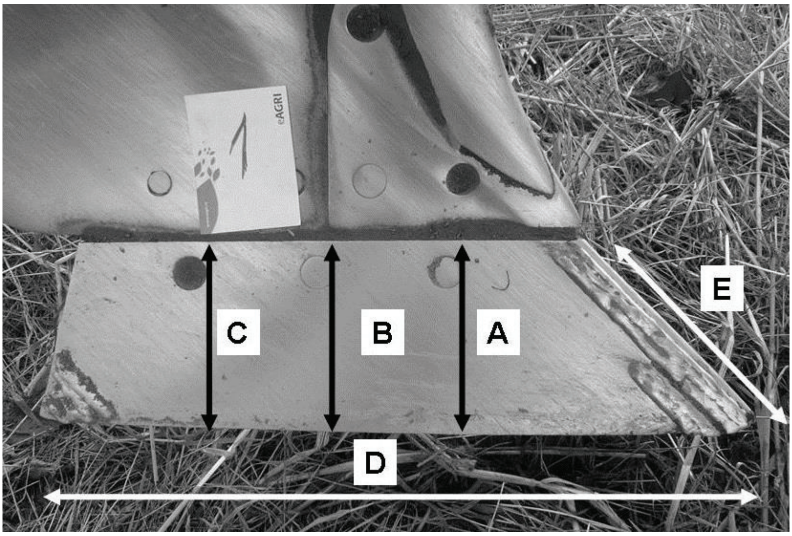

Figure 2. Ploughshare with oblique overlay and position of measuring points.

Parameters A, B and C were measured independently owing to the unevenness of the wear.

Changes in the tool shape (parameters A, B and C), mass loss (parameter M) and cutting edge shape (parameter D, E) were observed during testing the tool service life in field conditions. A five-share plough was used for the field tests. The tractor Zetor 120 45 (engine power 90 kW) was used for drawing the plough. The depth of ploughing was 0.22 m. The working speed was 6 km h^{-1}. Experiments were performed on a plot in Neperská Lhota near Benešov, which has mainly gravelly soil. The land plot had a predominantly light cambisol with the stoniness ranging from 1 (10% to 25%) to 2 (25% to 50%). The average humidity of the surface layer was 27% (measured with Theta Probe).

The ploughing resistance was very high and abrasive wear was above average. This type of soil was chosen on purpose owing to the extreme wear that occurred during ploughing in these conditions. The changes in the size, mass and geometry of the shares were measured after each 2 ha of ploughing. The entire area ploughed during the experiment was 14 ha. The reason for that was keeping approximately the same soil conditions within the chosen plot. All five ploughshares were measured and four of those had received an overlay (same overlay geometry but different types of overlaying material) and one was not treated (comparing etalon). The comparing etalon was a standard share.

RESULTS AND DISCUSSION

The ploughshare mass increased from 2.1 to 2.6% owing to the overlaying. The results of single measurements are shown in Fig. 3 to Fig. 8. It is clear from the experiment results that the overlaying material has better properties than the etalon.

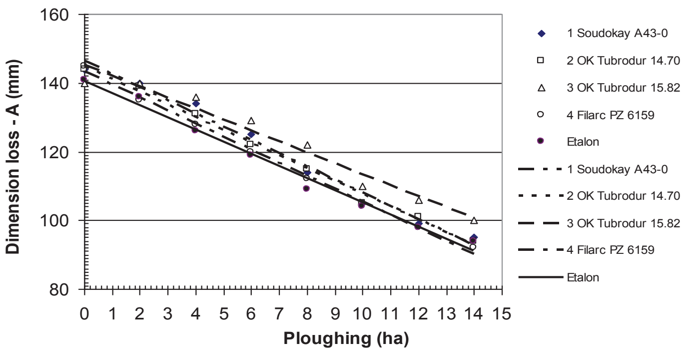

Figure 3. Course of share wear, dimension parameter A.

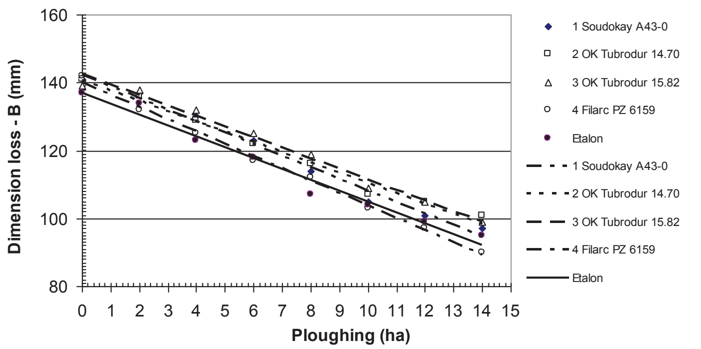

Figure 4. Course of share wear, dimension parameter B.

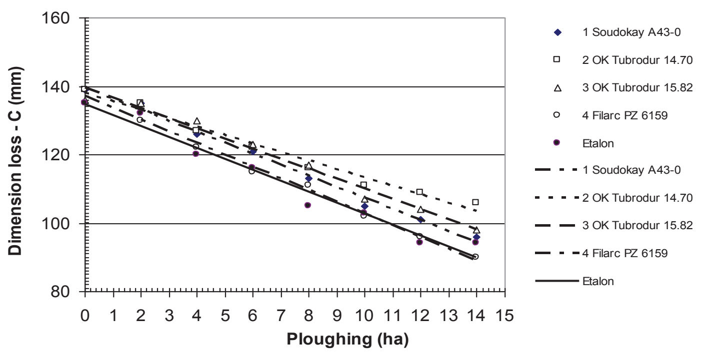

Figure 5. Course of share wear, dimension parameter C.

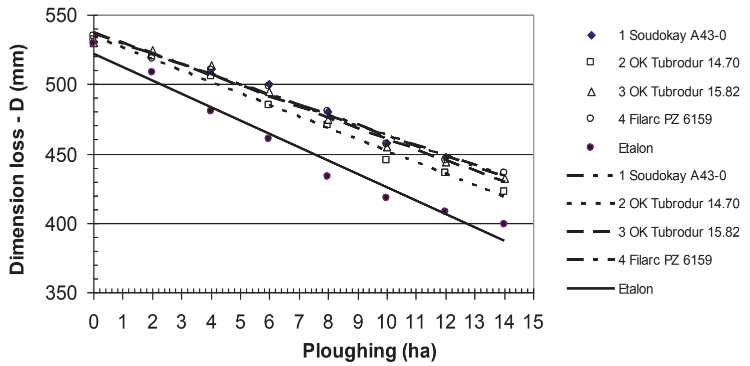

Figure 6. Course of share wear, dimension parameter D.

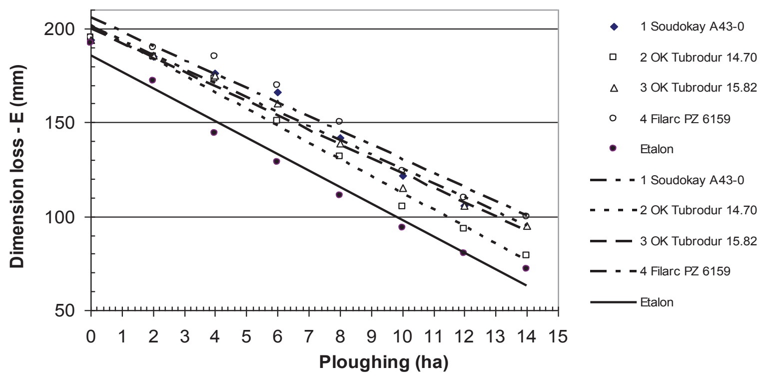

Figure 7. Course of share wear, dimension parameter E.

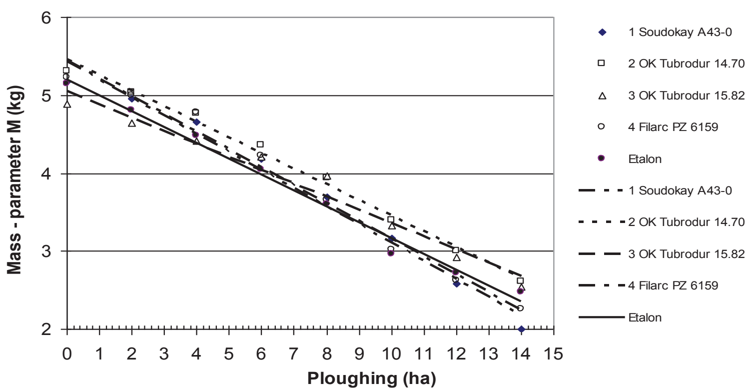

Figure 8. Course of share wear, mass.

The initial mass of the particular tested shares was slightly different. The percentage decrease remained in the interval of 48 to 60% for the shares with the overlay. The mass of the etalon decreased by 50%.

For correct evaluation, it is also important to verify the determination index R^2. This is problematic in terms of correlation analysis. The values of the determination index can be from 0 to 1. So far as R^2 equals 1, there is a perfect correlation in this sample (so there is no difference between the calculation and real values). The functions presented in Figs 3 to 8 are determined with the equations in Table 1. A strong dependence is revealed owing to the values stated in Table 1.

Table 1. Equations of linear functions: y–tested parameter, x–ploughing (ha)

Description		Functional equations	R^2	Description		Functional equations	R^2
A	1	y = -3.8452x + 146.42	0.985	D	1	y = -7.2857x + 536.57	0.978
A	2	y = -3.7202x + 144.92	0.994	D	2	y = -8.2619x + 534.83	0.992
A	3	y = -3.1845x + 145.17	0.962	D	3	y = -7.6667x + 537.42	0.983
A	4	y = -3.7857x + 143.25	0.996	D	4	y = -7.3512x + 536.33	0.988
A	Etalon	y = -3.5417x + 140.67	0.987	D	Etalon	y = -9.6607x + 522	0.972
B	1	y = -3.4048x + 142.33	0.988	E	1	y = -7.5714x + 201.29	0.967
B	2	y = -3.0179x + 140.75	0.986	E	2	y = -8.8988x + 201.42	0.987
B	3	y = -3.0952x + 142.42	0.983	E	3	y = -7.7024x + 200.17	0.982
B	4	y = -3.631x + 140.17	0.996	E	4	y = -7.5476x + 205.83	0.962
B	Etalon	y = -3.1964x + 137	0.977	E	Etalon	y = -8.7381x + 185.42	0.982
C	1	y = -3.2262x + 139.58	0.992	M	1	y = -0.2322x + 5.4253	0.982
C	2	y = -2.4702x + 137.92	0.976	M	2	y = -0.2002x + 5.454	0.991
C	3	y = -2.9524x + 139.42	0.979	M	3	y = -0.1702x + 5.0552	0.967
C	4	y = -3.4345x + 137.17	0.994	M	4	y = -0.2288x + 5.4507	0.983
C	Etalon	y = -3.2083x + 134.83	0.968	M	Etalon	y = -0.2037x + 5.2042	0.99

The F-test was used for statistical comparison. The zero hypothesis H_0 presents the state when there is no statistically significant differences ($p > 0.05$) between the mean values of the tested sets of data. In terms of the influence of various experimental variants (overlaying materials and etalon) on the measured parameters A to E, the results of the F-test are following: the hypothesis H_0 was proved to apply for all parameters: A ($p = 0.9437$), B ($p = 0.9117$), C ($p = 0.7799$), D ($p = 0.4803$) and E ($p = 0.6399$), so there is no difference between the particular tested variants at the significance level 0.05.

It is possible to claim the following on the basis of the results of the picture analysis: ploughshares with the overlays Soudokay A43-0 (marked 1), OK Tubrodur 14.70 (marked 2) and Filarc PZ 6159 (marked 4) kept their shape (primarily in the area of the cutting edge top) after 10 ha of ploughing. Results are shown in Fig. 9. The ploughshares were considerably worn after 14 ha of ploughing (Fig. 10).

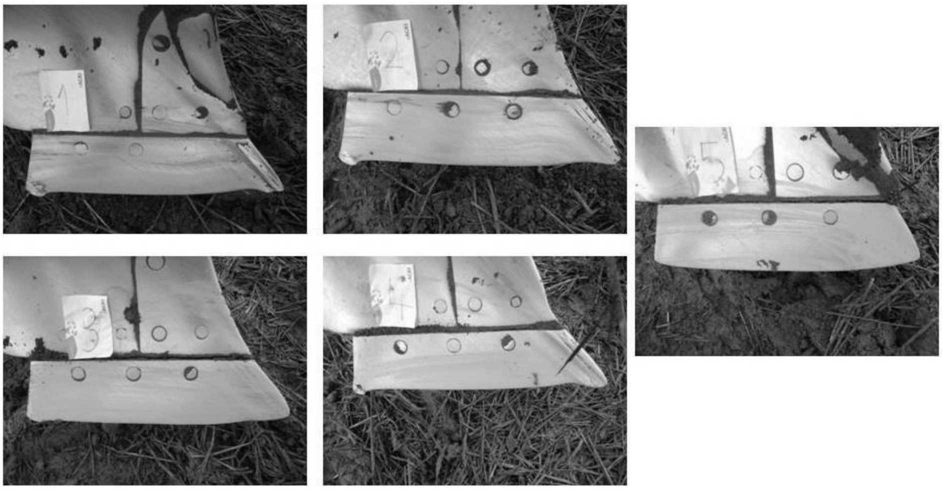

Figure 9. Wear of ploughshares after ploughing 10 ha.

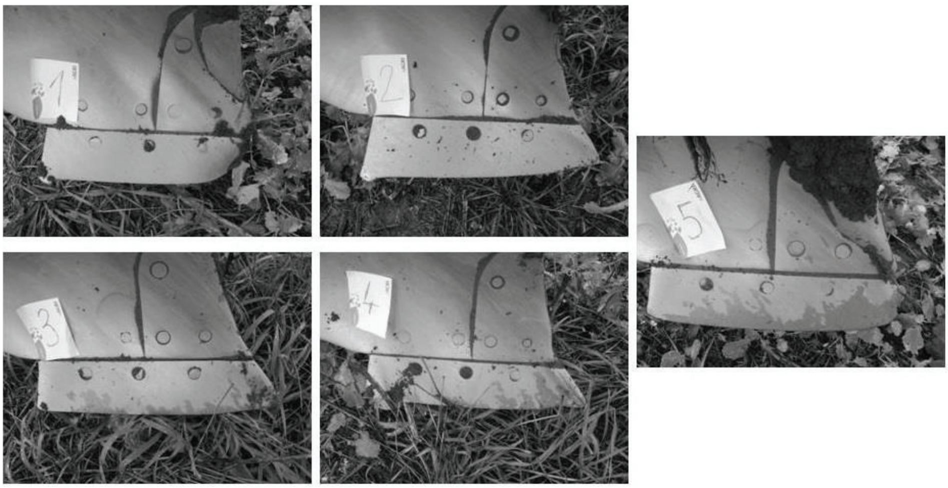

Figure 10. Wear of ploughshares after ploughing 14 ha.

The research results confirmed that it is necessary to conduct material and constructional research in the field of soil processing (Natis et al., 1999; Chotěborský et al., 2008; Natis et al., 2008; Doubek & Filípek, 2011; Hrabě & Müller, 2013; Kejval & Müller, 2013; Müller et al., 2013).

The reinforcement of the front and back part of the ploughshare is not sufficient for making the ploughshare more resistant to wear.

It is possible to create a wear resistant surface (overlay) and also use various geometrical positions of the covering layer (bead) with the aim of copying the course of the processed soil that drops of the share. A ploughshare with such a functional surface is worn unevenly during ploughing (Novák et al., 2014; Petrásek et al., 2014).

CONCLUSIONS

Owing to the high prices of replacement parts, the research project focused on extending ploughshares' service life by covering their surface with an oblique deposited overlaying material which is resistant to the abrasive wear.

The research results led to the following conclusions:

- Results of changing the height at which the cutting edge is fastened to shanks, the length from the bottom edge to the cutting edge top, the ploughshare's head length and the mass of the cutting edge did not explicitly prove that performing the overlay has significant benefits for the ploughshares. The course of partial dependences was similar to minimum differences. The occurrence of a statistically significant difference was not proved with the statistical comparison of mean values in the F-test.
- Tested variants (number 3 and 4 above all) proved that the service life of the area at the top of the ploughshare's cutting edge was extended. This parameter is essential for effective ploughing.

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REFERENCES

Bednár, R., Votava, J., Cervinka, J., Fajman, M. 2013. Suitability of technical materials for machinery subsoilers for soil tillage. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **61**(1), 9–16.

Červinka, J., Fajman, M. 2013. Suitability of technical materials for machinery subsoilers for soil tillage. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **61**(1), 9–16.

Doubek, P., Filípek, J. 2011. Abrasive and erosive wear of technical materials. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **59**(3), 13–21.

Hrabě, P., Müller, M. 2013. Research of overlays influence on ploughshare lifetime. *Research in Agricultural Engineering* **59**(4), 147–152.

Chotěborský, R., Hrabě, P., Müller, M., Savková, J., Jirka, M. 2008. Abrasive wear of high chromium Fe-Cr-C hardfacing alloys. *Research in Agricultural Engineering* **54**(4), 192–198.

Kejval, J. & Müller, M. 2013. Mechanical properties of multi-component polymeric composite with particles of Al2O3/SiC. *Scientia Agriculturae Bohemica* **44**(4), 237–242.

Liška, J., Filípek, J. 2012. The resistance of ledeburitic tool steels against the abrasive wear. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **60**(6), 231–242.

Legát, V., Jurča, V., Aleš, Z. 2011. Contribution to plough shares and chisels useful life optimization. *Scientia Agriculturae Bohemica* **42**(2), 73–78.

Müller, M., Valášek, P., Novák, P., Hrabě, P., Paško, J. 2011. Overlays and composites application in technology of sugar beet cultivation and harvest. *Czech sugar and sugar beet jurnal* **137**(9), 304–307 (in Czech).

Müller, M., Chotěborský, R., Valášek, P. & Hloch, S. 2013. Unusual possibility of wear resistance increase research in the sphere of soil cultivation. *Tehnicki Vjesnik-Technical Gazette* **20**(4), 641–646.

Müller, M., Hrabě, P. 2013. Overlay materials used for increasing lifetime of machine parts working under conditions of intensive abrasion. *Research in Agricultural Engineering* **59**(1), 16–22.

Müller, M., Novák, P., Hrabě, P. 2014. Innovation of material design solutions of ploughshare in conventional tillage cultivation of sugar beet *Czech sugar and sugar beet jurnal* **130**(3), 94–99 (in Czech).

Natsis, A., Papadakis, A. & Pitsilis, J. 1999. The influence of soil type, soil water and share sharpness of a mouldboard plough on energy consumption, rate of work and tillage quality. *Journal of Agricultural Engineering Research* **42**(2), 71–176.

Natsis, A., Petropoulos, G. & Pandazaras, C. 2008. Influence of local soil conditions on mouldboard ploughshare abrasive wear. *Tribology International* **41**, 151–157.

Novák, P., Müller, M., Hrabě, P. 2014.Research of material and constructional solution in area of conventional soil processing. *Agronomy Research* **12**(1), 143–150.

Petrásek, Muller: Setting of Angle of Soil Flow on Ploughshare at traditional Processing of Soil. Manufacturing technology **14**(3). 2014, 407–412.

Votava, J., Černý, M. & Filípek, J. 2007. Abrasive wear of ploughshare blades made of Austempered Ductile Iron. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **55**(1), 173–182.