EFFECT OF MICROSTRUCTURE ON THE ABRASIVE WEAR RESISTANCE OF STEELS WITH HARDNESS 450 HV

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ABSTRACT

Hardness has been considered the main factor controlling the abrasive wear of steels. However, microstructure also affects the wear behavior. Four steels with different microstructures were produced with a Gleeble 3800 thermomechanical simulator and tested for abrasive wear behavior. Different cooling rates and heat treatments were applied to obtain a surface hardness of approximately 450 HV. Mainly tempered martensite, pearlite and some bainite could be observed in the microstructures. Scratch testing with a CETR UMT-2 tribometer was conducted to produce wear tracks. The results revealed that each steel showed distinct wear behavior.

Keywords: Steel; microstructure; abrasion

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INTRODUCTION

Wear of steels has been studied intensively for many decades to discover the properties that affect the wear resistance. In most cases, increasing the surface hardness improves the wear resistance of the steels. The correlation between increasing surface hardness and improved resistance to abrasive wear has been widely accepted. Hence, martensitic steels with high surface hardness are often utilized as wear resistant materials in abrasive conditions.

However, it has been noted that abrasive wear resistance does not solely depend in the initial surface hardness. Increasing the surface hardness leads to improved wear resistance within the same microstructure, but different microstructures might show very different wear behavior for a given hardness level [1]. A comparison of bainite, pearlite martensite and tempered martensite with similar hardness level (350HV) revealed that multiphase microstructures might show better wear resistance [2]. Commercial 400 HB wear resistant steels also showed different wear behavior in high-stress abrasive testing despite the same hardness grade [3]. Differences in wear characteristics have been noted even in the very high hardness steels when comparing martensitic and carbide-free bainitic steels [4].

The current research was done to characterize the effect of microstructure on abrasive wear behavior. The main idea was to produce steels with similar hardness level but with different microstructures.

MATERIALS AND METHODS

Two compositions were selected for Gleeble simulations (Table 1). Samples were cut from laboratory scale casts and machined to 6 mm diameter 40 mm high cylinders. Several tests were performed to achieve the desired 450 HV hardness level. All samples were first heated to 1200 °C and held for 2 min. Subsequently

Table 1. Chemical compositions of the tested steels. Alloying element contents are given in wt.%, balance Fe.

Material	C	Si	Mn	Al	Ti	Cr	Ni	Mo
Steel A	0.35	0.25	0.51	0.033	0.003	0.77	2.0	0.15
Steel B	0.45	0.18	0.49	0.031	0.01	0.22	0.02	-

different cooling paths and tempering treatments were applied. Steel A (CR2) and Steel B (CR30) were cooled with 2 °C/s and 30 °C/s cooling rates. Steel A (T350) and Steel B (T350) were both cooled rapidly to 100 °C and then tempered at 350 °C. Thus, four steel samples were produced for hardness and wear testing. Samples were polished prior to testing.

Hardness measurements were done with the Vickers HV10 method and five indentations were measured from each sample. The average surface hardness was between 452 and 470 HV. High-stress two-body abrasion single scratch testing was done with a CETR UMT-2 tribometer using a standard Rockwell-C diamond tip intender. An increasing normal load (F_Z) from 10 N to 60 N was applied for 15 seconds with a constant speed. The coefficient of friction (COF) was measured during the scratching. A profilometer, a laser scanning confocal microscope and a FESEM were utilized to characterize the samples.

RESULTS AND DISCUSSION

Microstructures

Different microstructures were produced with the Gleeble simulations. Both Steel A and B (T350) samples showed tempered martensitic microstructure, but Steel B showed also pearlitic areas and some Widmanstätten ferrite. The slowly cooled Steel A (CR2) sample consisted of mainly highly autotempered martensite and possibly some bainite. Steel B cooled at 30 °C/s had a multiphase structure. This was the result of the medium-carbon composition, which did not transform fully into martensite even with high cooling rates. Thus, Steel B (CR30) was a mixture of different phases including martensite, pearlite and bainite. Fine and coarse pearlite, and also autotempered and fresh martensite could be detected. Prior austenite grain size was large (>100 μm) for all steels as no strain was applied after soaking at 1200 °C.

The composition of Steel A exhibited higher hardenability with more martensite present in both samples, even though the carbon content was higher for Steel B. The high deviation (±62HV) in hardness results (HV10) for Steel B (CR30) also indicated that the sample consisted of soft and hard phases: martensite showed significantly higher hardness, up to 600 HV0.05, whereas for the pearlitic areas the hardness was slightly above 300 HV0.05 when measured with a microhardness tester.

Wear testing

The effect of different phases could be noted in the single scratch testing. The coefficient of friction (Figure 1) was the lowest and also the steadiest throughout the test for the Steel A (CR2) sample. The highest COF was measured for the Steel A (T350), but the strongest fluctuation of the COF was found in Steel B (CR30), where the intender travelled through a variety of phases in the sample. Ploughing and delamination has occurred simultaneously due to the softer and harder phases present. Generally, the harder phases provide a lower friction coefficient [5], but this also depends on the load and indenter or grooving particle size.

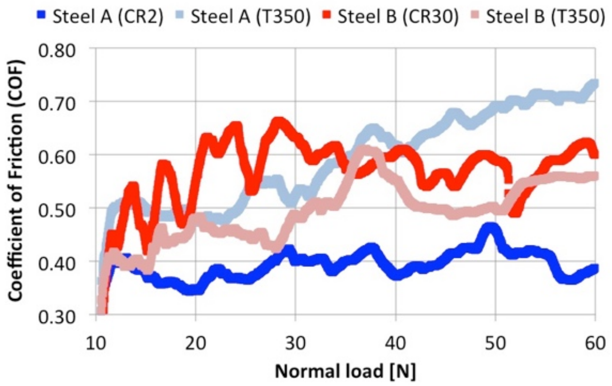

Figure 1. Coefficient of friction (COF) measured during the scratching.

Figure 2 shows a comparison of the wear tracks 1.6 mm from the point of the highest load. Steel B (CR30) shows the highest roughness on the track edges with a large amount of material ploughed aside. Also, some delamination can be seen. In contrast, the tempered samples appear to have smoother edge roughness. This could be another indicator that the mixture of hard and soft phases causes very uneven wear. Naturally, the different phases exhibit different deformation capability resulting in the aforementioned wear behavior.

Closer inspection of the wear tracks with FESEM revealed that Steel A (CR2) had a very smooth scratch surface compared to the other samples (Figure 2). Steel B (CR30) surprisingly also had quite smooth wear marks. Both tempered samples showed microcracking and delamination on the bottom of the groove in the microscale. Therefore, all samples showed distinct wear behavior despite the same hardness level.

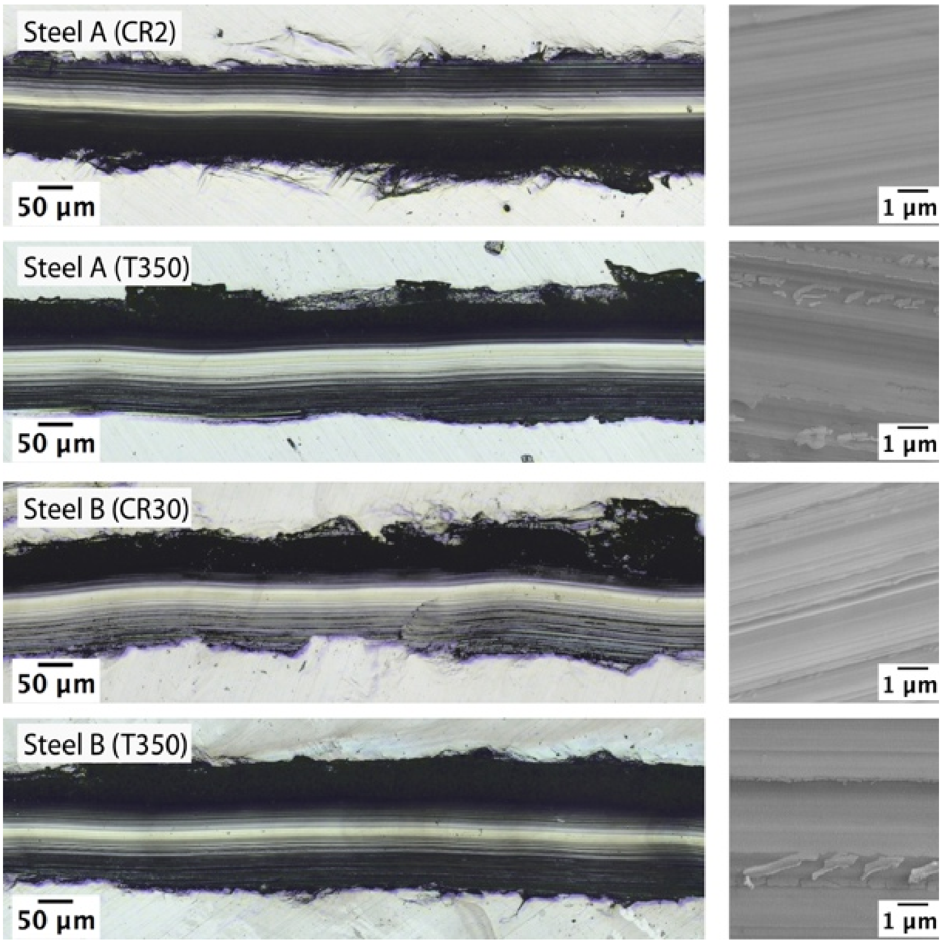

Figure 2. Laser scanning confocal micrographs and FESEM close-up images of the wear tracks. Scratching direction is from left to right.

CONCLUSIONS

- Different microstructures were produced with Gleeble thermomechanical simulator. The hardness level was nearly the same for all at 450 HV.
- A highly variable coefficient of friction was measured for the more inhomogeneous microstructures during scratch testing.
- The most severe ploughing and cracking was found in the sample with the multiphase microstructure.

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