ISSN 0543-5846
METABK 56(1-2) 226-228 (2017)
UDC – UDK 672.71:539.375.001.4:66.014-514.68:620.17=111

THE FAILURE ANALYSIS OF THE HOLDER OF A CRUSHER MOVING KNIFE

Received – Primljeno: 2016-08-15
Accepted – Prihvaćeno: 2016-11-15
Preliminary Note – Prethodno priopćenje

The paper deals with the analysis of the causes of knife holder failure. The holder is a part of the car tyre shredding equipment. Based on the evaluation of the operating conditions of the machine, examination of the condition of the knife holder after the failure, analysis of the fractured surface, as well as the material properties of the examined structural elements, it was possible to draw conclusions as to the reasons of eventual failures.

Key words: knife holder, analysis of failure, chemical composition, mechanical properties, microstructures

INTRODUCTION

The option for treating used tyres is to process them into a range of rubber granules. In the first stage of the recycling process, tyres are chopped into small pieces by the shredding machine, which has stationary knives and a slowly rotating rotor with moving knives (Figure 1).

The critical part of the shredder, where the breakage of the knife holder occurred, is the rotor in whose holders the moving knives are fixed with the bolts and the tongue. Their loading, wearing, subsequent grinding and adjusting are closely related to the fixed stationary knives. After approximately ten years of operation of the shredder, the moving knife holder broke. The paper presents the results of the examination of this failure and its analysis [1 - 4].

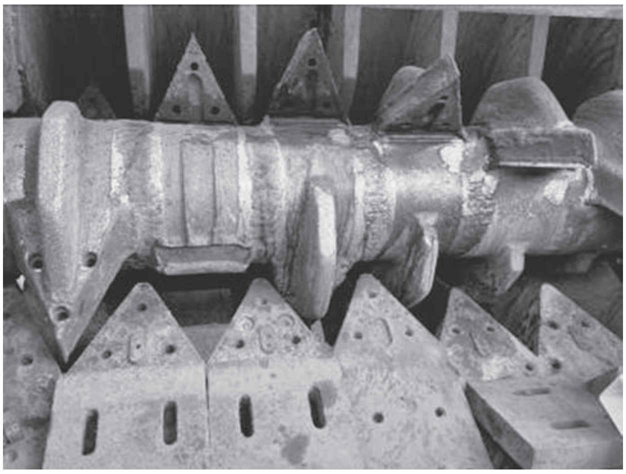


Figure 1 Moving and stationary knives of the shredding machine

DESCRIPTION OF THE STRUCTURAL COMPONENTS OF THE TYRE SHREDDING MACHINE

On the holders welded with fillet welds to the rotor of the shredding machine there are twelve cutting (moving) triangular knives arranged in two rows with six knives in each row. Stationary knives are fixed with bolts in the holders to the stationary parts of the machine. They are placed in one level with five full knives in the centre and one half-knife at each end. Tyres are shredded by the combined action of the moving and stationary knives during rotation of the machine rotor. Mechanical stress of the rotor substantially affects the sharpness of the knives' edges, as well as the size of the cutting gap between the knives. Therefore, optimal cutting conditions are provided by frequent adjusting and sharpening of the knives at the intervals specified in the instructions for the operation of the machine.

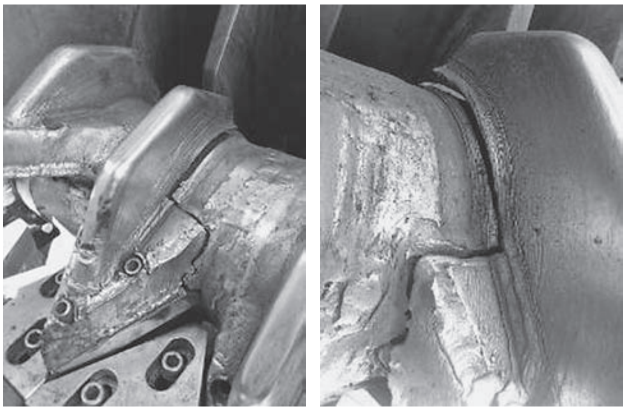
M. Pástor, P. Trebuňa, F. Trebuňa, F. Šimčák, Technical University of Košice, Faculty of Mechanical Engineering, Košice, Slovakia

FAILURE ANALYSIS OF THE MOVING KNIFE HOLDER

Moving knives are fixed by three bolts in the holders which are welded with fillet welds to the rotor of the shredding machine (Figure 1). The broken weld of the moving knife holder is shown in Figure 2a. The details of the broken weld joint of the holder are given in Figure 2b.

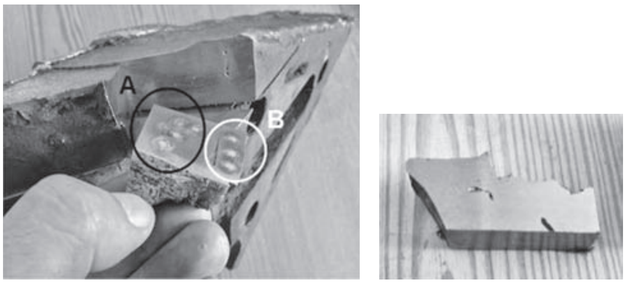
Samples were taken from the location of the fractured surface of the knife holder in order to determine its chemical composition and hardness, as well as to perform metallographic analysis with the aim to identify material quality and assess its welding properties (Figure 3a). In the samples, subsurface cracks were found in the locations of the welds (Figure 3b).

Chemical composition was determined by spectrometric analysis in two areas: A and B (Figure 3a), since two different materials were used there. To adjust the moving knives, steel plates were welded to the holders to support the knives. Table 1 and Table 2 contain average values of the chemical composition obtained by



a) b)

Figure 2 Failure of the welded joint of the moving knife holder a) general view, b) detailed view of the broken welded joint



a) b)

Figure 3 a) Locations, where samples were taken and analysed, b) subsurface cracks in the samples

measurement and chemical composition of these materials determined on the basis of the data as given in [5].

Table 1 **Chemical composition for area A (knife holder) / wt %**

	C	Si	Mn	P
Determined by measurement	0,21	0,27	0,917	0,011
Material 21NiCrMo2	0,17-0,23	0,40	0,65-0,95	max. 0,035
	S	Cr	Mo	Ni
Determined by measurement	<0,002	0,637	0,236	0,459
Material 21NiCrMo2	max. 0,035	0,35-0,70	0,15-0,25	0,40-0,70

The hardness of the moving knife holder material was measured using the testing procedure of Vickers (STN EN ISO 6507-1) or Rockwell (STN EN ISO 6508-1). Hardness values obtained by Vickers method were in the range of 263 – 287 HV. Hardness measured on the Rockwell scale was 28 HRC. The value for the tensile strength of the material was then determined to be at $R_m \approx 950$ MPa, based on the above-mentioned values.

Mechanical properties of the 21NiCrMo2 material, which are given in Table 3 show that the tensile strength of the material of the moving knife holder was about 10 % higher that the upper bound of the prescribed value.

The place on the holder, from where the sample was taken for metallographic documentation, is shown in Figure 4a. Metallographic analysis was performed in the cross-sections of two mutually perpendicular planes. Figure 4b shows the cuts in these planes.

Table 2 **Chemical composition for area B (steel plate) / wt %**

	C	Si	Mn	P
Determined by measurement	0,146	0,48	0,581	0,11
STN 41 1483	max. 0,20	max. 0,55	max. 1,40	max. 0,045
	S	Cu	Cr	Ni
Determined by measurement	0,002	0,091	0,055	0,143
STN 41 1483	max. 0,045	max. 0,30	max. 0,30	max. 0,30

Table 3 **Prescribed mechanical properties of the 21NiCrMo2 material**

E / MPa	R_m / MPa	A_5 / %	σ_c / MPa	R_e / MPa
200 000	650 – 880	8 - 25	275 - 275	350 - 550

The microstructure of the material is shown in Figure 5. Based on the results of the metallographic analysis of the basic material of the knife holder, it appeared that the structure of the material in both planes was identical. Their microstructure was consisted of ferritic-carbidic mixture with polyhydric grains and a local line, like the arrangement of the carbide particles.

The weldability of the material of the holder was assessed taking into account the chemical composition measured in accordance with the procedure in STN EN 1011-2, as given in Table 1. The analysis showed that the material was weld able when preheated to 150 - 180°C.

The material of the moving knife was also assessed. Table 4 shows the average values of the chemical composition determined by measurement, as well as the chemical composition of the corresponding quality of the material - steel STN 41 9569.

The measured value of the material hardness was determined to be 53 HRC. According to the information

a) b)

Figure 4 a) Samples taken for the metallo-graphic analysis, b) cuts in two mutually perpendicular planes

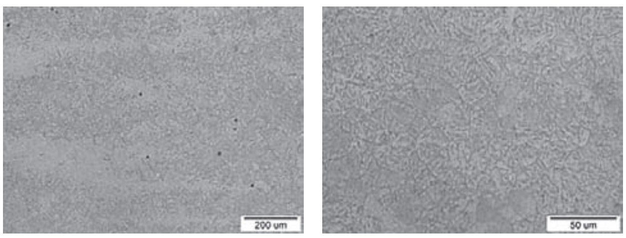


Figure 5 Microstructure of the material at various scales

provided by the operator of the shredding machine, the hardness of the knives declared by the supplier was 59 HRC.

This hardness for 19 569 steel is obtained by its tempering at the temperature of about 200 °C [4, 5], that is why the measured hardness of 53 HRC indicated that the knife material was tempered at the significantly higher temperature.

Table 4 **Chemical composition of the material of the moving knife / wt %**

	C	Si	Mn	P
Determined by measurement	0,568	0,762	0,277	<0,002
STN 41 9569	0,58 -0,68	0,70 -1,1	0,25 - 0,55	max. 0,030
	S	Cr	Mo	V
Determined by measurement	0,003	5,43	1,22	0,39
STN 41 9569	max. 0,035	4,5 - 5,5	0,8 -1,2	0,20 - 0,40

CONCLUSION

On the basis of the analysis of the operating conditions of the used tyre shredding machine, assessment of the condition of the moving knife holder after its failure, analysis of the fractured surface and material properties of the holder and the knife, the following conclusions can be drawn:

– Based on the chemical composition it was determined that the failed material conformed to the prescribed quality– steel 21 NiCr Mo 2.
– Microstructure was consisted of built by ferritic-carbidic mixture with polyhydric grains and a local line, like the arrangement of the carbide particles.
– Material hardness was 28 HRC, which corresponded to the material strength of 950 MPa.
– The analysed part of the machine failed due to the repetitive mechanical stress. Fatigue failure initiated at a point of a defective, poor quality welds and stress concentration.
– The failure could also occur because of the increased mechanical stress of the welds of the holder of the moving knife, as it was not supported by the holder along its whole length.
– Another cause of the failure could be attributed to improper thermal processing of the material of the moving knife that led to wear and the increase of shear force during tyre shredding.

Acknowledgement

This paper was supported by the projects of the Slovak Grant Agency, VEGA No. 1/0751/16, VEGA No. 1/0393/14 and KEGA No. 090TUKE-4/2015.

REFERENCES

[1] T. R. Gurney, The Fatigue Strength of Transverse Fillet Welded Joints, City of Publication, 1991 Abington Publishing, Cambridge
[2] L. Tong, X. Huang, F. Zhou, Y. Chen, Experimental and numerical investigations on extremely-low-cycle fatigue fracture behaviour of steel welded joints, Journal of Constructional Steel Research 119 (2016), 98-112.
[3] H. Mozafari, S. Najafian, Stress Analysis and Study the Fracture Mechanics in Planetary Gear Set Using FEM, Acta Mechanica Slovaca 17 (2013) 1, 68-74.
[4] F. Trebuňa, F. Šimčák, Odolnosť prvkov mechanických sústav. EMILENA, Košice, 2004
[5] I. Fürbacher, K. Macek, J. Steidl, Lexikon technických materiálů. Svazek 1, Verlag Dashöfer, Praha, 2005

Note: English language: Chabová, Košice, Slovakia