MACHINERY FOR FOREST CULTIVATION – INCREASE OF RESISTANCE TO ABRASIVE WEAR OF THE TOOL

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The submitted paper deals with an analysis of machinery tools for forest cultivation and the way of wear of their functional parts. It analyses the state of tools of crusher of undesirable advance growth, which are exposed mainly to abrasive and fatigue wear in operation. On damaged tools – teeth, the effect of wear and mechanical and structural properties of teeth materials of different construction realisation were evaluated. Based on the material analysis results, the proposals for increase of resistance of the functional surfaces to abrasive wear in order to extend their lifespan are processed in the paper. Using visualization of the tool, the functional parts are determined, where hard layers should be applied to extend tool lifespan. At the end, the suggestions of experimental solution of the described problem are presented.

KEYWORDS

tools of crushers, wear, microstructure of material, tool visualization, lifespan

1 INTRODUCTION

In modern forestry, cultivation of quality seedlings and trees is emphasised because of effective renewal of forest stands and the demands on the preparation of stands before seeding are increased, too [Hnilica 2012a]. Machinery is necessary for preparation of forest surfaces before planting young trees and new forest cultivation. This machinery removes self-seeding stands, it aerates soil etc. The machines used for these activities are usually additional devices to the universal wheeled tractor. Except for the mentioned base machine (universal wheeled tractor) as a carrier of adapters, forest wheeled tractors are used as well. Due to their passability and slope accessibility, they are suitable base machines for carrying adapters [Hnilica 2012b]. Construction of these adapters depends on base machine and on energy transfer. Their construction is worked out as an additional device to base machines or as single-purpose, e.g. crushers, mulch machines and milling cutters powered by special base machines. Tools of these machines (see Fig. 1 and 2), as shown in the pictures of the patents from 1959 and 1979, were developed for decades.

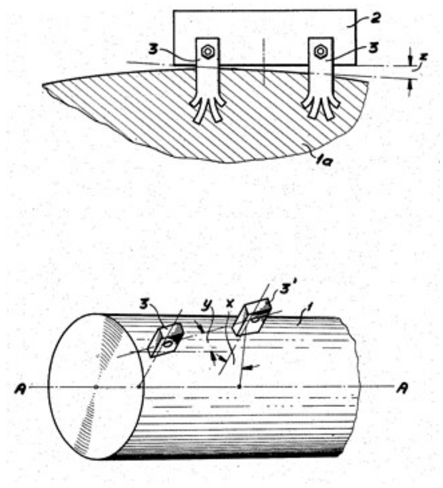

Figure 1. Knife crusher tool – patented in 1959

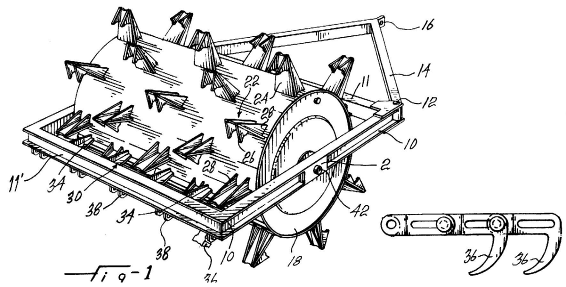

Figure 2. Crusher tool with teeth – patented in 1979

2 MATERIAL AND METHODS

Nowadays crushers, rotating tools with working tools – called flails, knives, hammers or teeth (see Fig. 3) are used to remove undesirable advance growth. Crusher – mulch machine operates in the plant stands and eliminates it. At the same time, it can work in the soil environment, where it destroys surface layer. From the properties of these two environments, completely opposite demands on cutting tools, which are efficient components of the crusher - mulch machine, emerged. When cutting in the plant environment, the most important demand from the energetic viewpoint is their sharpness. With progressive blunting of working tools, the energetic demands of cutting increase sharply, while work quality decreases [Hnilica 2015]. Work tools of crushers in operation are exposed to dynamic load and shocks in the heterogeneous environment (wood, rocks, soil of different quality) at high revs of 500-1000 rpm.

Figure 3. Crusher of undesirable advance growth – additional device

The Fig. 4 displays different shapes of tools (teeth) of crusher depending on the producer of crushers / mulch machines.

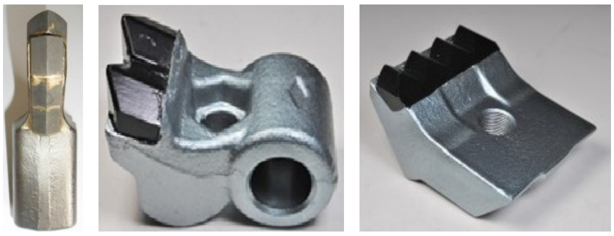

Figure 4. Selected tools
a) Single tip [AHWI 2016], b) double tips [SEPPI M. 2016], c) forth tips [AHWI 2016]

Well-known producers are for example Italian company SEPPI M. and German company AHWI. The prize of one tool is not negligible, e.g. double tips tooth (by SEPPI M.) costs approximately 80 € and there are approximately 50 of them on the rotating cylinder.

Teeth wear in operation is considerable and frequent, as it is visible in Fig. 5. The teeth are used for max. 1200 hours (6 h / 200 days) before putting out of service. The wear size depends on the tooth position on the rotating cylinder. The outer teeth are worn out earlier than the ones in the middle part of the cylinder. The teeth resistance to abrasive wear should be provided by hard alloyed teeth.

3 RESULTS

A material analysis of worn tooth was necessary to carry out in order to consider adjustment of functional surfaces to extend the lifespan. For the assessment of the tooth state we conducted the following tests:

- Macroscopic analysis,
- Chemical analysis,
- Hardness testing,
- Evaluation of material microstructure of the tooth body and tip.

3.1 *Macroscopis analysis of the decommissioned tooth*

We photographed crusher teeth that were decommissioned because of considerable damage. Figure 5 shows the state from several viewpoints.

Figure 5. Worn out tool of the crusher of undesirable advance growth

The tool produced by SEPPI M. had originally three tips from cemented carbides made by powder metallurgy and soldered to the tooth body, i.e. a forging from structural steel. In Figure 5, it is shown that one tooth tip was broken in operation. A soldered joint is not resistant enough to impact stress and consequently, the tooth body (which is softer than the tip) is worn so much that it gets worse the function of the whole device and the exchange is inevitable.

3.2 *Chemical analysis of the tooth material*

The content of elements in the body and in the tip of the tool was determined by spectral analysis (see Tab. 1 and 2).

Table 1. Chemical composition of material of the tool body

Element	Mn	C	Cr	Cu	Sn	Mo	Fe
%	1.4	0.31	0.33	0.21	0.06	0.01	96.31

Table 2. Chemical composition of the tool tip

Element	W	Co	Fe	Ag	Ni	Zn	Mn
%	84.32	11.2	2.89	0.64	0.39	0.36	0.2

According to the chemical composition of the forging, we determined equivalent to analysed structural steel. The content of elements is close to the composition of steels STN 41 4240 or STN 41 4331. They are structural steel suitable for refinement, alloyed by manganese and chromium.

The tips are made by sintering powders on the base of tungsten and in the presence of Co and Ni to suppress fragility. The content of silver in the table indicates that a solder contained Ag and therefore, it was the hard solder, which is applied at the temperatures over 500°C.

3.3 *Hardness testing*

Utility properties of the components depend on the state of structure and mechanical properties of the material. Hardness is one of easily measured indicators, which affects considerably the resistance to wear [Viňáš 2013].

The hardness of both parts of the tooth was measured by the methods HB and HRC according to Figure 6 at marked places. The results of measurements are in Tables 3 and 4.

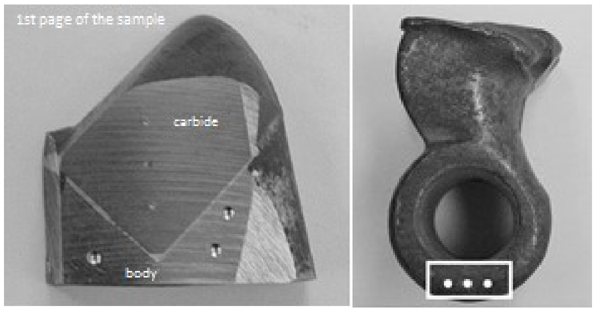

Figure 6. Hardness measurement on the samples – tooth, after decommissioning

Table 3. Results of hardness measurement on the tooth body

Imprint	Hardness $HB_{2,5/187,5}$
1.	229
2.	229
3.	229

Table 4. Results of hardness measurement on the body and tip of the tooth

Imprint	Hardness values $HB_{2,5/187,5}$		Hardness values HRC	
	Body 1st side	Body 2nd side	Hard alloy 1st side	Hard alloy 2nd side
1.	187	111	68	67
2.	111	229	67	64,5
3.	207	111	68	68

Hardness values on the tooth body close to a soldered joint are lower than on the tooth eye. It could be caused by structure change after heat influence during soldering. It follows from measured hardness values that forging has hardness corresponding with the state without heat treatment after forging.

3.4 Microstructure assessment

The sample for metallographic analysis was taken as a cross cut through the tip and body of the tooth. In Figure 7 the structure of both tooth parts with solder is visible.

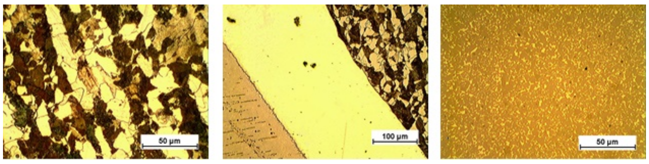

Figure 7. Microstructure of analyzed tool sample
a) body of the tool, b) soldered joint, c) sintered carbides

The microstructure of the tool body was developed by 2% Nital. It is ferritic and pearlitic, with distinctive lining, what confirms that forging was not heat treated. The soldered joint is not etched and the tooth structure was partially displayed. It is homogenous and characterises a product produced by PM technology.

It follows from obtained information on the tooth state after dismantlement that it is necessary to study and experimentally test possibilities for increasing wear of the tooth functional surfaces to abrasive wear. In Figure 8 there is a visualization of surfaces (in the graphic programme Inventor) on the tooth body, which are the most stressed and damaged. To these surfaces, we recommend to apply and experimentally test selected methods of surface hardening or hard-surfacing to increase their resistance to wear and consequently to extend their lifespan.

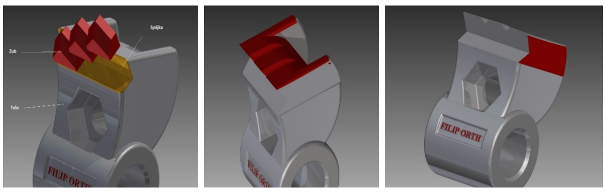

Figure 8. Visualization of the tool and damaged functional surfaces

4 DISCUSSION

There are several ways to increase resistance to abrasive wear of functional surfaces of the tools. Hard layers can be created in dependence on the way of stress, size of tools and required layer thickness, e.g. by surface hardening, cementing, nitriding, coating or hard-surfacing [Valasek 2013]. When choosing a method to create hard layer, we have to take into consideration a composition of the basic material. Surface hardening or hard-surfacing, which provide greater thickness of layers, are the methods suitable for work conditions of crusher tools, or mulch machine tools. Hard-surfacing is applied to agricultural tools or tools of earth-moving machines. When hard-surfacing, it is important to distinguish which hard-surfacing materials are suitable, because cutting wedge of cutting tools is stressed in a different way than crushers' jaws. Other hard-surfacing materials are suitable for the work with sand and gravel, other ones for soil treatment tools during impact load [Hrabe 2004; Kotus 2011]. It is known from statistic data and practical experience that a lot of agricultural components are exposed to demanding operational conditions.

As much as 90% of all damaged parts are decommissioned mainly for the reason of abrasive wear in agricultural machinery. 80% of them lose their functionality because of abrasive wear. These two figures are a sufficient reason for searching for the solutions and they lead to the research how to achieve lifespan extension of such stressed tools [Brozek 2003; Muller 2013].

In several works, authors demonstrate that there has not been found a consensus about the most suitable structure yet (from the viewpoint of resistance to abrasive wear). These different opinions follow from variedness of the abrasive wear process and from a wide range of real operational conditions. The highest resistance to abrasive wear is gained in case of austenitic – carbidic structure. It is suitable under the conditions of high specific pressure and impacts. Parameters of carbide and austenite grids are closer than the parameters of martensite and carbides grids. Therefore, the connection of these structural components influences the ability to resist to abrasive wear in the most favourable way.

5 CONCLUSION

Considering that it is not possible to achieve austenitic and carbidic structure in the tooth body material (structural low alloyed steel), we suggest several available solutions to extend the lifespan of the crusher parts.

- Heat treatment of the forgings by hardening and tempering before soldering the teeth tips to achieve a homogeneous fine-grained structure with higher hardness, but with required toughness. Consequently, to solder the teeth tips and to test in operation.
- Surface hardening of the functional surfaces – by induction or laser and subsequently solder the teeth tips from sintered carbides.
- Increase the surface hardness of selected surfaces by hard-surfacing and solder the teeth tips from sintered carbides after regrinding.

After adjustments, the experiments to test the teeth in operation will be performed in order to determine how the martensitic structure and hard-surface work on functional surfaces in operation. After decommissioning the analyses of treated tools properties will be carried out.

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