Management Systems
in
Production Engineering

2018, Volume 26, Issue 4, pp. 222-226

Date of submission of the article to the Editor: 06/2018
Date of acceptance of the article by the Editor: 09/2018

DOI 10.1515/mspe-2018-0036

EVALUATION OF SOME PARAMETERS OF HARD SURFACING TREATMENT OF THE FUNCTIONAL SURFACES OF FORESTRY TOOLS

Miroslava ŤAVODOVÁ, Daniela KALINCOVÁ, Ivana SLOVÁKOVÁ
Technical University in Zvolen

Abstract:
In this paper we discuss the possibility of increasing service life of tools used in forestry for mulching of undesirable forest growths. In a heterogeneous working environment in which they are operated, such tools are subjected to constant abrasion and impact loading. There are several ways how to extend their service life and operational fitness. One of these is hard surface treatment, or hard surfacing of their functional surfaces. In our experiment, we chose suitable hard surfacing materials and applied these on the sample materials using the MMA and MAG welding. The hard surface was applied in an one layer. Subsequently, we performed hardness tests, microscopic analysis of the structure of the basic material and the hard surface and evaluation of the fusion penetration of the base material with the hard surfacing weld. Fusion is crucial as it determines the cohesiveness of the weld and base materials and thus also the actual extension of the service life of the tools.

Key words: *tools for mulching of undesirable forest growths, hard surfacing, hardness, microstructure, fusion*

INTRODUCTION

Extending the service life of the tools used in forestry for mulching of the wood growths is a part of maintaining the quality of these processes. The tools work in a heterogeneous abrasive environment which often features not only wood, but also elements with a much higher hardness than wood [6, 8]. High speeds of the rotor (over 1000 rev/min) upon which the tools rest, as well as uneven load of the individual tools arising out of their arrangement on the rotor, and possible tool material defects cause their premature wear and affect their service life. The price of the tools is a considerable factor. Depending on the type and construction of the tool it ranges from about 50 to 100 Euros per piece, while the traditionally used adapter rollers contain some 40 to 60 such pieces. It seems that of great help here might be the hard surfacing of those parts of the tool which after the loss of WC tips further stand as the working surface. In agricultural and forestry technology, up to 90% of all damaged machinery is discarded mainly due to excessive wear. Up to 80% of this machinery lose its functionality due to abrasive wear. These two figures are a good reason for attempting at finding solutions and lead to research on how to achieve a longer service life particularly for such stressed tools [2, 3, 12].

MATERIAL AND METHODS

Mulchers of undesirable forest growths are characterized as a medium power class mechanical mulchers. Their task is to crash undesirable vegetation, and at the same time to mellow the soil surface layer. These two tasks place somehow contradictory requirements on their operating tools [5]. The tools for crushing undesirable growths are usually composed of two parts, the body and the tip. The tip is formed by a tooth that can consist of several prongs. The tools are loosely mounted by a screw onto the rotor which is connected by adapter to a forest tractor. (Figure 1)

Fig. 1 Base machine adapter (a) and examples of tools for crushing undesirable growths (b)
Source: [1].

The tools are subjected to wear caused by abrasion and shocks during their life cycle. The wear is generally defined by the Slovak technical standard STN 01 5050 as a permanent undesirable surface change caused by interaction of functional surfaces or functional surface and a wear inducing medium, which manifests as a separation and removal of the material particles from the worn surface and is a result of mechanical impacts and possibly other impacts (e.g. chemical, electrochemical, electrical). The pre-conditions for wear are determined by:

a) the nature and characteristics of the worn body and the wear inducing body, the characteristics of the contact surfaces, the condition and properties of the surface and subsurface layers, or the characteristics of the wear inducing medium,
b) the characteristics of the relative movement of the two bodies,
c) load characteristics,
d) environmental characteristics [7, 11].

In shock wear, the tool material is exposed to impacts and high pressures which cause its deformation or local ruptures and may lead also to its total break. Shock wear also occurs in mulching and grinding, as is our case, and is accompanied with fine particle abrasion. Under such conditions, tools need to have hard surfaces that are more wear resistant.

Abrasive wear is characterized by separation of particles from the worn surface and is mechanically caused by:

a) scratching and cutting the surface with hard particles – hard foreign particles cut or scratch the surface of the body. Abrasive wear may also be caused by hard objects getting between the two contact surfaces. In this case, the particles may temporarily stick to one of the surfaces or may be pressed into a softer surface and scratch or cut the other surface;
b) scratching and cutting caused by a hard and rough surface of another body – protruding parts of an uneven surface of a harder body penetrate into a softer surface of another body and make grooves in it. The material thus removed is usually in the form of free particles [3, 8].

The term tool service life refers to an aggregate service life from the first use of the tool until its discarding. One way of how to extend the service life is to apply a hard surface weld layer of a suitable material onto the functional surface of the tool. With hard surfacing or surface welding we can obtain resistance of tools to a certain type of wear or certain desired properties of the tools. Hard surfacing is primarily used as a way of tools refurbishment, in order to renew their functional surfaces and restore their functional status, but it is also used in the production of new tools because it allows manufacture of a new tool from a cheaper material while the desired surface properties are achieved by its hard surfacing. The hard surfacing metal has to have properties which fit the intended use and the conditions of such usage. Simply said, one needs to select the welding material according to the conditions in which the tool will work [4]. In order to set the proper welding material for a particular use, it is necessary to know the type of wear to be challenged, the base material (of the workpiece), the preferable welding process, and the desired surface type. The hard surfacing material can be applied onto the workpiece by any welding method [13].

There is still no uniform view as to what should be regarded as the most appropriate type of structure when it comes to the resistance to abrasive wear. Some authors consider as the most appropriate the austenitic-carbide – which is particularly suitable for abrasive conditions characteristic by high specific pressures and shocks. The others favour the martensitic-carbide structure – suitable for rather low tension abrasion. These differing views stem from the diversity of the abrasive wear process and a wide range of actual operating conditions [9]. Laboratory tests help solve problems that arise in practice. This also applies to tools wear. The results of measuring the mechanical properties of materials and observing the structure of the tool as well as the structure of the welds by means of microscopy create the prerequisite for successful problem solving [10].

THE EXPERIMENT

In order to improve the abrasive properties of the tools and correctly determine the material for hard surfacing we need to know the tool base material and have to define its functional surfaces by means of macroscopic analysis. After this, we proceed with hard surfacing and then perform laboratory tests, which will consist of:

- measuring of hardness of the tool base material and hard surface layer,
- metallographic analysis - evaluation of the microstructure and fusion penetration of the base material with the hard layer.

Fig. 2 shows a new and worn tools for mulching of undesired forest growths. The tool consists of a body (forged piece) and a brazed WC tips. The tool base material is 36Mn5 steel. It is Mn-Cr low carbon steel intended for heat treatment.

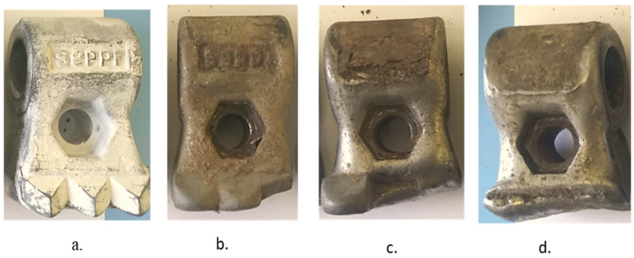


Fig. 2 The phases of tool wear for mulching of undesired forest growths

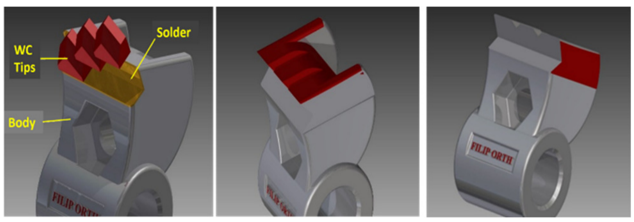


Fig. 3 Visualization of the tool functional surfaces

If after the loss of tips or their wear tool continues to be employed with its body lacking sufficient mechanical properties it wears down quicker and is prone to deformation, especially in the most exposed area above the WC tips (Fig. 4).

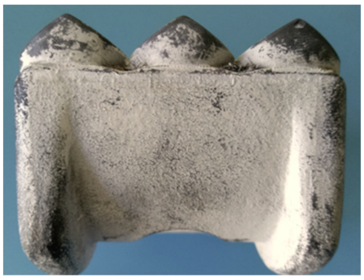


Fig. 4 Tool exposed area intended for surface welding
Source: [1].

In choosing the surface welding material we took into account the way the tool will be coming in contact with another objects, its base material and the environment in which the tool will be employed. Based on these data, i.e. for the tool intended for mulching of undesirable growths we chose Abradur 58 electrode and LNM 420FM wire. The characteristics of the selected welding materials are shown in Table 1.

Table 1
Characteristics of the welding materials

Welding materials	Chemical composite of welding steel [w. %] C	Mn	Si	Cr	Hardness of hard-surface	Producer
Abradur 58	3.2	-	-	32.0	57-62 HRC	SIJ Elektrode Jesenice
	Rutile electrode to create a hard surface with extreme abrasion resistance and mild impact. For welding of soft ores, parts of earthmoving machines, etc.					
LNM 420FM	0.5	0.4	3.0	9.0	55-60 HRC	LINCOLN ELECTRIC
	Full wire suitable for create hard surface, resistant to abrasion, abrasion and impact wear. Ferritic and martensitic structure.					

As a sample for the experiment we used a discarded tool which we cut lengthwise into two halves onto which the hard surfacing materials were applied (Fig. 5). Welding was performed at a specialized welding workshop of PPS Group a.s. Detva company. Abradur 58 layer was carried out by MMA welding. The electrode thickness was 2.5mm, welding current 120A. The electrode was dried at 300°C for about 1.5 hours. The LMN 420FM layer was applied by MAG, in the protective atmosphere of the Ar + 20% CO_2 gas mixture; the wire thickness was 1.0 mm.

a, b,

Fig. 5 The applied hard surfacing on the tool samples: a. Abradur 58; b. LMN 420FM
Source: [1].

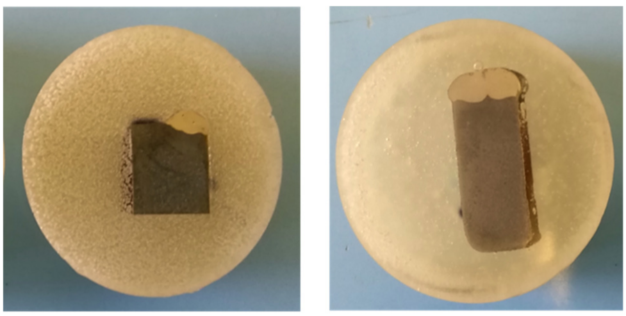
Samples were prepared for hardness measurement and macroscopic analysis (Fig. 6). The hardness of the base material was measured by the Brinell method and the hardening method by the Rockwell method (Table 2). HB core material hardness values were converted to HRC hardness units for better comparison.

Fig. 6 Measuring hardness of base material and hardsurfaces
Source: [1].

Table 2
Hardness values measured on the tool sample

Measuring	Base material HB 2.5/187.5	Base material HRC	Adradur 58 HRC	LNM 420FM HRC
1	231	21	45.5	57.5
2	228	21	45	56.5
3	232	21	45	57.5
Average value	**231**	**21**	**45.2**	**57.2**

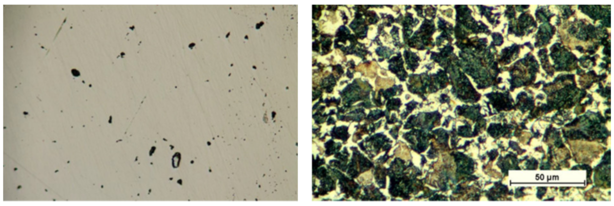
Samples for the microscopic analysis of the material and determination of fusion of base material with the weld were prepared in a standard manner (Figure 7). The base material is a structural steel, so as an etching medium we used Nital 2%. For the welds we used Snyder-Graff etchant. The samples were observed under optical light microscope VERSAMET UNION 6416.



a. b.

Fig. 7 Prepared samples: a. Abradur 58, b. LNM 420FM
Source: [1].

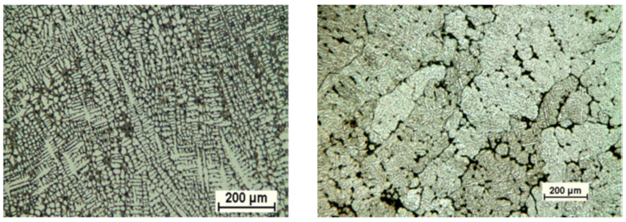
Figure 8 shows the purity of the base material 36Mn5and its etched structure. As can be seen from the illustration, the base material comprises non-metallic inclusions of various sizes. The structure of the base material is ferritic-pearlitic.



a. b.

Fig. 8 Purity (a.) and etched structure of the base material (b.) (Magnified 400x)

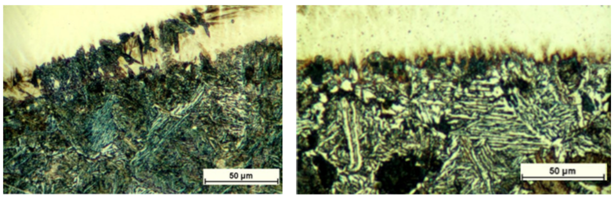
Fig. 9 shows etched Adradur 58 (a.) and LNM 420FM (b.) hard surfacing welds, with the structure typical of the given weld material.



a. b.

Fig. 9 Etched welds structure (Magnified 50x)

Fig. 10 shows fusion of base material with hard surfacing in both samples – Adradur 58 (a.) and LNM 420FM (b.)



a. b.

Fig. 10 Zone of the material fusion (Magnified 400x)

We can say that there has been sufficient fusion penetration of the materials. There are no visible cracks, cavities or other defects that could reduce the quality of the weld. There is also a heat-affected area in the base material, containing martensite.

RESULTS

On a tool which was originally designed and employed for mulching of undesirable wood growths and was subjected to great abrasive and shock wear in the heterogeneous environment in which it worked, we carried out hard surfacing with use of ABRADUR 58 electrode and LINCOLN ELEKTRIC LNM 420FM wire. We then evaluated the welds by lab tests, which consisted of the hardness test of the base material and the welds materials, and the metallographic analysis - the analysis of microstructure of the tool material where we evaluated the structure of the material and fusion penetration of the welds with the base material.

The measured hardness of LNM 420FM weld material was almost identical with the hardness stated by its manufacturer. However, in Abradur 58 the measured values were somewhat lower than those declared by the manufacturer (Fig. 11). On average it was only 45 HRC. The manufacturer states hardness ranging from 57-62 HRC. And so the sample achieves only about 75% of those values. This insufficiency could have been brought by a failure to observe the required welding parameters. However, compared to the hardness of the base material (21 HRC), this still represents more than a 200% increase in hardness.

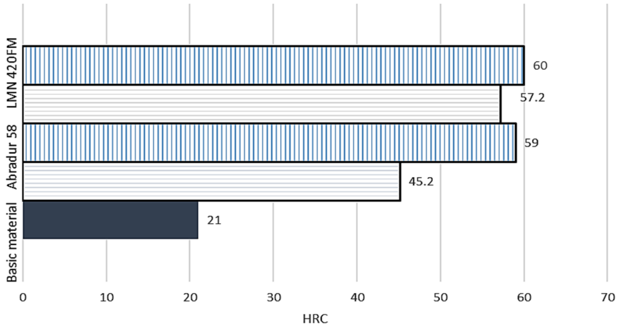


Fig. 11 Comparison of the measured and declared hardness values of the base material and weld materials

In the overall assessment of the welds quality, we can conclude that the fusion penetration of the basic and hard surfacing materials was sufficient; with the fusion zone featuring no defects which would reduce the ability of the weld to resist the abrasive and shock load of the tool used for mulching of undesirable growths (Fig. 10). The choice of welding materials can be considered correct.

CONCLUSION

With the global trend of environmental protection and ecological approach to forest management, it has become very important to use resources efficiently while operating modern, efficient and safe technology and respecting the sustainable development of the forest environment. Hard surfacing treatment of the exposed areas of the tools used for mulching of undesirable wood growths is one of the means how to increase the service life of the used machinery in the forestry. The correct choice of the welding material and the quality craftsmanship of the welding process allow extending their employment in operation.

ACKNOWLEDGEMENTS

„This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0194".

REFERENCES

[1] M. Griglak. *Zlepšovanie abrazívnych vlastností funkčných častí mulčovacích nástrojov pomocou návarov*: Bakalárska práca. Zvolen: Technická univerzita vo Zvolene. Fakulta environmentálnej a výrobnej techniky. 2018. 55s.

[2] R. Hnilica, M. Kotus, M. Jankovský, M. Hnilicová, M. Dado. Qualitative classification of mulchers. In. *Agronomy Research* 15(5), 1890-1896, 2017.

[3] D. Kalincová, M. Ťavodová, M. Hnilicová. „Opotrebenie nástrojov drvičov nežiadúcich nárastov - možnosti zvyšovania ich životnosti", In *Kvalita, technológie, diagnostika v technických systémoch* 2016. ISBN 978-80-552-1506-8. s. 124-130.

[4] J. Kovač, R. Tolnai „Zlepšenie mechanických vlastností povrchových vrstiev ocelí 14 220 a 15 203 nasýtených bórom“, in *Acta technologica agriculturae*, vol. 9, no. 1, pp. 1-3. ISSN 1335-2555.

[5] J. Kováč, J. Krilek J. Jobbagy, J. Dvořák. *Technika a mechanizácia v lesníctve*. Vysokoškolská učebnica. Technická univerzita vo Zvolene. 2017. ISBN 978-80-228-2021-8. s. 266.

[6] K. Krauze, Ł. Bołoz, T. Wydro. Parametric factors for the tangential-rotary picks quality assessment, *Archives of Mining Sciences*, vol. 60, no. 1, 2015, DOI: 10.1515/amsc-2015-0018, pp 265-281.

[7] K. Krauze, Ł. Bołoz, T. Wydro, K. Mucha. Durability testing of tangential-rotary picks made of different materials, *„Mining – Informatics, Automation and Electrical Engineering*” nr 1, 2017, pp. 26-34.

[8] V. Ľuptáčiková. „Možnosti zvyšovania životnosti a trvanlivosti komponentov a nástrojov používaných v lesníckych a drevárskych technológiách“, in *Mobilné energetické prostriedky - Hydraulika - Životné prostredie - Ergonómia mobilných strojov: zborník abstraktov.* Zvolen, 2017, s. 16-17. ISBN 978-80-228-2995-3.

[9] M. Müller, P. Novák, R. Chotěborský, P. Hrabě. „Reduction of ploughshare wear by means of carbide overlay“ in: *Manufacturing technology*, Vol. 18., No., 1 2018, ISSN 1213-2489.

[10] N. Náprstková, J.Cais, D.Stančeková, P.Kraus. Analysis of the composition of selected interts using electron microscopy. In: *Manufacturing technology*, Vol. 16, No. 5, 2016, ISSN 1213-2489.

[11] STN 01 5050:1968 Opotrebenie materiálu. Názvoslovie

[12] E. Sujová, H. Čierna, R. Hnilica. „Methodology proposal for identifying life-cycle costs (LCC) of mulchers of undesirable growth“, in MM SCIENCE JOURNAL, 2016, No. OCTOBER, pp.1166-1170, ISSN 1803-1269, DOI : 10.17973/MMSJ.2016_10_201693

[13] M. Ťavodová, D. Kalincová, M. Kotus „Možnosti zvyšovania odolnosti voči opotrebeniu funkčných plôch mulčovacieho nástroja“, in CD Zborník prednášok z 45. medzinárodnej konferencie ZVÁRANIE 2017: 08.-10. november 2017: Tatranská Lomnica, Vysoké Tatry, Slovenská republika. ISBN 978-80-89296-21-7. 2017. pp. 116-123.

Msc. Miroslava Ťavodová, PhD.
Doc. Ing. Daniela Kalincová, PhD.
Technical University in Zvolen
Faculty of Environmental and Manufacturing Technology
Študentská 26, 960 53 Zvolen, Slovak Republic
e-mail: tavodova@tuzvo.sk
kalincova@tuzvo.sk

Mgr. Ivana Slováková, PhD.
Technical University in Zvolen
Institute of Foreign Languages
T.G. Masaryka 24, 960 53 Zvolen, Slovak Republic
e-mail: slovakova@tuzvo.sk