

INVESTIGATIONS OF EXTREME WORKING CONDITIONS TO THE MECHANICAL PROPERTIES OF CRAWLER VEHICLE

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Abstract

In this paper are presented investigations of the influence of working conditions to the mechanical properties of the bulldozer track pads used for the slag removal in the steel plant. Crawler vehicles are generally used as earth moving equipment. In our case bulldozer is used for slag removal from the floor in steel plant. So in this case pretty different working conditions are present i.e. elevated temperature over to 400 °C and quite different media i.e. hot slag. To understand better working conditions and their influence to the properties of track pads different investigations were performed. As first, measuring track pads wearing off and measuring of slag and track pad temperature. Chemical composition of the slag and track pad was determined too. Metallographic investigations comprise determination of nonmetallic inclusions and microstructure. Mechanical investigations consist of hardness measurements, and tensile testing. Performed investigation confirm that material of the track pad is good for usual working condition but for slag removal at elevated temperature intensive wearing of pads happen.

KEYWORDS: CRAWLER VEHICLE, BULLDOZER TRACK PAD, SLAG, WEAR, MECHANICAL TESTING

1. Introduction

Crawler vehicles are generally used as earth moving equipment working at ambient temperature. The most often their working media are sand, rocks, sludge, ground or clay. The hardness, granulation and wearing properties of these media are quite different. But, in our case Komatsu 155 bulldozer is used for quite different assignation i.e. removal of metallurgical slag from the floor of steel plant. After finishing of steel scrap melting process the slag is poured on the floor. The hot slag is crushed by bulldozer ripper, gathered, taken in trucks and removed from the steel plant. So in this case very different and extremely working conditions are present i.e. elevated temperature higher than 400 °C (sometimes much higher) and media i.e. slag with different chemical composition and mechanical properties compared with earth. Such conditions contribute for more intensive wearing of bulldozer parts mainly track pads which are in direct contact with hot slag. In order to understand better the factors and mechanisms for such intensive wear of the track pads and to prolong their exploitation life many different investigations were performed.

2. Experimental procedure

Measurement track pads hills highness was performed in order to determine influence of working conditions to their wearing off (figure 1). For comparison, the same measurements were done to the track for the same bulldozer working in the other period of time and in another conditions i.e. very fine grains sand.

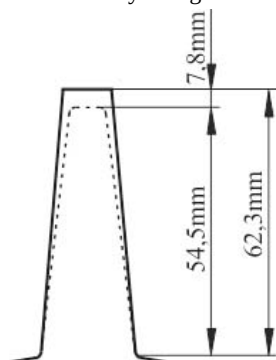


Figure 1 Wearing of track pad

For determination of slag temperature and the temperature of track pads, thermo camera type Fluke was used. This device enable measuring of temperature trough the measurement of IR rays intensity, figure 2.

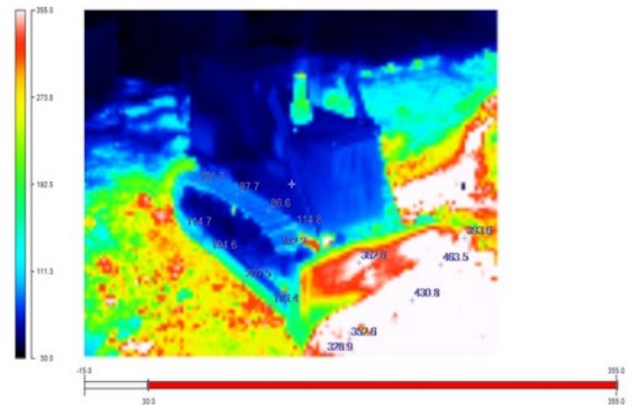


Figure 2 Temperature distribution recorded with thermo camera Fluke

Chemical composition of the slag was determined too (Table 1). These dates gave important information about working conditions in steel plant. In fact from chemical composition could be concluded which components could be most detrimental for abrasion of track pad. For comparison chemical analyse of fine grain sand as a working medium for the same bulldozer was determined too.

Table 1 Chemical composition of slag

Slag component	Composit., %	Slag component	Composit., %
F_{FeO}	32,25	MnO	7,80
S_{FeO}	15,9	Fe_{tot}	29,25
C_{FeO}	24,1	Fe_2O_3	3,07
MgO	8,25	F_{Fe}	1,90
Al_2O_3	5,15	-	-

Because the composition of track pads was not known their chemical analyse was performed. It was analysed exploited parts and new ones. The results of chemical composition of track (used) are given in table 2.

Table 2 Chemical composition of base material steel for manufacturing track pads

Chem. elements	Content, %	Chem. elements	Content, %
C	0,330	B	0,0023
S_i	0,295	A_i	0,0349
M_n	1,10	C_r	0,488
P	0,024	Ni	0,0458
S	0,0119	T_i	0,0358

Metallographic investigation was performed to old and the new track pads because of microstructure comparison. Standard metallographic preparation of specimen was performed. Mechanical grinding, polishing and etching with NITAL. Microstructure can be seen at figure 3. Besides, presence of nonmetallic inclusions was analyzed in order to check purity of steel. It was analyzed polished surfaces at magnification of x100 (figure 4).

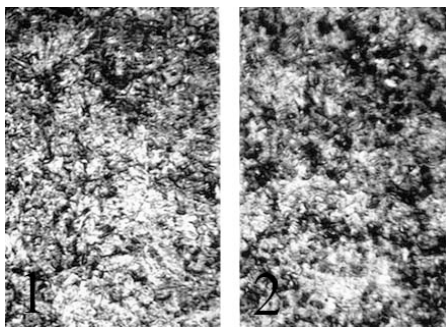


Figure 3 Microstructure (x500) of track pad 1. old pad 2. new pad

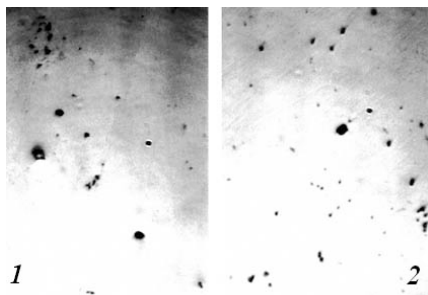


Figure 4 Nonmetallic inclusions 1. old pad 2. new pad

Metallographic specimens were used for hardness measurements too. Rockvel method (HRC) was applied. Nine measurement were done at each specimen in different positions as can be seen at figure 5. Results from these measurements are presented in table 3.

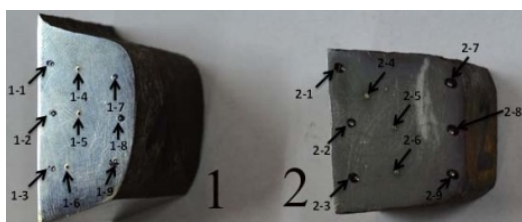


Figure 5 Metallographic specimens of track pads and hardness measuring points

Table 3 Hardness values (HRC) at different positions

Sample 1	Hardness [HRC]	Sample 2	Hardness [HRC]
1-1	43	2-1	40
1-2	45	2-2	42
1-3	44	2-3	44
1-4	42	2-4	36
1-5	41	2-5	39
1-6	44	2-6	38
1-7	42	2-7	40
1-8	41	2-8	41
1-9	44	2-9	43

Tensile strength testing was performed to used and new track pads. Besides testing at room temperature, tensile testing was performed at elevated temperature of 300 °C (figure 6). Tensile machine with heating chamber was implemented for this investigations. Three probes were tested in all cases.

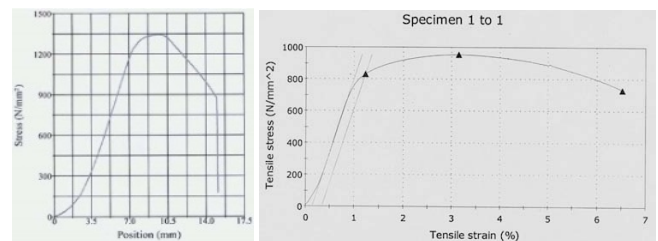


Figure 6 Diagrams strength/elongation at room and temperature of 300 °C (for new track pad)

3. Discussions

Extremely working conditions in the steel plant showed very intensive wearing of bulldozer track pads. As can be seen from the figure 1, for the period of 6 months almost 8 mm of track pads were worn off. For the same period of time, only 3 mm of the track pads (chains) were worn off if the same bulldozer worked at fine grain sand separation. Although the main component of sand is SiO₂ with almost 80% which is very abrasive material.

Next step was to determine temperatures of the slag and the temperature at which track pads near the contact surface slag/metal. Results from investigations with thermo vision camera showed that max measuring temperature of slag during this investigation was 465 °C, and the temperatures of the track pad was between 180 and 208 °C. But our experience showed that in some periods of the bulldozer work, the temperature was much higher. Red colour of slag on figure 7 the best confirms that.



Figure 7 Working conditions in steel plant

Performed investigation of track pad chemical composition confirmed that material for their manufacturing is B1(30MnB) steel. This steel is produced by quenching and tempering (Q&T). The ripper and blade of bulldozer was produced from the same material [1]. Literature review [2,3] showed that almost all bulldozer producers use this steel for track pad manufacturing. Metallographic investigation of new and old parts of the track pads confirmed that in both cases are present oxide inclusions. There is no clusters of inclusions or extremely coarse grain inclusions (figure 4). Microstructure in both cases is very similar. It consists of tempered martensite (figure 3). It is obtained by heating of steel to temperature of 850°C, and tempering it in temperature interval 550-630 °C [4]. Additional improvements of mechanical properties is obtained by small addition of boron [5].

Hardness measurement of used track didn't show some significant difference at different location of track pad i.e. near the contact surface of track with slag and at most distance parts. Besides, there is not some difference in hardness between used and new track pad. So this ultra high strength steel poses excellent wear resistance at ambient temperature. But at elevated temperature the strength and wear resistance are lowered. It means that heating and because of that softening happen only at contact surface. Grinding of such softened surfaces is much more easier. And because of that wearing of happen at this surface.

Tensile testing showed that in both cases tensile strength at room temperature is higher compared with investigations at 300 °C which is in accordance with our expectations. But tensile properties of old track pad are something lower compared with the new ones. This is not in accordance with hardness measurements which didn't show

any difference between used and new track pads. need additional considerations..

4. Conclusion

Very good mechanical properties and wear resistance of track pads are obtained by quenching and tempering. So this steel is excellent material for normal working condition. But bulldozer Komatsu work at quite different conditions. Increased temperature causes softening at contact at the contact surface Because of that it can it can be concluded that some grinding action on the track pad happen . The question is how to improve wearing of the track pad hill. Probably the only way in our case is implementation of reparative welding with filler material intended for such working conditions

5. Literature

[1]**BS EN 10137-2:1996**, Plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions. Delivery conditions for quenched and tempered steels

[2]<http://www.keytometals.com/page.aspx?ID=CheckArticle&site=kts&NM=212>

[3]<http://www.keytometals.com/page.aspx?ID=CheckArticle&site=kts&NM=214>

[4]http://www.cat.com/cda/files/2500335/7/Med%20TTT_How%20to%20Build.pdf

[5]http://www.komatsu.com/ce/products/pdfs/D275A-5R_.pdf