

Application of the Weld Deposits on Function Surfaces of the Forest Machines Components

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The abrasive wear of pulley surfaces at winding of the ropes causes changes of the shape and quality surface of the groove and has influenced lifetime of the skidding machine. The pulley is made of steel C45E without heat treatment and its structure is not suitable for the abrasive wear of the pair metal-metal. Contribution describes a research aimed to changes in material structure by the heat treatment. The pulleys (first one in original state and second one after heat treatment) were tested in operating load at skidding during 320 hours. After experimental test, measurable properties as weight loss, groove dimensions of the pulleys were compared. On the samples from the pulleys, material resistance to wear was tested too. Another alternative for change of material properties would be an application of various types of weld deposits on the steel C45E. We have examined the quality of weld deposits and compared their hardness and microstructure. The results of experimental tests resulted to recommendations for practice.

Keywords: pulley, resistance to wear, weld deposit, microstructure, hardness

1 Introduction

The abrasive, adhesive and failure types of wears, are involving to destruction of function areas of the components in the process of load by the large share. Before the planned lifetime, repairs of machines and equipments are done many times in unfavorable and unpredictable conditions. It is in the forest during timber harvesting or cultivation of forests before planting, or other activities related to forestry. At the complex view of the economy and the impact on the environment, the need of the solving the lifetime of some of the less watched components is shown so far. Research of the wear and increasing of the life functional areas of selected components comes out from the needs of forest enterprises and is focused on a number of specific components of the equipment used for forest cultivation. In the heavy conditions, great care is not taken to this phenomenon. In forestry enterprises are usually problems solved without any greater investigation of the origin of premature failures by replacing components. However, in a deeper analysis of spare parts consumption and time spent on repairs, it is suggested that it would be investigated how increase purchased components lifetime. These are, for example, tools for removing of the unwanted vegetation or mulching machines tools, knives for removing of branches, pulleys of the reel for skidding, etc. [1]. Function complexes stop fulfilling their function owing to the abrasive wear. It is necessary to replace them. This replacement requires increased economic costs but mainly a shutdown of the machine caused by the replacement of parts. This replacement is very laborious and time demanding [2].

2 Material and methods

By log skidding, the rope is wound on the winding drum by the directional pulley. During of winding, between the rope and pulley the friction force is acting. Two types of wear - adhesive and abrasive are created by friction of the rope at groove of the pulley. Wearing occurs during repeated contact of functional surfaces. The result

of contact fatigue is degradation of the surface layers, namely the peeling off the layers from surface of the groove, it results to change of its dimensions and premature replacement of the component [3]. Fig.1 illustrates a winding drum mechanism with a directional pulley, however the state of pulley after load in service.



Fig. 1 Winding drum with directional pulley and detail groove pulley after wearing

2.1 Method of the material evaluation

The pulleys are made of structural carbon steels C45E. In Fig. 2 is microstructure of the steel in original state.

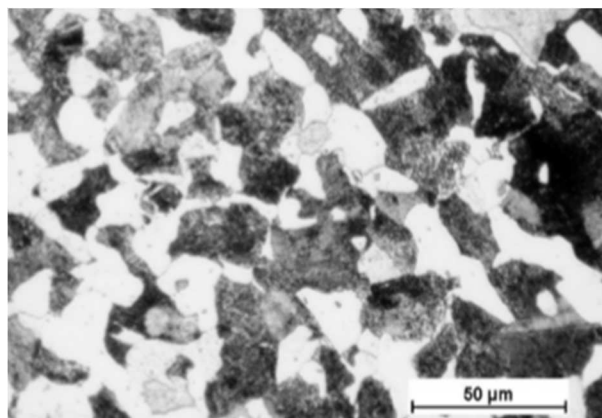


Fig. 2 Microstructure of the steel C45E

By input analysis of the pulley - measuring of the material hardness and evaluating its microstructure, we have

found the material is not heat treated and the ferritic-pearlitic structure of the material is not enough satisfactory for abrasion wear resistance and fatigue process on the contact surfaces. The average value of the hardness this steel is 205HB_{2.5/187.5}.

2.2 Design of the methods for increasing of the pulley lifetime

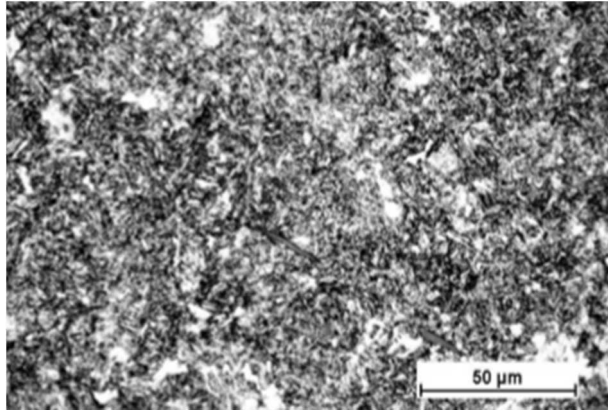


Fig. 3 Microstructure of pulley after hardening and tempering

As the first variant, we have suggested the heat treatment for change of the material microstructure. According to the authors who studied the abrasive wear of the component surfaces according to their structure [4,5,6], higher resistance to abrasion wear have fine-grained structures after heat treatment, than the ferritic-pearlitic heterogeneous structure of the original state. Therefore, as the first step for improving of the pulley material characteristics, we have realised hardening and tempering and then we compared the lifetime of the two pulleys in operating tests. The hardening was done at a heating temperature of 820°C with cooling in oil, followed tempering at temperature of 600°C with cooling in air. The

microstructure (Fig. 3) is formed of the tempered martensite and troostite. We have evaluated of the pulley mechanical properties too. We have tested hardness and toughness of material. The average hardness value after heat treatment of steel is 22HRC ($R_m = 800\text{MPa}$). The toughness of the material in original state and after heat treatment was tested by the Charpy impact test according to standard STN EN ISO 148-1: 2017. The values are as follow: energy for destruction of the samples - material without heat treatment: $K = 18\text{J}$, material after heat treatment: $K = 25\text{J}$.

Experimentally, both pulleys were loaded for 320 hours and then we have compared the measurable properties. Using the weighing method (weighing pulleys on the weight of CAS, AD-1, with measuring range 200g to 30kg and accuracy $e = 10\text{g}$), we found decreasing of material weight after abrasive wear. The weight of the new, untreated pulley - 3810g, the one of the worn, untreated pulley - 3760g, difference - 50g. The weight of the new hardened pulley - 3820g, the weight of the worn hardened pulley - 3790g, difference - 30g. The state of the groove after wear in terms of dimensions and change groove profile of the both pulleys were evaluated by measuring, using the Walter 3D device (Fig. 4). Using of the 3D measuring gives higher accuracy and higher quality of production too [7]. The measurement results are shown in Fig. 5. We can declare, the profile hardening pulley is less worn as pulley without heat treatment.

Experimental procedures for changing the pulley microstructure have brought the positive results in operating tests. That was also confirmed by the wear resistance test done on TF SPU in Nitra according to ČSN 01 5084 - Determination of resistance of abrasive wear on the abrasive cloth [8]. The average weight loss for four standard non-treated samples is 0.128g, for hardened samples is 0.109g, difference in weight loss - 0.019g. The results of the tests were better for the hardened steel.

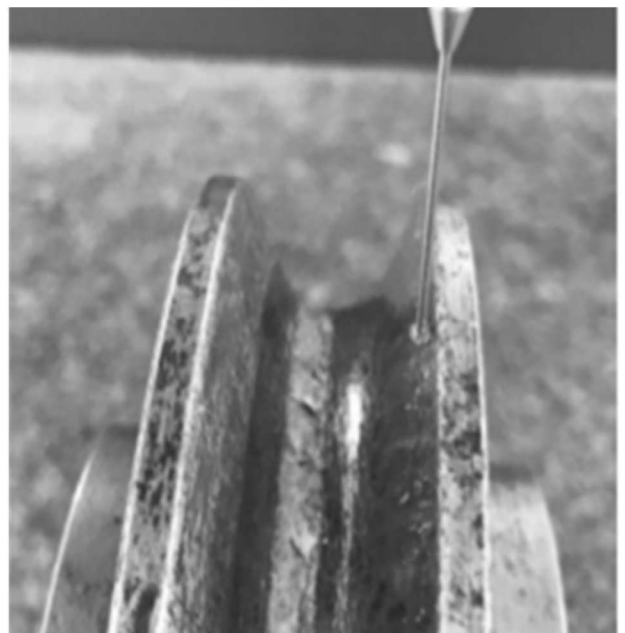


Fig. 4 Measurement of the pulley profile

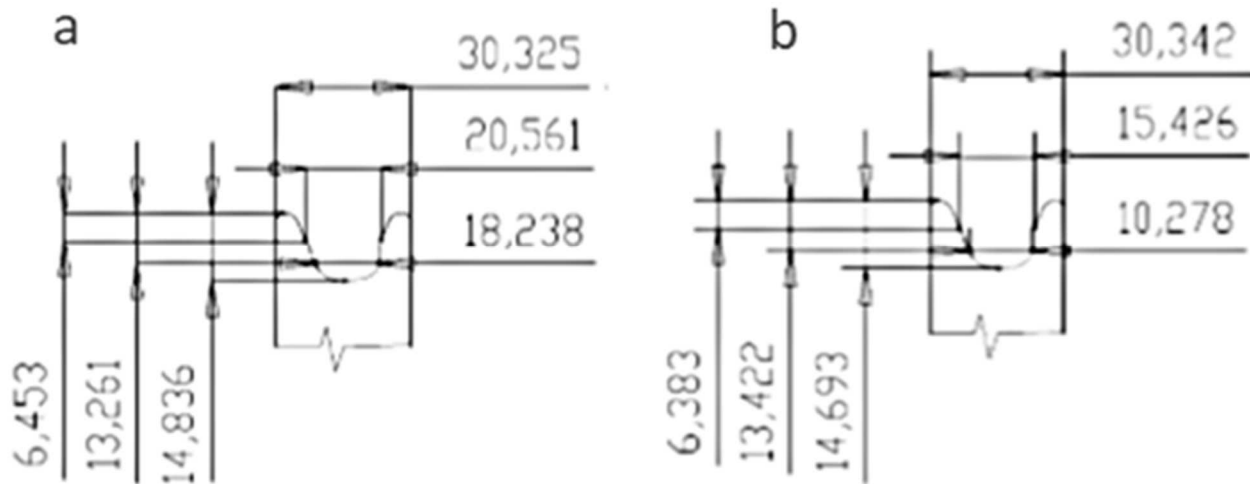


Fig. 5 Diameters of the pulleys groove profile: a – pulley without heat treatment, b – pulley after hardening

As the second alternative was chosen the application of weld deposits to the pulley groove for increasing its service life. Type of weld deposits were selected on the base of analysis of the suitability welding electrodes for steel C45E. On the experimental specimens of weld deposits we have done laboratory tests. From the experiment results, optimal welding electrode and technologies were chosen. The pulleys are made of steel C45E. This is known the steel with a higher carbon content has a difficulty weldability [9]. Several types of weld materials were used to form weld deposits, such as welding rods, granular powders, fluxes, coated electrodes, metal-ceramic electrodes, wires, welding compositions and pastes. Metals for weld deposits can be divided into groups according to their characteristics and wear resistance as follows:

- (a) on the basis of iron: martensitic alloys, austenitic alloys and alloys with a high carbide content,
- (b) non-ferrous alloys: cobalt-based alloys and nickel-based alloys.

Martensitic alloys are used for shape restoration, also as hard weld deposits, have good resistance wear in the metal-metal interaction, good impact resistance and acceptable abrasion resistance. *Austenitic alloys* have excellent impact resistance, they are appropriate for shape reparation and have acceptable abrasion resistance. *Carbide alloys* are characterized by excellent abrasion resistance, acceptable corrosion resistance [4,10,11].

Based on the analysis of welding electrodes and wires, we selected three types of welding materials for testing in the experiment. The samples of weld deposits were made at the welding workplace at company PPS Group in Detva. The choosing of welding method is very important in terms achieving of the optimal weld deposit [12,14]. For renovation of less components, manual arc welding with coated electrode is optimal method. Weld deposits can be applied for two groups based materials:

- a) carbon or low alloys steels, b) manganese-austenitic steels.

The welding parameters for these two groups are completely different. Carbon and low alloy steels require di-

fferent steps, depending on the carbon and alloying elements. This are for example preheating of the based material, heat treatment after welding, slow cooling, etc. On the other hand, austenitic manganese steels must be welded without any preheating or heat treatment after welding. Preheating of the base material increases the mixing value. Due to the welding conditions, different degrees of mixing can be achieved, also different proportion of the structural phases in the welding layer. The welding layer wear resistance is affected too [15].

2.2 Characteristic of weld deposits samples

For experiment three types of material to create of the weld deposits were chosen. Those were applied to plate from cross cut of the round rod from steel C45E. The samples are shown in Fig.6.

Sample No. 1 – electrode ESAB OK 83.50, diameter Ø 2.5 mm, manual arc welding

Sample No. 2 – electrode HARD FRO 500 diameter Ø 3.2 mm - manual arc welding

Sample No. 3 – welding wire LINCOLN LNM 420 FM, diameter Ø 1.2 mm, welding semiautomatic – MAG method.

Electrode ESAB OK 83.50 is a rutile electrode (content of elements in wt %: 0.40% C, 0.7% Mn, 0.4% Si, 6.0% Cr, 0.6% Mo, rest Fe) for repair of worn parts of earth and agricultural machinery and forestry technique. Preheating of base material - temperature 250°C, hardness of the weld deposit 50-60 HRC, weld deposit is stable to temperature approx. 500°C [10].

Electrode HARD FRO 500 is a basic electrode, is intended to form of the wear-resistant layers (content of elements in wt %: 0.35% C, 0.5% Mn, 5.5% Cr, max. 5% Mo, rest Fe). Hardness of welding deposit is 50-54 HRC.

Welding wire LINCOLN LNM 420 FM - solid wire (content of elements in wt %: 0.5% C, 0.4% Mn, 9.0% Cr, 3.0% Si, rest Fe), is intended for hard wear resistant layers, weld deposit has ferritic-martensitic structure, high resistance to corrosion, abrasion and impact deformation, hardness 55-60 HRC [13].



Fig. 6 Samples No. 1, 2, 3 - weld deposits (a-double layer, b- single layer)

3 Experimental evaluation of the weld deposits quality

Experiments of quality evaluation of weld deposits were done on the all samples, but we have described only results from testing of Samples 1a and 1b.

Measurement of hardness course on the weld deposit

cross-section was done after macrostructure etching. The thickness of weld deposit in the double layer is from 3 to 3.5 mm, the single layer thickness is about 2.5 mm. We have used HV5 method for measurement of hardness according to standard STN EN 6507. There are the places of measurement in Fig. 7. The values are processed in Table. 1 and 2, and displayed in Fig. 8.

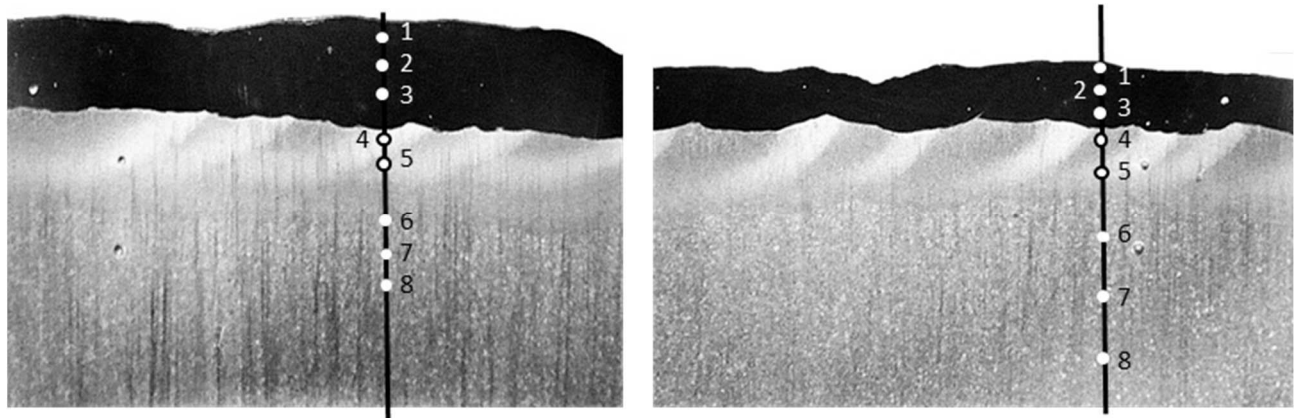


Fig. 7 Macrostructure – places of the measurement a) double layer, b) single layer weld deposit

Tab. 1 Hardness values - double layer weld deposit - Sample No. 1a (HAZ - heat affected zone)

Place	Weld deposit			HAZ		Basic material		
Measurement No.	1	2	3	4	5	6	7	8
Hardness HV5	920	760	740	230	230	190	185	185

Tab. 2 Hardness values - single layer weld deposit - Sample No. 1b

Place	Weld deposit			HAZ		Basic material		
Measurement No.	1	2	3	4	5	6	7	8
Hardness HV5	920	920	920	360	285	230	230	230

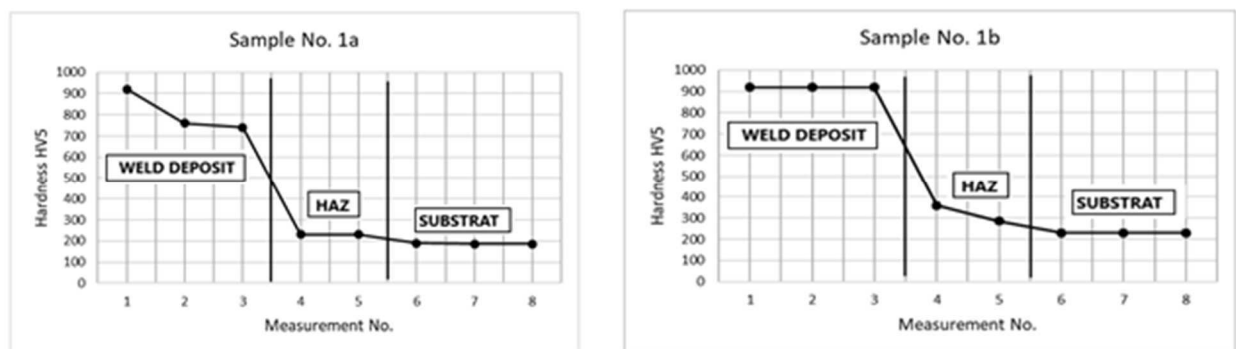


Fig. 8 Graphs - the course of hardness – Sample 1a and 1b

The graph in Fig. 8 - Sample 1a: it can be seen, the hardness values of the double layer weld deposit are 920 - 740HV5, in the single layer one - 920HV5. The lower values in the heat affected zone were found in the double layer weld deposit, because of annealing. All weld deposits (Samples 2a, 2b, and 3a, 3b), have alike values of hardness as is reported by the manufacturer of weld electrodes. On the surface double layer weld deposit (Samples 1a) were measured hardness values from 52 to 54HRC, on the single layer one were measured hardness values

from 50 to 52HRC.

Samples for microstructure evaluation were prepared as classic, they were etched by the 2% Nital. The structure has evaluated by the light microscope Union Versamet. At evaluating the quality of weld deposits, we have focused on the state of melting zone, metal mixing and weld defects in area, where could be cause defects during load. In Fig. 9 there is microstructure of melting zone - Sample 1a. The weld electrode has a high Cr content, so weld deposit is not etched.

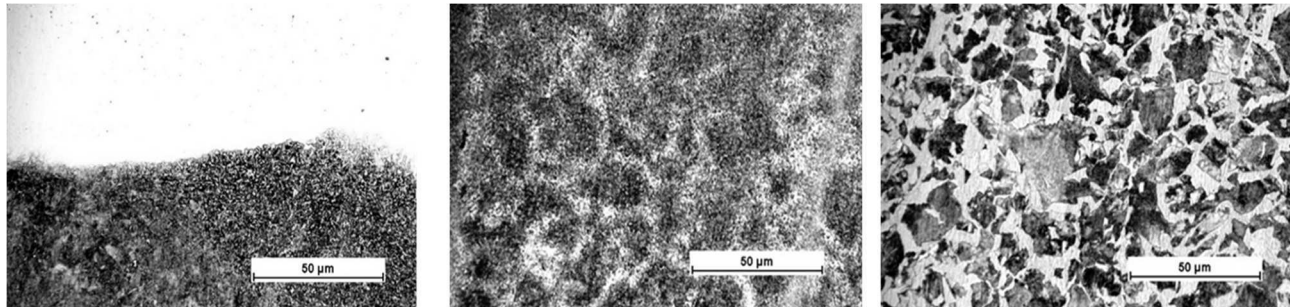


Fig. 9 Microstructure of Sample 1a – melting zone; HAZ - heat affected zone; basic material

There were no errors at the melting zone, there is the slight mixing of the basic material and weld deposit. The weld metal is clean, and does not contain non-metallic inclusions of larger dimensions or cavities. In the HAZ, which was heated to the partial recrystallization area, there is a network of unmodified ferrite and fine granular

perlite. The basic material has ferritic-pearlitic structure, the ferrite is around original austenitic grains.

In Fig. 10 is the melting zone of the single layer weld deposit, HAZ, and the basic material microstructure of Sample 1b.

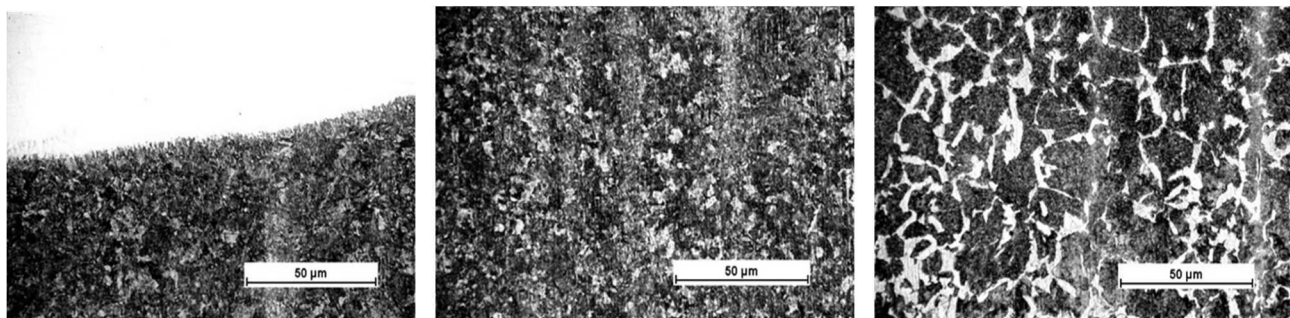


Fig. 10 Microstructure Sample 1b – melting zone; HAZ; substrat

In the melting zone there were a finely mixed materials, there were not inclusions, cavities, as well cold joints in the weld deposit. In the HAZ there is a fine-grained ferritic-pearlitic structure. In the basic material is ferritic-pearlitic structure with a smaller share of the ferrite on the borders of original austenitic grains - Sample 1b. This indicates the heat input during welding was different in the observed samples and it has influenced of the phase transformations during heating and cooling of the basic material.

4 Conclusion

As can be seen from the results of comparison of pulley properties after the load over 320 hours, the heat treatment of the steel increased the resistance of the material to wear. However, the structure after hardening and tempering is not the most suitable for abrasive wear of the components, as is reported at research work [16]. The best

of the structure is due to another researcher austenitic-carbid structure, for example high alloy Hadfield steels, or weld deposits made of electrode with higher content of alloy components. Structure of steel after hardening gives higher hardness and toughness of the pulley material in comparing with original state, but wear resistance was increased only negligibly. It was confirmed by the tests of wear resistance and 3D measurement of profile pulley groove. It would be more suitable to apply hard layer by welding to bottom of groove pulley.

A great advantage of welding is a relatively quick way how to create hard layers to increase wear resistance for example in renovation of the components too. This methods are applied there, where are not suitable conditions to create required surface quality by conventional heat treatment methods.

We plan to recommend this technology to renovate the worn parts of components of equipment used in difficult forestry conditions. From tested weld electrodes,

ESAB 83.50 is the most suitable for use, because of quality of the weld deposits - high hardness and good properties in melting zone of deposit.

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