THE RELATIONSHIP BETWEEN TRIBOLOGICAL PROPERTIES AND MICROSTRUCTURE OF 90CrV6 STEEL

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Abstract

The wear resistance of the material and the wear mechanism are considered as the most important properties of tool materials. Changes in microstructures of tool materials may also results in the wear mechanism changes. Therefore, the aim of this study was to determine the relationship between microstructure and wear resistance of the hypereutectoid steel. Material used in investigations was 90CrV6 hypereutectoid steel. The material was heat treated on the basis of CCT diagram. After heat treatment the tribological tests were performed by the use of T-05 tribological test machine. Metallographic analysis of the microstructure and microanalysis of the wear surface for each samples after tribological test were performed. Analysis of the material microstructure and wear mechanism allowed to define the relationship between the microstructure and wear resistance of the samples. For samples with perlitic matrix the friction coefficient increased simultaneously with their hardness. Increase of the bainite volume fraction results in the decrease of average friction coefficient. The average friction coefficient changes were related with different wear mechanism for the bainitic microstructure. The wear area of samples with bainitic microstructure the microridging mechanism was observed. For the martensitic microstructure the wear was the biggest. The decrease of the wear resistance was probably related with the spalling of martensite.

Keywords: Sliding wear, wear mechanism, microstructure, phase transformation, tool materials

1. INTRODUCTION

Impact of tool material microstructure on the mechanical properties of finished items is directly related with the kinetics of phase transformations. The microstructural changes during production and work of the material could dramatically effect on their properties [1-4]. Material wear resistance is one of the most important parameter for tool material applications. In the most of cases the wear is the main cause of the material damage [5,6]. The microstructure of the subsurface layer is directly related with the material wear resistance. The phase compositions, hard precipitations at the grain boundaries, and phase transformations significantly effect on material tribological properties. The influence of retained austenite destabilization and the white layer formations on tribological properties of the material have been investigated in work [7]. The destabilization of retained austenite increase a friction coefficient and caused surface brittle fracture. White layer formation changes the wear mechanism in the friction zone. Great hardness of white layer decreases friction coefficient, but its fragility and spalling from material surface dramatically increases material wear. It has been confirmed that the hard precipitations in subsurface layer decreases material fracture toughness [8].

Therefore tribological properties are very important matter which should be taken in to account in the material design. Hence the aim of this study was to determine the correlation between the the relationship between microstructure and wear resistance of the 90CrV6 hypereutectoid steel.

2. MATERIAL FOR INVESTIGATION

Material for investigation was 90CrV6 hypereutectoid tool steel. The chemical composition of investigated steel is presented in table 1. The microstructure of investigated steel consist of perlitic matrix with spheroidal secondary cementite precipitations. Rectangular samples with dimensions 4x4x20 mm were heat treated on the basis of CCT diagram (Fig. 1). They were austenized at 850 ºC for 20 min and cooled with the rate of: 1 – 0.076 ºC/s; 2 – 0.24 ºC/s; 3 – 0.83 ºC/s; 4 – 2.17 ºC/s; 5 – 6.5 ºC/s; 6 – 21.4 ºC/s. Microstructural analysis was performed by the use of light microscope. The cross sections were etched with 2% nital. The hardness measurements were performed by the use of HPO-250 hardness tester with the 294 N load (HV30). Tribological tests were performed by the use of T-05 tribological tester, equipped with block on roll friction couple. The load during the test was 100 N and time 2000 s. Tests were performed without the lubrication in the room temperature. The counter sample was 100CrV6 steel heat treated on the hardness approximately 57HRC. During the test the continuous measurements of friction force and attrition depth has been performed. The friction zone was observed by the use of light microscope.

Table 1 Chemical composition of 90CrV6 steel (% mass)

C	Mn	Si	P	S	Cr	Mo	V	Ni
0.87	0.28	0.28	0.006	0.012	1.45	0.08	0.10	0.28

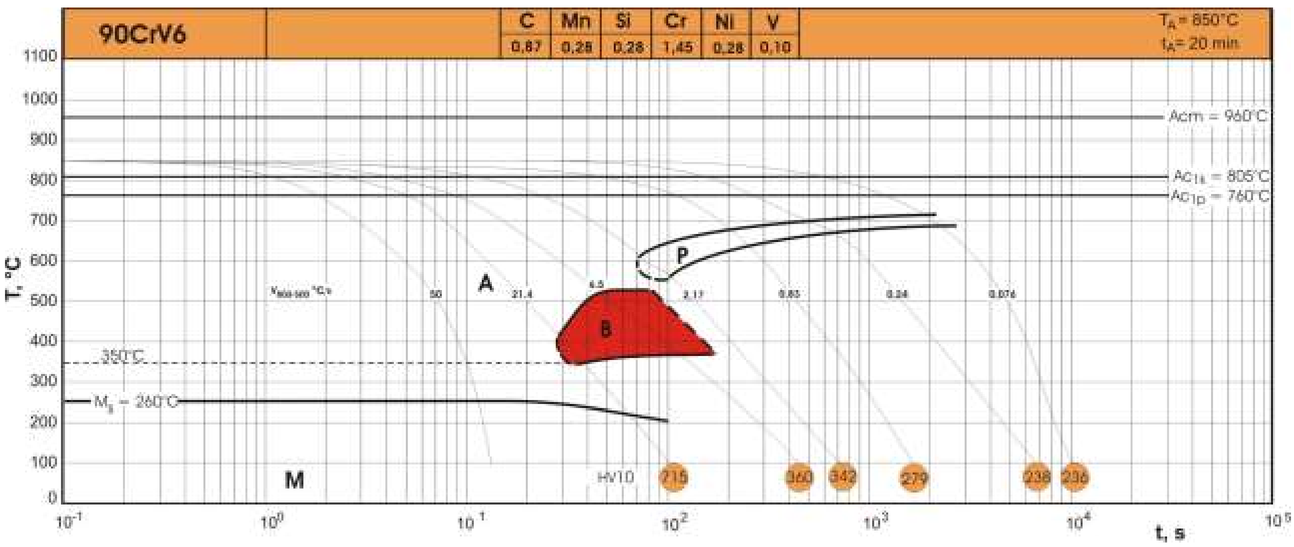


Fig. 1. CCT diagram of 90CrV6 steel [7]

3. RESULTS AND DISCUSSION

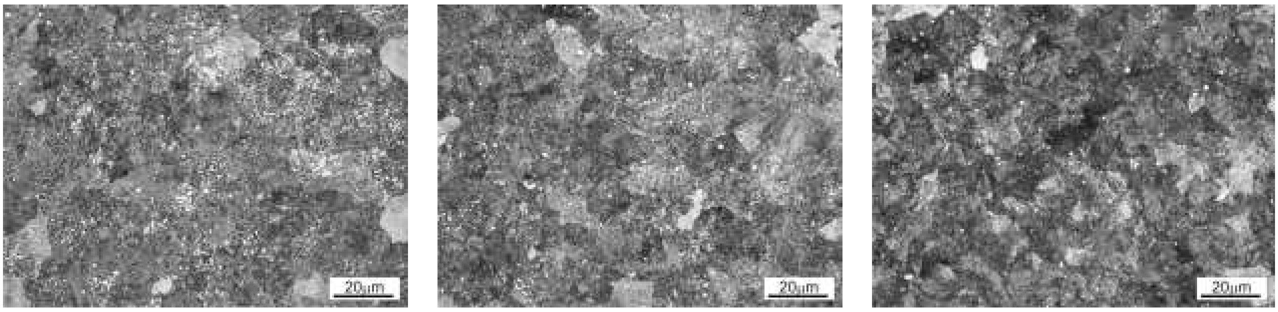
3.1. Microstructure of the samples after heat treatment

The changes in cooling rate effect on the samples microstructures (Fig. 2). For sample number 1 the microstructure was coarse perlite with the spheroidal precipitations of secondary cementite (Fig. 2a). Increase of the cooling rate resulted in the decrease of interplane distance in perlite (Fig. 2b-d). Further increase in cooling rate resulted in the bainite formation. Sample 4 was characterized by the perlitic microstructure with the secondary cementite precipitations and small amount of upper bainite (Fig. 2d). Upper bainite was dominated microstructure of the sample for 6.5 ºC/s cooling rate (Fig. 3e). Also in the microstructure the secondary cementite precipitations and perlitic regions have been observed. For the cooling rate of 21.4 ºC/s the sample matrix was martensite with secondary cementite precipitations (Fig. 3f). The hardness of the samples is presented in Table 2.

Table 2 Samples hardness after cooling

Lp	1	2	3	4	5	6
Cooling rate [ºC/s]	0.076	0.24	0.83	2.17	6.5	21.4
HV 30	255±6	284±3	316±2	370±7	403±3	875±27

a) cooling rate 0.076 ºC/s b) cooling rate 0.24 ºC/s c) cooling rate 0.83 ºC/s



d) cooling rate 2.17 ºC/s e) cooling rate 6.5 ºC/s f) cooling rate 21.4 ºC/s

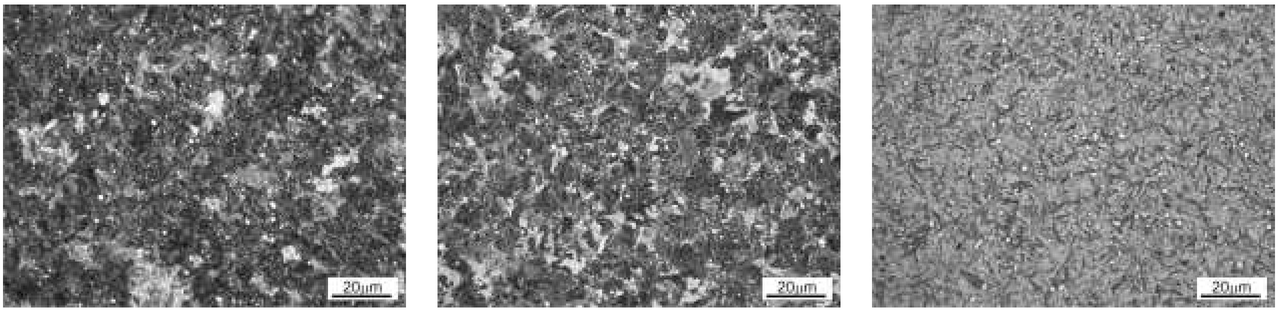


Fig. 2 Microstructures of the 90CrV6 steel after heat treatment

3.2. Analysis of wear mechanism

Images of the friction zone are presented in Figure 3. Additionally the observation of the cross-sections perpendiculary to the friction plane has been performed. In wear area of perliic samples the sliding wear has dominated. Brittle fracture observed on the wear area was probably caused by the white layer formation (Fig 3a-d). White layer creation was also observed on the cross-sections of perlitic samples (Fig. 4c,d). The surface develops after the tribological test decreases with the increase of the samples hardness. Plastic deformation of the subsurface layer, caused by the friction, was observed for all samples with perlitic matrix (Fig. 4a-d).

Different wear mechanism was observed for the bainitic and martensitic samples. Microridging was the main mechanism for the bainite microstructure (Fig. 3e). The wear area of the sample with martensitic microstructure was characterized by the adhesion wear (Fig. 3f). The white layer formation and plastic deformation of the subsurface area have not been observed for the samples with baintite and martensite microstructures (Fig. 4e,f). The baintiic microstructure reveals the biggest resistance for the adhesive wear.

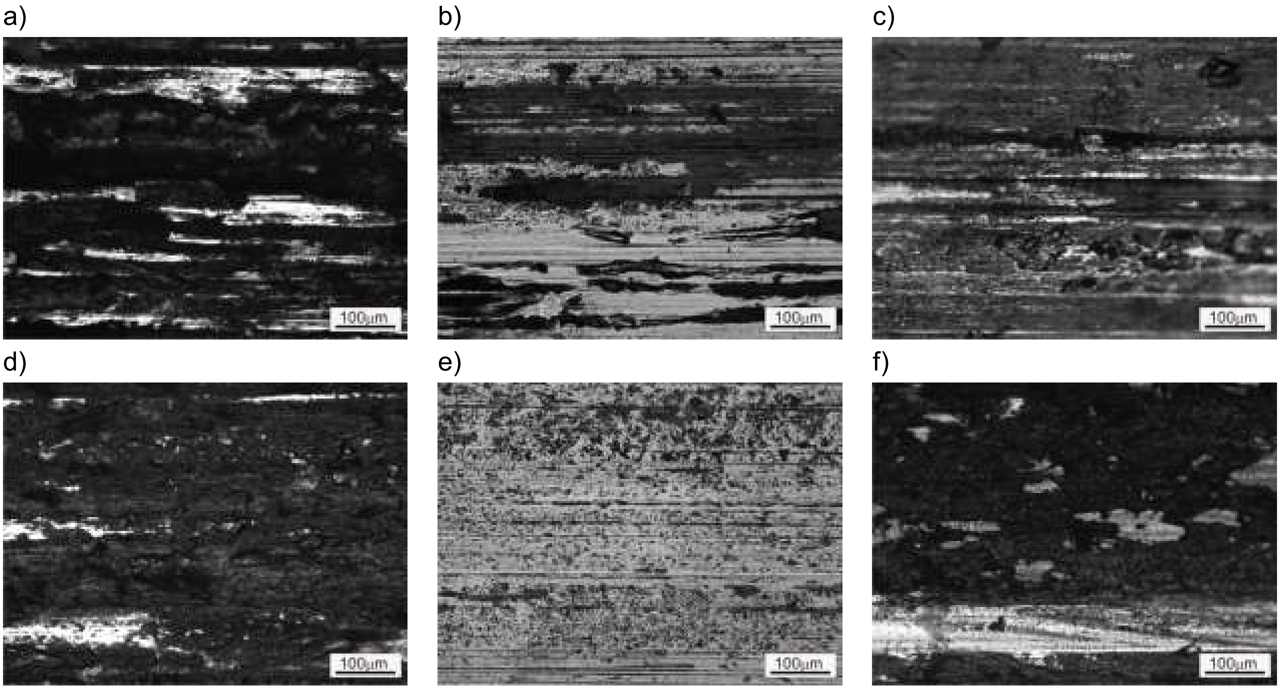


Fig. 3 The image of the wear surface of the samples cooled with the cooling rate of: a) 0.076 ºC/s; b) 0.24 ºC/s; c) 0.83 ºC/s; d) 2.17 ºC/s; e) 6.5 ºC/s; f) 21.4 ºC/s

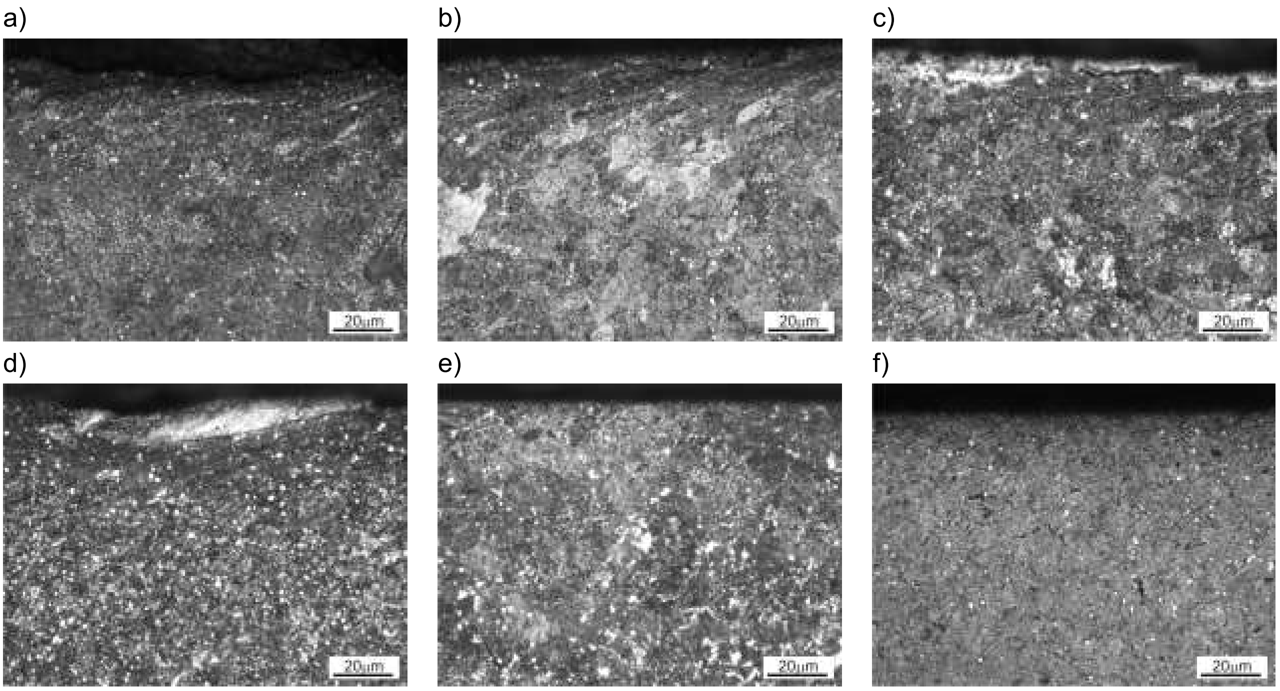


Fig 4 Microstructure of the samples in cross section cooled with the cooling rate of: a) 0.076 ºC/s; b) 0.24 ºC/s; c) 0.83 ºC/s; d) 2.17 ºC/s; e) 6.5 ºC/s; f) 21.4 ºC/s

4.3 Analysis of the friction coefficient, mass lost, and hardness of the samples

Relationship between friction coefficient and the samples hardness was presented in Figure 5. Perlite microstructure was characterized by the simultaneity increase of the friction coefficient and hardness (Fig 5a). The mass loss also decreases with the increase of hardness. Correlation between the friction coefficient and the mass loss confirmed the pervious state (Fig 6a). Relationship between the friction coefficient and the mass loss for the samples 4, 5 and 6 allow to state that the friction coefficient of baintie is the lowest (fig. 5b).. The friction coefficient value is related with change of wear mechanism to micrordging, there was not three body contacts. The biggest friction coefficient was observed for the martensite microstructure, it is caused probably by the spalling of martensite, caused by the structural stresses and adhesive joints creation. The diagram of the friction coefficient and mass loss dependence (Fig. 6b) shows that for the martensite microstructure the mass loss is the biggest.

a) b)

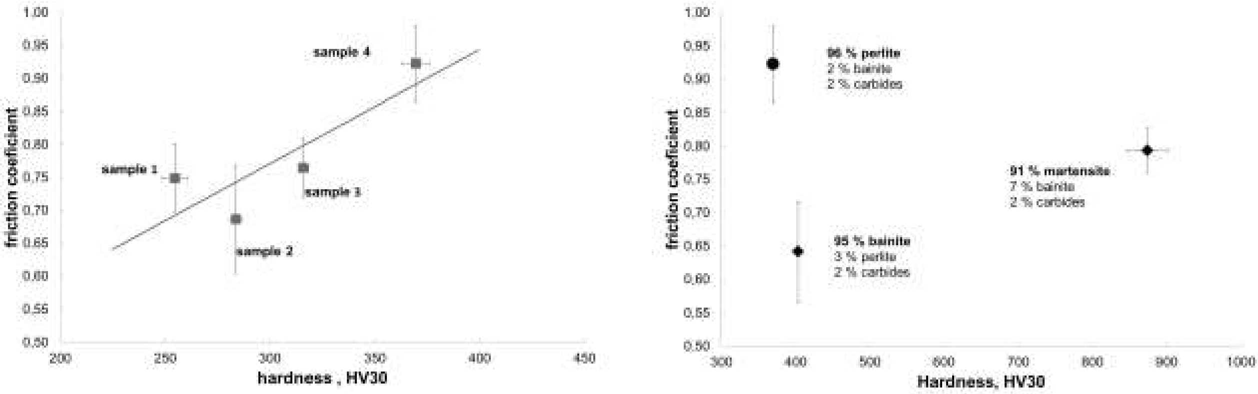


Fig 5 The correlations between hardness and friction coefficient: a) samples with perlitic matrix, b) samples with bainite and martensite in the microstructure

a) b)

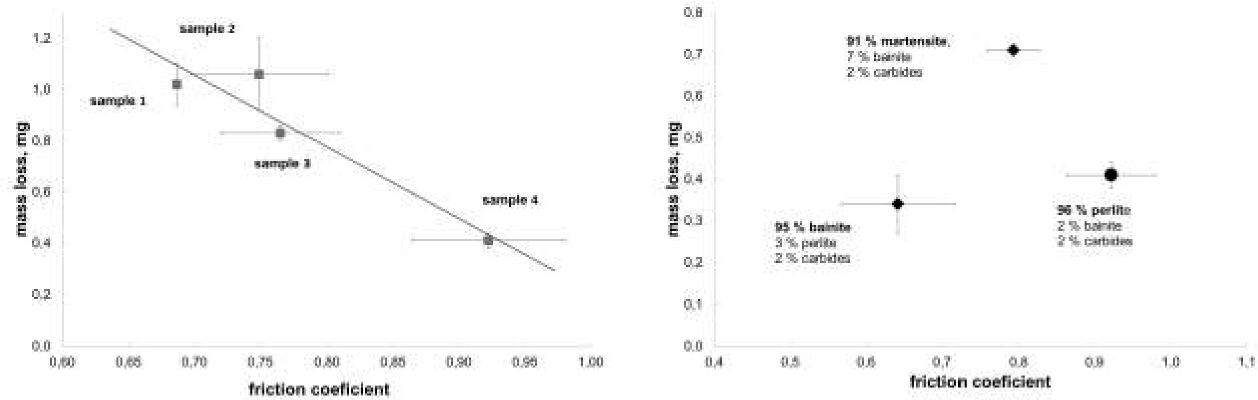


Fig 6 The correlations between friction coefficient and mass loss: a) samples with perlitic matrix, b) samples with bainite and martensite in the microstructure

CONCLUSION

Refinement of perlite microstructure, results in increase of material hardness, which effect on wear resistance increase. Simultaneously with increase of perlitic samples hardness increases the friction coefficient. Phase transformations influence on the wear mechanism changes. Martensite microstructure was characterized by adhesive mechanism of wear. Bainite microstructure has the biggest wear resistance caused by microridging . Resistance for adhesive joints creation resulted in the smallest mass loss of baintic sample.

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