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# WEAR BEHAVIOUR ANALYSIS & MICROSTRUCTURE OF AISI440 STEEL BY TEMPERING PROCESS: A REVIEW

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## ABSTRACT

AISI440 grade type of steel is a excellent martenstic steel which offers a high measure of hardness with compressive strength and abrasion resistance. In the present study, the author has taken AISI440 steel was subjected to varying heat treatments like tempering. The microstructures were studied through a combination of scanning electron microscopy (SEM), energy dispersive spectrometer attached to SEM (*i.e.* SEM-EDS).The bulk hardness decreased with increase in tempering temperature from 423 K to 848 K. The precipitation of $Cr_7C_3$ after 598 K tempering did not cause an appreciable increase in the hardness. At higher tempering temperatures (848 K), the martensite decomposed to give ferrite and cementite. Comparison of hardening and tempering process were carried out on specimens. The abrasive wear tests were carried out on hardened and tempered specimens by using pin on disc. The abrasive wear mass loss increased with increase in the tempering temperature. It was been observed that increase in hardness increased the abrasive wear resistance.

***Keywords:*** *AISI440 steel; hardening; tempering; carbides; martensit*.

## I. INTRODUCTION

AISI440 is a martenstic steel which offers a high degree of hardness with compressive strength and abrasion resistance. The abrasion resistance of steels did not show consistent correlation with the bulk hardness. There are contradictory opinions in the reported literature – some authors suggested that increase in hardness increases abrasive wear resistance, while few others reported a decrease in abrasive wear resistance with the increase in hardness, in particular, where abrasive wear by brittle fractures pre-dominates. Relatively less data is published regarding the abrasive wear behaviour of AISI 440 steel. This has been the motivation for the present study.

The present study is an effort in obtaining physical understanding and co-relation, if any, between the wear behavior and different microstructure in AISI440 steel. The microstructural and hardness variations in AISI440 steel were obtained by using tempering heat treatments. The microstructures were characterized using scanning electron microscopy (SEM), energy dispersive spectrometer attached to SEM (SEM-EDS).

***Table1.Chemical composition (in wt% alloying elements) of AISI440 steel.***

| | C | Mn | Cr | Si | Mo | P | S | Fe |
|---|---|---|---|---|---|---|---|---|
| AISI440 steel | 0.65 | 1.00 | 18 | 1.00 | 0.75 | 0.04 | 0.03 | balance |

## II. EXPERIMENTAL METHODS

In the present investigation, the author determined AISI 440 steel in the as-rolled and annealed initial condition was used to study the abrasive wear behaviour. The chemical composition of the as- received (*i.e.* as-rolled and annealed) steel as determinedly wet chemical analysis is given above. The specimens used were in the form of a pin of 30 mm length with a diameter of 6 mm.

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For hardening treatments, specimens were initially austenized at 1 123 K (± 5 K) for 3 600s followed by oil quenching. For tempering treatments, the oil quenched samples were heated at temperatures of 423,598, 723 and 848 K respectively for 2 400 s followed by air-cooling to room temperature (298 K). It need to be noted that tempering was done immediately after hardening treatment. All the samples were vacuum sealed to avoid oxidation during hardening and tempering treatments

## III. RESULTS AND DISCUSSION

**Hardness and microstructures**

Figure1shows the hardness of as-quenched, quenched & tempered and as-received AISI440 steel. The as-received materials has the lowest hardness (22 HRc), while the as quenched material has the highest hardness (60 HRc). After tempering at 423 K, the drop was insignificant (2 HRc). It has been reported that quenching from austenization temperature leads to a microstructure containing martensite about 6 vol% of retained austenite and 3–4% of cementite particles which fail to dissolve during the austenizing treatment. When the steel is tempered at low temperatures (<473 K) to relieve the internal stresses, retained austenite decomposes and precipitation of transition carbides of iron takes place from the supersaturated martensite, At temperatures in excess of 473 K, the material softens. In the present study, there is a gradual drop in hardness with the increase in tempering temperature from 423 K to 873 K. Such monotonous decrease in hardness with the increase in tempering temperature. This decrease in hardness with tempering temperature could be attributed to reduction in dislocation density and decomposition of martensite into ferrite and cementite.

***Table 2.Bulk hardness (HRc) of heat treated AISI440 steel samples.***

| As reciev--ed | As quenched | Quenched and tempered at423 k | Quenched and Tempered at 598k | Quenched and tempered at 723 k | Quenched and tempered at 848k |
|---|---|---|---|---|---|
| 22 | 60 | 58 | 53 | 47 | 38 |

To find the micro-mechanisms of two body abrasive wear, SEM of worn surfaces (all conditions) was carried out. The SEM micrographs of worn out as-received, a squenched and quenched + tempered En31 steel specimens at a load of 10 N.

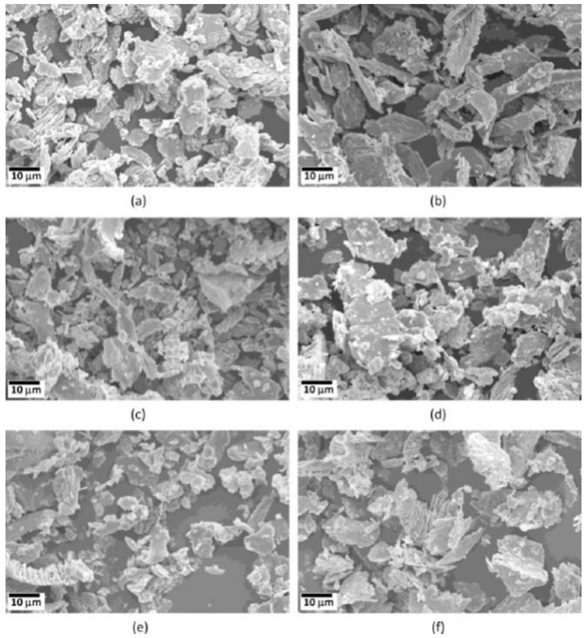


Fig. 1 Secondary electron scanning electron microscopy (SEM) images of wear debris of AISI440 steel. (a) and (b) in as-received (annealed – 1123 K followed by furnace cooling to room temperature) condition, (c) and (d) in as-quenched (austenized at 1123 K for 3600 s followed by oil quenching) condition, (e) and (f) after tempering at 598 K for 3600 s. The left hand side images are for load of 10 N, while the right hand side images are for load of 20 N.

## IV. CONCLUSIONS

In the present study, the author has concluded the microstructures of AISI440 steel after hardening and tempering were analyzed and the effect of microstructures and bulk hardness on the abrasive wear behaviour was studied along with characterization of worn out surfaces. The as-received microstructure of AISI440 steel consisted of pro-eutectoid ferrite along prior austenite grain boundaries and pearlite.

Martensite was formed after hardening, while the un-dissolved cementite which remained after hardening coarsened after low temperature tempering (423 K). After tempering at 598 K, the microstructure consisted of alloy carbides (Cr7C3) along with tempered martensite.

At higher tempering temperatures (848 K), the martensite decomposed to give ferrite and cementite. With increase in tempering temperature the morphology of the carbides became coarser. The abrasive wear resistance of heat treated AISI440 steel exhibited good correlation with bulk hardness; an increase in hardness increased the abrasive wear.

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