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# THE INFLUENCE OF THE HARD-FACED LAYERS PATTERN ON THE WEAR RESISTANCE OF THE WHEEL LOADER'S BUCKET TEETH

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***Abstract:*** *The topic of this paper is the investigation of the influence of the hard-faced layers pattern on the wear resistance of the wheel loader bucket teeth. The bucket teeth of the wheel loader are the parts that are most exposed to wear and the reason for this is that they are in direct contact with the materials being loaded (mainly rock materials). The materials that are loaded often have a hardness that is greater than the hardness of the teeth themselves and with the addition of sliding of that hard materials over the bucket teeth that occurs during loading, material loss from the bucket teeth (i.e. wear) is inevitable. Through earlier research, it was established that by reparing worn mechanisation parts by hard-facing, instead of buying new parts, great economic savings can be achieved. In this sense, for this specific part, the appropriate hard-facing technology according to the base material has been prepared. The suitability of the welding technology itself was verified through several different tests, and through the tests presented in this paper, the wear resistance of bucket teeth that were hard-faced according to three different layer patterns were tested. Each pattern was applied to a separate tooth. The first pattern implied that the axes of the hard-faced layers are parallel to the direction of sliding of the material during loading. In the case of the second pattern, the axes of the hard-faced layers are perpendicular to the sliding direction, and the third pattern orientation was a combination of crossed hard-faced layers, which have the shape of a honeycomb. Based on the obtained results it was determined that the first pattern shows the best wear resistance, as it allows for easiest sliding of particles that are being loaded.*

**Keywords:** *Wear resistance, wheel loader, bucket teeth, hard-facing*

## 1. INTRODUCTION

Wheel loader buckets are essential components in heavy-duty earthmoving operations and mining industries, where they are constantly exposed to intensive abrasive wear. The bucket teeth, in particular, represent critical points of material loss due to their direct contact with soil, rocks, and other abrasive media. In order to improve their service life and reduce downtime due to frequent replacement, various surface engineering techniques have been developed [1].One of the most widely used methods for increasing wear resistance is hard-facing – the application of a wear-resistant overlay material by welding. The choice of filler metal and welding parameters significantly influences the properties of the deposited layer. However, an often overlooked aspect of hard-facing is the orientation of the weld beads, which may affect the wear resistance due to directional abrasion effects.

This research focuses on evaluating how different hard-facing orientations – longitudinal, transverse, and cross-hatched – affect the performance of excavator bucket teeth in real working conditions. Through comparative analysis of visual and mass degradation, the study aims to identify the most effective orientation strategy for enhancing durability and performance.

The findings of this work can contribute to the optimization of repair and maintenance procedures for mining and construction equipment, with potential implications for operational efficiency and cost reduction.

## 2. EXPERIMENTAL PROCEDURE

### 2.1 Base and filler materials

Base material used for the tested loader bucket tooth samples is GS-36 Mn 5. This type of material is used for the production of parts that require high resistance to wear processes. The analyzed chemical composition of the base material is given in the table 1 and mechanical properties in the table 2 [1].

**Table 1.** Chemical composition of GS-36 Mn 5

| [%] C | [%] Si | [%] Mn | [%] P | [%] S |
|---|---|---|---|---|
| 0.35 | 0.40 | 1.85 | 0.04 | 0.035 |

**Table 2.** Mechanical properties of GS-36 Mn 5

| $R_m$ [MPa] | $R_{eH}$ [MPa] | $A_5$ [%] | Hardness |
|---|---|---|---|
| 780-930 | 390 | 7 | 340-430 [HB] |

Filler materials for hardfacing were selected based on the manufacturer's recommendation. ABRADUR 58 is a specially thick-coated rutile electrode used for surfacing components exposed to intense abrasive wear and medium impact loads. It is intended for surfacing austenitic manganese steels. It is used for hardfacing components of excavators and bulldozers, crusher parts for processing softer rock materials, roller conveyors, etc. The hardfaced layers have high hardness and can only be machined by grinding. Before hardfacing, it is recommended to apply a plastic buffer layer using INOX B 18/8/6 or E Mn 17 Cr 13 electrodes. The manufacturer does not require preheating prior to hardfacing. The INOX B 18/8/6 electrode is coated austenitic basic multi-purpose electrode for welding and hardfacing of medium and high-strength steels with poor weldability. This electrode is used for surfacing plastic buffer layers and corrosion-resistant coatings. It can be successfully used for welding stainless, heat-resistant, chromium, and chromium-nickel steels. This electrode produces non-magnetic overlays resistant to cracking and oxidation at temperatures up to 800°C, and with good toughness down to -100°C. Chemical composition and mechanical properties are displayed in the tables 3 and 4 [2].

**Table 3.** Chemical composition of filler materials

| | [%] C | [%] Si | [%] Mn | [%] Cr | [%] Ni |
|---|---|---|---|---|---|
| ABRADUR 58 | 3.60 | - | - | 32.00 | - |
| INOX B 18/8/6 | 0.12 | 0.80 | 7.00 | 19.00 | 9.00 |

**Table 4.** Mechanical properties of filler materials

| | $R_m$ [MPa] | $R_{Eh}$ [MPa] | $A_5$ [%] | KV [J] | HARDNESS |
|---|---|---|---|---|---|
| ABRDUR 58 | - | - | - | - | 58 [HRC] |
| INOX 18/8/6 | 590-690 | >350 | >40 | >80 | 200 [HB] |

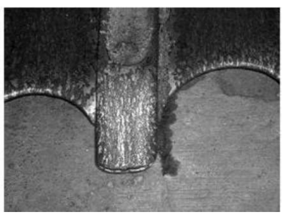
### 2.2 Hard-facing

The base material belongs to the group of manganese-carbon steels [3] with increased manganese (1.85%) and carbon (0.35%) content, and is not the most suitable for welding or hardfacing. According to standard criteria for weldability assessment, this steel is classified as conditionally weldable. Therefore, repair hardfacing of loader bucket teeth made from this material should be performed with additional (special) precautions to prevent the formation of cracks, as brittle phases may form during hardfacing due to the material's tendency to harden. Parameters of hard-facing, using described filler materials are given in the table 5.

**Table 5.** Parameters for MMAW hard-facing [4]

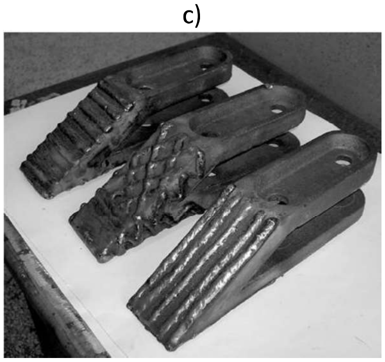
| Filler material | Electrode core dimeter [mm] | Current [A] | Voltage [V] | Welding speed [cm/s] | Heat input [J/cm] |
|---|---|---|---|---|---|
| ABRADUR 58 | 3.25 | 130 | 25 | 0.124 | 20968 |
| ABRADUR 58 | 5.00 | 160 | 26 | 0.145 | 22952 |
| INOX B 18/8/6 | 3.25 | 100 | 24 | 0.136 | 14118 |
| INOX B 18/8/6 | 5.00 | 140 | 26 | 0.178 | 16360 |

Three damaged teeth were hard-faced (repaired) with prescribed technology using three different layer patterns. Appearance of damaged and repaired (hard-faced) parts are displayed on the figure 1.




a) b)

c)



d)

**Figure 1.** Display of teeth before and after hard-facing

After hard-facing metallography investigations and hardness measurements were conducted and obtained results are displayed on the figure 2.

Greatest hardness is achieved approx. 4 mm from the top surface. Maximum measured hardness is 750 HV, assuring substantial resistance to wear.

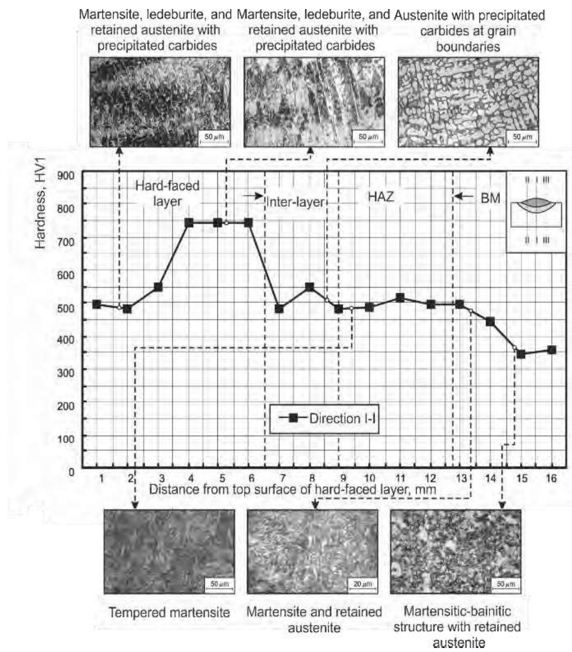



**Figure 2.** Microstructure of hard-faced layers and hardness distribution through hard-faced layers

## 3. RESULTS AND DISCUSSION

After hard-facing, mass of all teeth (new and repaired) was measured and it was used as start point to assess the wear resistance of all teeth, through weight loss of teeth. Bucket of this tested wheel loader contained 9 teeth, and the three repaired were set in the middle of the bucket (figure 3), since they are under the greatest load. Other six teeth were set at the ending of the bucket. Teeth were numbered from 1 to 9 with first and last three being the unrepaired (new) teeth. Teeth number 4, 5 and 6 were hard faced. On teeth number 4 hard-faced layers were deployed longitudinal. Teeth number 5 contained transverse pattern of hard-faced layers and number 6 contains cross-shaped honeycomb pattern of layers.

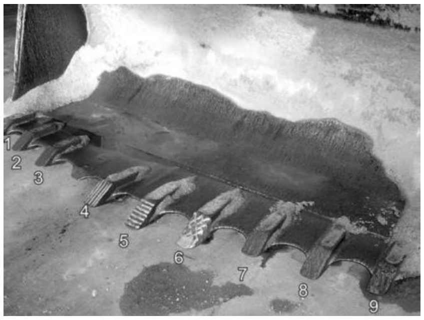



**Figure 3.** Display of repaired teeth and their position on the bucket in this experiment

After weight measurement bucket was set to work on the wheel loader and bucket teeth periodically withstood visual control to check if cracks or some other defects occurred. After 3200 hours of work teeth were demounted again measured and visually assessed. Weigh measurements before and after work are displayed in the table 6 and visual appearance of teeth after work are presented of figure 4.

**Table 6.** Weight of all teeth mounted on bucket before and after 3200 h of work

| Toth mass | Non hard-faced | | | Hard-faced | | | Non hard-faced | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Before work | 8.600 | 8.580 | 8.620 | 9.020 | 9.050 | 9.620 | 8.670 | 8.600 | 8.640 |
| After work | 7.750 | 7.720 | 7.840 | 8.800 | 8.650 | 9.220 | 7.620 | 7.740 | 7.820 |
| Mass loss, kg | 0.850 | 0.860 | 0.780 | 0.220 | 0.500 | 0.400 | 0.950 | 0.860 | 0.820 |
| Mass loss, % | 9.88 | 10.02 | 11.09 | 2.44 | 5.46 | 4.16 | 11.08 | 10.00 | 9.49 |

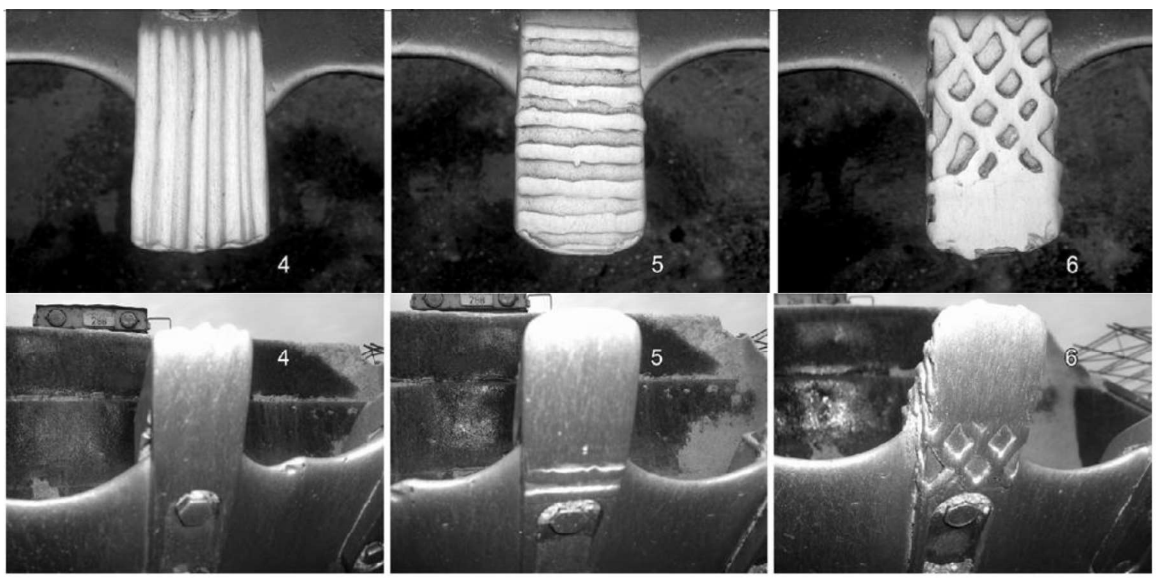



**Figure 4.** Display of repaired teeth after 3200 h of work upper and lower surface

Before work almost all teeth have similar weight. Hard-faced teeth have slightly greater weight. They are approx. 0.400 kg heavier. After 3200 working hours teeth were demounted and their weight was again measured. Obtained results show that new teeth had lost from 0.780 to 0.950 kg. Hard faced teeth had lost from 0.200 kg to 0.500 kg. This once again confirms that hard-faced parts are 2-4 times more wear resistant than base material. Comparing wear resistance among hard-faced teeth, longitudinal pattern shows the greatest wear resistance, since its weight loss is the least, cross-hatched honeycomb pattern had the second greatest wear resistance and transverse patterns was the least wear resistant. Possible explanation of obtained results could be connected with amount of resistance (friction) to moving rock particles that each of patterns provide. The least resistance is provided in the longitudinal pattern since it allows particles to move freely. Transverse pattern shows greatest resistance to particle movement thus weight loss in this case is the greatest. Resistance in the case of cross-shaped honeycomb pattern is between longitudinal and transverse case since the weight loss is in-between values of previously mentioned cases.

## 4. CONCLUSION

The high rate of wear experienced by bucket teeth in wheel loaders used in mining and construction environments necessitates effective and economical repair strategies. Hard-facing, as a surface engineering technique, offers a practical solution by significantly enhancing wear resistance and extending component life. However, beyond the choice of filler materials and welding parameters, the orientation of the hard-faced layers plays a critical role in determining performance under abrasive conditions.

This research investigated three different hard-facing patterns—longitudinal, transverse, and cross-hatched (honeycomb)—applied to worn bucket teeth. The evaluation was based on visual inspection and mass loss measurements after 3200 working hours in real operating conditions. The results clearly indicate that the longitudinal orientation of the hard-faced layers, aligned with the direction of material flow during bucket operation, offers the greatest wear resistance. This configuration allows abrasive particles to move along the surface with minimal resistance, thereby reducing material degradation.

The cross-hatched honeycomb pattern demonstrated intermediate performance, combining features of both directional and multidirectional reinforcement. The transverse pattern, with layers oriented perpendicular to the direction of material movement, showed the highest wear due to increased friction and obstruction of sliding particles.

In conclusion, the study confirms that not only the application of hard-facing but also the optimization of layer orientation can significantly influence the wear behavior of bucket teeth. These findings provide valuable insights for the development of more durable repair techniques, contributing to reduced downtime, lower operational costs, and improved equipment efficiency in demanding industrial conditions.

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