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To cite this article: T Kovács-Coskun and P Pinke 2013 IOP Conf. Ser.: Mater. Sci. Eng. 47 012032

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The Effect of Microstructure on the Local Wear Behavior of Dual Phase Steels

T Kovács-Coskun¹ and P Pinke²

¹Óbuda University, Bánki Donát Mechanical and Safety Engineering, Budapest 1081, Népszínház u. 8. Hungary
²Faculty of Materials Science and Technology Trnava, Slovak University of Technology Bratislava, Paulínska 16, 917 24 Trnava, Slovak Republic
E-mail: kovacs.tunde@bgk.uni-obuda.hu

Abstract. For experimental purposes we used a micro-scale ball-cratering tribometer. In case this test, the process parameters (load, angular speed) were constant, the solution of the wear-kinetic differential equation could be expressed in a simple, closed form. It was tested four types of samples according to the next microstructure, low martensitic steel sample (30% martensite and 70% ferrite), medium martensitic steel sample (50% martensite and 50% ferrite), high martensitic steel sample (70% martensite and 30% ferrite), full martensitic steel sample (100% martensite).

Introduction

It is known that the friction and wear properties of metals and alloys show a strong correlation with their chemical composition, hardness and microstructure. The aim of this work was to analyze and evaluate the correlations between the microstructure and the wear properties of low alloyed, heat treated dual phase steel during dry friction. This type of steel consists of both hard martensite and soft ferrite phases which are formed by applying intercritical heat treatment. Dual phase steels are generally low carbon and/or low alloy steels which have low hardenability in depth. In this type of steel, while the ferrite provides ductility and toughness, the martensite increases hardness and tensile strength to a great extent. It was search a relationship between microstructure and the mechanical properties.

Material and experimental procedure

It was use a low carbon contained and low alloyed heat treated steel the chemical composition is showed by the Table 1 [4].

| C   | Mn   | Cr   | Si   | V    | Nb   |
|-----|------|------|------|------|------|
| 0.28% | 1.45% | 0.21% | 0.20% | 0.13% | 0.01% |

The heat treatments for 1 hour (in the alpha and gamma region at 737 °C, 754 °C, 779 °C and 900 °C) and after water quenched were applied to get low, medium, high and full martensitic structures in the steel, successively. The heat treated samples mechanical tests results find in the Table 2. The tensile and hardness tests were also taken for each sample groups. Further, the fatigue tests were made using a high cycle rotational bending machine while stress was used as a control variable, in the laboratory of the Osmaniye Korkut Ata University Turkey [4]. The Table 2 shows the mechanical properties of the experimented samples us function of the quenching temperature.
Table 2. Mechanical properties of the quenched samples [4]

| Quenching Temperature (°C) | Yield Strength (MPa) | Tensile Strength (MPa) | Elongation (%) |
|---------------------------|----------------------|------------------------|----------------|
| 900                       | 1192                 | 1652                   | 2.1            |
| 779                       | 997                  | 1417                   | 2.5            |
| 754                       | 788                  | 1286                   | 3.2            |
| 737                       | 634                  | 1167                   | 4.2            |

Table 3. Microstructures and heat treatments parameters of the investigated steel [4]

- Quenching at 737 ºC, martensite content ~30%
- Quenching at 754 ºC, martensite content ~50%
- Quenching at 779 ºC, martensite content ~70%
- Quenching at 900 ºC, martensite content ~100%

Test of the wear
In case the tests used the setup showed in Fig.1, the quenched steel bearing ball (d=20mm) wears a crater in the surface of the sample while the displacement transducer is recording on-line the depth of the crater each the help of the Windaq software.

Fig. 1. The ball-cratering tester [2]
The new experimental apparatus designated to evaluate the local wear processes occurring during dry friction can be considered as a modified and further developed version of the micro-scale, ball-cratering test equipment. This new tribometer has the following essential advantages: the wear process can be monitored continuously during the experiments; the stochastic movement of the ball makes it possible to obtain a uniform wear distribution on the ball surface, and it keeps the original spherical geometry of the ball [2-3]. The constant normal load (N=0,86 N) was assured by the spring hanger without any other attached couple.

We used for the wear coefficient calculations the modified Archard equation:

\[ K = \frac{C_k}{2 \cdot N} \quad [m^2/N] \]  

Where: \( S \): wearing distance \([m]\), \( t \): time of the wearing process \([\text{min}]\), \( h \): depth of the wear crater \([m]\) and the rotation of the rolling axe \( f = 500 [1/\text{min}]\)

\[ h = C_k \cdot \sqrt{f} \quad [m] \]  

\[ C_k = \sqrt{2KN} \]  

Results and discussion

The experiments results are showed in the Fig. 2-4. The wear resistance (it mean 1/K) is highest in case of the full martensite structured sample. Between the dual phase samples the 30% martensite content samples showed the best wear resistance it mean the highest ferrite content (70%) structure showed the good wear resistance although its fatigue limit is also high. The hardness of the samples as function of the martensite content shows a known tendency Fig.2. The fatigue limit and the wear coefficient also as function of the martensite content show different result. As the heat treated temperature was different in case of dual phase steels theirs martensite hardness have to be also different. We didn’t measure martensite hardness even that the Table 3 shows the significant difference in case of the different samples microstructure. The hardness results show an average hardness in case of the dual phase steels. It knows that the pure ferrite hardness is about 100-150 HV and the hardness of the martesite structured steels depend on the carbon content. The experimented heat treated samples was quenched from different temperature the alpha and gamma region so the gamma phase carbon content was effectively different because of the ferrite solution power is very low. When the quenching temperature was 779°C the heat treated gamma carbon contain was higher than at the 737°C gamma.

| Martensite content (%) | Hardness (HV) | Fatigue limit (MPa) | Wear coefficient \((m^2/N)\) |
|------------------------|--------------|---------------------|---------------------------|
| 100                    | 580          | 110                 | 1.76 \cdot 10^{-22}       |
| 70                     | 437          | 220                 | 6.02 \cdot 10^{-22}       |
| 50                     | 377          | 310                 | 7.44 \cdot 10^{-22}       |
| 30                     | 296          | 300                 | 3.97 \cdot 10^{-22}       |
Conclusion
We observed that the microstructure of the steels is very important about the wear behavior. The full martensite structure showed the best resistance against the wear load but between the dual phase samples the best was the 30% martensite content structure. This behavior can we interpret by the different properties of the ferrit and martensite structure, because the ferrite provides ductility and toughness, but the martensite increases hardness and tensile strength. The two different structures in case of suitable relation can show good wear resistance, fatigue limit and hardness. It needs some new experiments to recognize the hardness and structure of the martensite in case of the different samples and fine a reason of the different wear resistant of dual phase steels.

Acknowledgement
We acknowledge the financial support of this work by the Hungarian State and the European Union under the TÁMOP-4.2.1. B -11/2/KMR-2011-0001 project.
Also we have to thank Prof. Dr. Mustafa ÜBEYLI about his interoperability, because he shared his investigational results with us.

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