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Effect of Austempering and Martempering on Microstructure and Mechanical Properties of EN31 Steel

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ABSTRACT- Heat treatment processes are used to improve the properties of steel. In this study, the effect of austempering and martempering on microstructure and mechanical properties of EN31 steel was examined. The steel was austenitized at 950^{o}C for 60 min and then austempering was held at 360^{o}C and martempering was conducted at 160^{o}C for 15, 30 and 45 min followed by water cooling and air cooling. After heat treatment process different types of mechanical testing was carried out to determine the mechanical properties. Microstructural elements were characterized by using the metallurgical microscope. Experimental result showed that, mechanical properties in case of austempering depend on retained austenite, bainite, ferrite and carbide whereas in case of martempering process it depends on martensite, bainite and pearlite.

Keywords- EN31, Austempering ,Martempering.

1. INTRODUCTION

Heat treatment of a bearing component made of EN31 steel is carried out to accomplish high hardness, wear resistance, and strength. Rolling bearing made of EN31 steel are expected to deliver a high degree of performance when operated at the high speed and comparatively less amount of lubrication, to attained this types of service demand bearing tribologist continuously discover newer ideas to advance the performance. The EN31 steel used for making rolling bearing for different engineering application has tempered –martensitic microstructure and it also contained the appropriate amount of retained austenite. Due to the combination of martensitic microstructure and retained austenite good mechanical properties are obtained. In most of the cases rolling bearing are failed due to rolling contact fatigue, these failures in rolling bearing are because of crack proliferation close to repetitive load cycle surface after the crack proliferation material are removed from the crack surface, and failure takes place.

Lots of researchers have conducted their research to enhance the resistance to rolling contact fatigue. It should be pointed out that rolling contact fatigue is very much affected by the surface properties of the bearing because all the fatigue failure is initiated at the surface. The fatigue failure could be avoided by the proper examination of the surface quality of the bearing material [1].

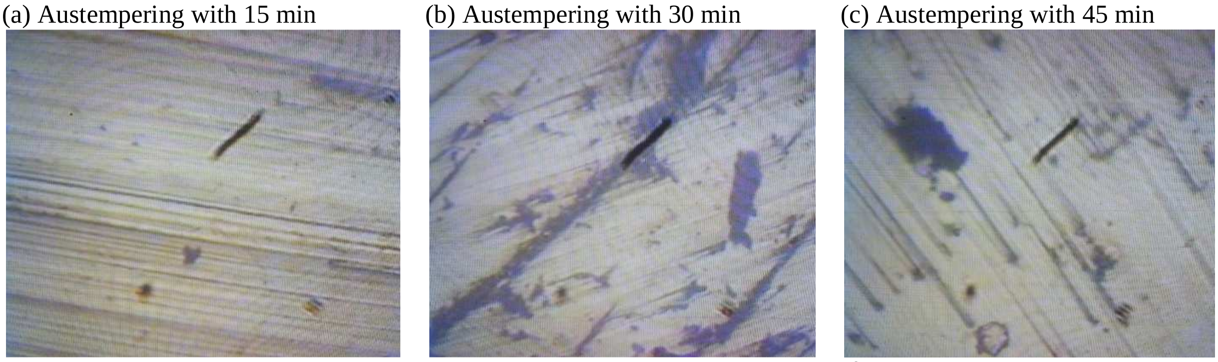
Heat treatment is the process in which metal is heated and then cooled so that their mechanical and physical properties can be improved without changing the original shape of the workpiece. In heat treatment process the metal is heated to required temperature and hold there for sufficient time to cooled, so that the machining, formability, ductility can get better [2].

Austempering consists of heating the steel above the austenitization temperature and then quench it into a hot bath which is held above the martensite start temperature. The product obtained from this decomposition is bainitic structure and contained high hardness and toughness.

In the martempering process, the steel is heated above the austenitization temperature and then quench the steel to a temperature equal to the martensite start temperature; the steel is maintained at this temperature and then cooled to room temperature in the air. The purpose of martempering process is to equalize the temperature of the entire part before transformation takes place and then cool slowly in the range of martensite start temperature to the martensite finished temperature so that stress developed in the steel during contraction when steel is cooled and expansion when austenite is transformed into the martensite can be reduced [3].

Swapnil R. Nimbhorkar and Prof. B.D. Deshmukh (2013) study the effect of case hardening treatment on the structure and properties of automobile gears, The aim of present study is to achieve optimum value of mechanical properties. which consist of a carburizing process which is a case hardening process. They made a comparative study of the different types of gear that are EN353, SAE8620, and 20MnCr5 and concluded that retained austenite in EN353 is more than SAE8620,20MnCr5 due to higher hardening temperature[4].

(a) Austempering with 15 min (b) Austempering with 30 min (c) Austempering with 45 min



(d) Martempering with 15 min (e) Martempering with 30 min (f) Martempering with 45 min

Fig. 1. Microstructure of different heat treated samples (100× magnification)

2. EXPERIMENTAL DETAILS

EN31 steel having a nominal composition of 0.90%C, 0.35%Mn, 0.35%Si, 1.6%Cr, 0.04%S, 0.04%P and rest Fe(in wt%). The dimension of the specimen for impact test is 55mm×10mm×10mm, for tensile test 60mm gauge length and 12 mm gauge diameter and for hardness test the dimension is 30mm×10mm×10mm. The Specimens were austenitized at 950^{o}C for 60 min then austempered at 360^{o}C and martempered at 160^{o}C for 15, 30, 45 min soaking period. After heat treatment the specimens were subjected to mechanical testing and Microstructural analysis.

3. RESULTS AND DISCUSSIONS

3.1 Microstructure

After heat treatment, microstructure contains martensite + bainite and retained austenite. The dark needle-shaped structure is bainite. The dark brown region is martensite and white/gray areas are retained austenite. Figure 1 (a) Austempered specimen with 15 min soaking time shows the good density of carbides. Figure 1 (b) Specimen with 30 soaking times has less carbide compare to 10 min soaking time. Figure 1 (c) The specimen austempered with 45 min soaking time has a good number of carbide but only in selected areas. After martempering process, (Figure 1 (d, e, and f)) the microstructure contains martensite, bainite, and pearlite .The dark needled – shaped structure is bainite. Brown region is martensite and lamellar structure is pearlite. Martempered specimen with 15 min soaking time shows the good density of martensite and pearlite. As the time increases moderate bainite increases and reduced the extent of martensite and retained austenite.

3.2 Tensile Strength

From the figure 2 In case of austempering process the value of tensile strength decreases with increasing austempering time because the amount of retained austenite increases with time. The maximum value of tensile strength is obtained at 360°C for 15 min soaking time. In case of martempering process maximum value of tensile strength is achieved in the entire samples because of formation of martensite from austenite. As the holding time increases the value of tensile strength decreases because moderate bainite increases and reduced the extent of martensite and retained austenite. The maximum value of tensile strength is obtained for 15 min soaking time.

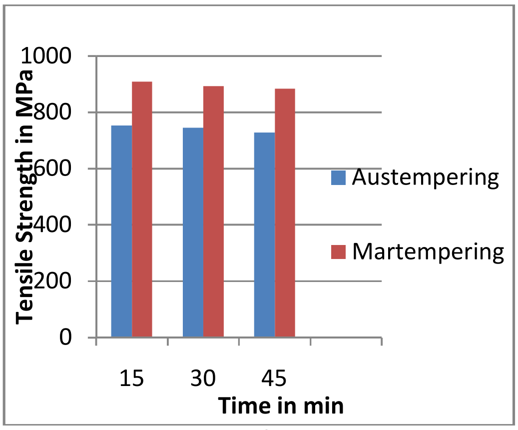


Fig. 2. Tensile strength of heat treated samples

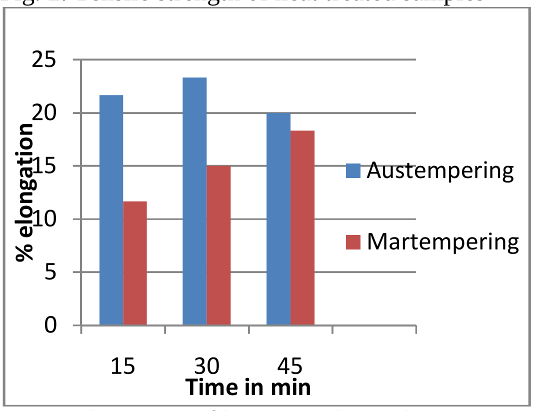


Fig. 3. Elongation of heat treated samples

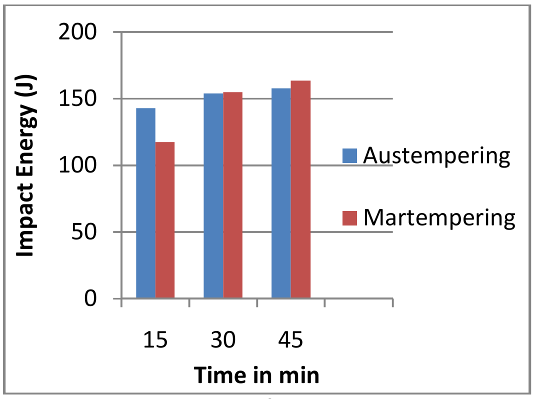


Fig. 4. Impact toughness for heat treated samples

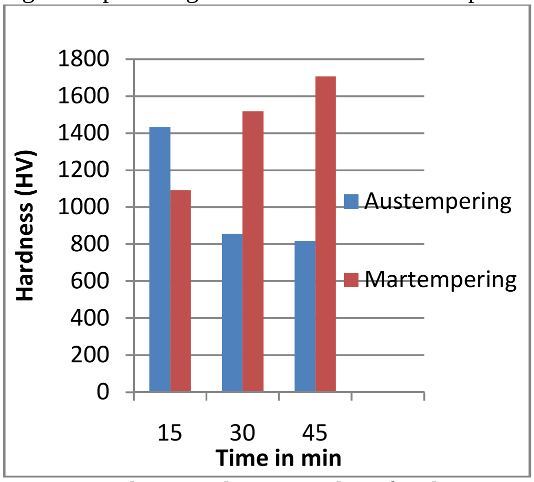


Fig. 5. Vicker Hardness number for heat treated samples

3.3 Elongation

From figure 3 In case of austempering process the ductility is found to be increased up to 30 min due to increasing in the amount of retained austenite with austempering time and less martensite on subsequent cooling to room temperature. Beyond 30 min the ductility is decreased because the retained austenite decomposes into the bainite ferrite and carbide. In case of martempering the ductility is found to be increases with time because of formation of pearlite in the microstructure. Pearlite is formed in the microstructure because of slow air cooling.

3.4 Impact Toughness

According to figure 4 In case of austempering the value of impact toughness is increasing with austempering time because the percentage of bainite increases and the austenite and martensite volume decreases with time [5]. The maximum value of toughness is obtained at 360°C for 45 min soaking time. Whereas in case of martempering process as the holding time increases the value of toughness is increases because of increment in amount of bainite and reduced the extent of martensite and retained austenite [6]. The maximum value of toughness in case of martempering process is obtained at 160°C for 45 min soaking time.

3.5 Vicker Hardness

From the figure 5 it is clear that the value of hardness is increased as the austempering time increasing because of higher bainite volume fraction at higher austempering time. The maximum value of hardness is obtained at 360°C for 15 min soaking period. The martempered samples are hardest among the entire specimen because the austenite is converted into martensite. As the holding time increases the value of hardness is increases because of formation of bainite as well as pearlite. The maximum value of hardness in case of martempering process is obtained at 160°C for 45 min time.

4. Conclusions

EN31 steel was subjected to various heat treatment processes for enhancing the material properties. From the present study, the following conclusions are drawn.

- The specimen austempered for 15 min has a higher value of tensile strength and for 45 min time has the least value of tensile strength, because of retained austenite present in the microstructure.
- The specimen austempered for 30 min has a higher value of ductility, and 30 min has the least amount of ductility, because of bainite ferrite and carbide formation.
- The specimen martempered for 15 min has a higher value of tensile strength and 45 min has the least value, whereas maximum value of ductility is obtained at 45 because of martensite formation.
- Austempering conducted for 45 min has a higher value of impact toughness, and 15 min has the least value whereas the samples martempered for 45 min has the higher value in entire heat treated samples because of bainitic structure in the samples.
- The maximum value of hardness is obtained for 15 min soaking period in case of austempering because the martensite formation cannot be prevented.
- The maximum value of hardness is obtained at 45 min soaking time in entire heat treated samples in case of martempering process because of martensite formation.

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