COMPARATIVE STUDIES ON MECHANICAL PROPERTIES OF AISI 4340 HIGH-STRENGTH ALLOY STEEL UNDER TIME- QUENCHED AND AUSTEMPERED CONDITIONS

Gurumurthy B M[1], Shivaprakash Y.M[2], Gowri Shankar M.C[3], S.S Sharma[4], Achutha Kini[5]

[1]*Assistant Professor Mechanical & Manufacturing Engg. Dept, MIT, Manipal, Karnataka, India*
[2]*Assistant Professor-Sr.Scale, Mechanical & Manufacturing Engg. Dept, MIT, Manipal, Karnataka, India*
[3]*Assistant Professor-Sr.Scale, Mechanical & Manufacturing Engg. Dept, MIT, Manipal, Karnataka, India*
[4]*Professor, Mechanical & Manufacturing Engg. Dept, MIT, Manipal, Karnataka, India*
[5]*Professor, Mechanical & Manufacturing Engg. Dept, MIT, Manipal, Karnataka, India*

Abstract

In the present work, the mechanical properties and microstructures of AISI 4340 high strength alloy steel under different conditions are investigated. Generally time quenching is substituted for surface hardening wherein martensite structure is formed in the case of the softer products towards core but austempering gives always uniform grained bainitic structure without any residual stresses and retained austenite. Austempering is given to hot working dies and springs to obtain maximum elastic limit. To assure uniform finer grains in the specimen normalizing treatment is given prior to other treatments. Samples were prepared and all of them were normalized at 900^0C for 2 hrs and then air cooled to room temperature. After normalizing specimens are separated into 2 groups, timed quenching is performed on one set and austempering heat treatment is performed on another set of specimens. During timed quenching, the specimens are heated to 900^0C. After reaching $900\ ^0$C, the specimens are soaked at that temperature for two hours. The specimens are then taken out of the furnace and quenched in engine oil for less than 4 seconds followed by air cooling. Hardness, microstructure and impact tests were performed on the timed quenched specimens to analyze the hardness value, grain size distribution and the energy absorbed respectively. Another set of the normalized specimens were taken and austempering was carried out on them. During austempering the specimens were heated at 900^0C for 2 hrs in one furnace followed by transferring the specimens to the second furnace immediately within 10 seconds, which was maintained at 320^0C and the specimens were soaked in the second furnace for 2 hrs and 45 min and then furnace cooling was done.

Hardness, microstructure and impact tests were again performed and obtained values were compared with timed quenched specimens. Difference in the mechanical properties of AISI 4340 steel at timed quenched and austempered conditions was observed. It is found that grain size of the austempered specimen is higher than the time quenched specimen. It is also observed that the austempered specimen has maximum strength and very good impact energy as compared to that of the timed quenched specimen. As a result mechanical properties like tensile strength, impact strength are improved in the austempered specimens than the timed quenched specimens..

Keywords: *Microstructure, Impact energy, Ductility, Austempering, Hardness, Grain size*

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1. INTRODUCTION

AISI 4340 alloy steel is a heat treatable and low alloy steel containing chromium, nickel and molybdenum. It has high toughness and strength in the heat treated condition. The addition of Molybdenum prevents the steel from being susceptible to temper embrittlement. When discussing high strength steel, it is crucial to realize that the definition of so-called high strength depends entirely upon how the steel is to be used. These usages tend to fall into a number of different categories where different combinations of properties are required. In each of these categories, works being carried out to develop higher strength steels have to take the manufacturing processes, the heat treatment and the alloying technology into consideration An understanding of the mechanical properties of metals during deformation over a wide range of loading conditions is of considerable importance for a number of engineering applications. In recent years quenched low alloy steels have been used for critical structural aircraft and aerospace and solid propellant rocket applications [1, 2]. However, the use of these steels is limited by their poor ductility [1, 2]. In recent years, to overcome this problem and improve the mechanical properties of steels, many different methods such as the modified austemper[2-10], short time austenitizing[11], interrupt fast cooling[12], repetitive heat treatment, and step quench, have been proposed[13]. The proposed heat treatment methods in this paper are timed quenching and austempering which simultaneously meet the severe engineering requirements in strength and ductility. The results of the effect of timed quenching on the mechanical properties of AISI4340 steel such as microstructure, hardness value and impact strength is compared with that of austempering heat treatment.

2. EXPERIMENTAL DETAILS

2.1 Material

Commercial AISI4340 steel was used in this investigation. The chemical composition of which is as shown in table 1. The steel was obtained in the form of 25mm diameter round bars.

2.2 Preparation of Specimens

2.2.1 Impact Specimen

The available diameter i.e. ¾ inch diameter EN24 rod was procured from the market. Rod was cut into 80 mm pieces using band saw. Facing was done to reduce the length to 75mm. Drilling was done at one end in order to hold the work piece with the tail stock. Turning was done to reduce the diameter to 14.14 mm. Shaping was carried out to obtain 10x10 mm square cross section. V notch was made on the square work piece using shaper

2.2.2 Hardness and Microstructure Specimen

Rod was cut into 25 mm pieces using band saw. Facing was done to obtain smooth surface and length was reduced to 20mm. Grinding and polishing were done to obtain mirror finish on the surface

After the preparation of the specimens, normalizing treatment was given on all the specimens .In normalizing, all the specimens are heated to 900 ^{0}C for two hours. The specimens are then taken out of the furnace and air cooled to room temperature.

One set of the specimens are subjected timed quenching and the 2nd set of specimens for austempering heat treatments. During timed quenching, the specimens are heated to 900^{0}C. After reaching 900 ^{0}C, the specimens are soaked at that temperature for two hours. The specimens are then taken out of the furnace and quenched in engine oil for less than 4 seconds. The motive is to take out the specimens from the engine oil before the temperature of the specimens and the quenching media is balanced. Then it is cooled to room temperature in air. During the treatment, the case is converted into harder martensic structure with balanced pearlitic structure towards the core. In austempering, all the specimens are put in the furnace and heated to 900 ^{0}C. Then these specimens are soaked at this temperature for 2 hrs. These specimens are then taken out of the furnace and immediately shifted to another furnace maintained at 320 ^{0}C within 10 seconds. Then these specimens are soaked at this temperature for 2 hours and 45 minutes. After this, the furnace is switched off and the specimens are furnace cooled. Hardness, microstructure and impact tests are performed to check the hardness value, grain size and energy absorbed by the specimen simultaneously

2.2.3 Method Impact Test

The specimens are tested for toughness using Izod impact test. The specimen was placed in the holding vice. Dial gauge was set to maximum (180 joules) and the pendulum is released to strike the specimen with impact load. The energy absorbed before failure is noted.

2.3 Microstructure

The microstructure recorded in inverted mettalurgical microscope at 200x magnification. The cylindrical specimens are polished with 1/0, 2/0, 3/0, 4/0 emery papers in the order. The final polishing to mirror finish is done with disc polisher with velvet cloth and alumina paste (Al_2O_3). Then it is etched with NIDOL

2.4 Hardness Test

Specimens are polished op to mirror like finish. The specimen was placed on the hardness testing fixture. Magnification was set to 400x. Micro-indentation was made on the surface of the specimen by applying 100gf for 15 seconds. Using the eye piece, the length of the diagonals of the indentation was noted down. Using the lengths of the diagonals the machine generated the hardness value. 3 trials were performed and the average value was documented as the hardness value of EN 24 steel.

The results of austempering are then compared and analyzed with that of the timed quenching heat treatment.

3. RESULTS AND DISCUSSION

The beneficial results of austempering depends on the primary microstructure, the grain size of the prior austenite, the chemical composition of the steel and the temperature of austempering [3]. Based on the literature survy[4] , for austempering treatment, the temperature for heating is selected as 900^{0}C for 2 hours followed by quick transfer to second furnace and isothermal holding at 320^{0}C for 2 hours 45mins. This treatment was given to obtain uniform hardness and tougher 2 phase binetic structure.

3.1 Impact Test

The impact test for time quenched condition is as follows. The average energy absorbed by the specimens is 26 joule. The impact test of austempered condition . the average energy absorbed by the specimen is 49 joule. The result follows that impact resistance of the austempered specimen is nearly one and a half times more than that of the time – quenched specimen.

3.2 Microstructure Study

The grain size of the specimen in time quenched condition is found to be 2 and grain size of the specimen in austempered condition is found to be 6.

4. FIGURES AND TABLES

Fig 1: Microstructure and Hardness specimen

Fig 2: Broken specimen of impact test

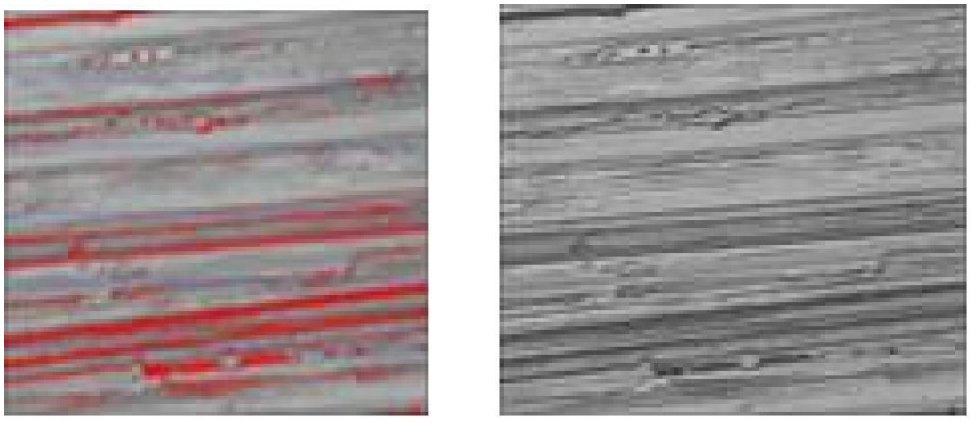

Fig.3: Microstructure of the timed quenched specimens

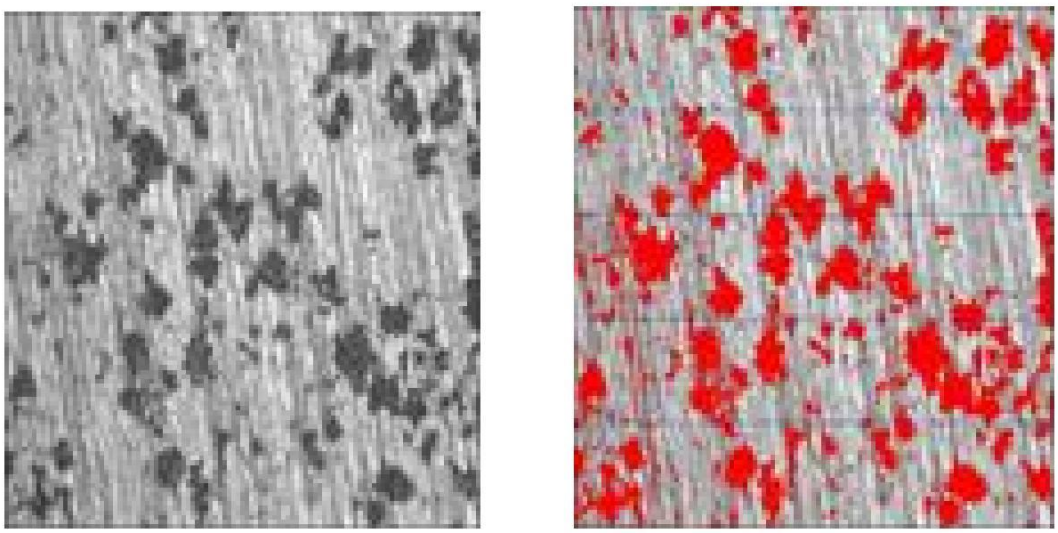

Fig.4: Microstructure of austempered specimens

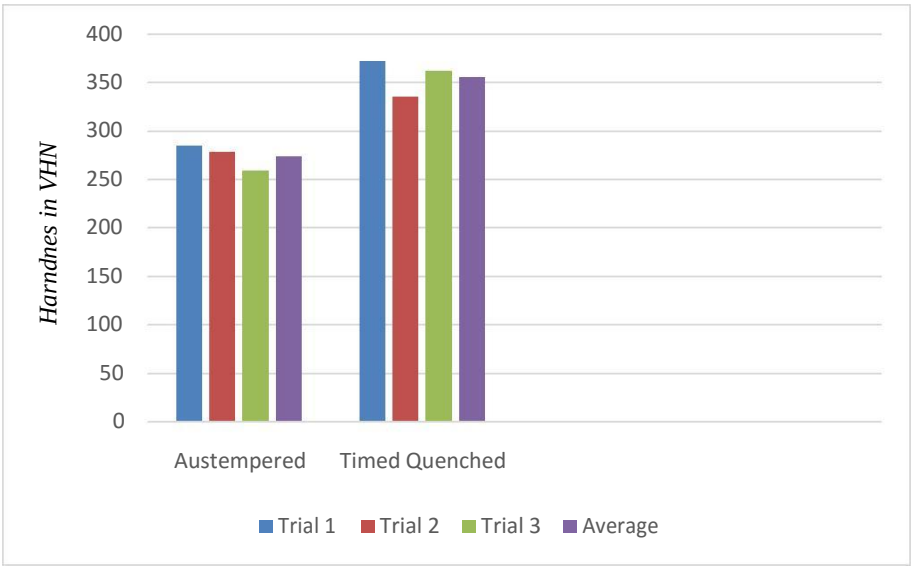

Fig 5: graph denoting hardness test results

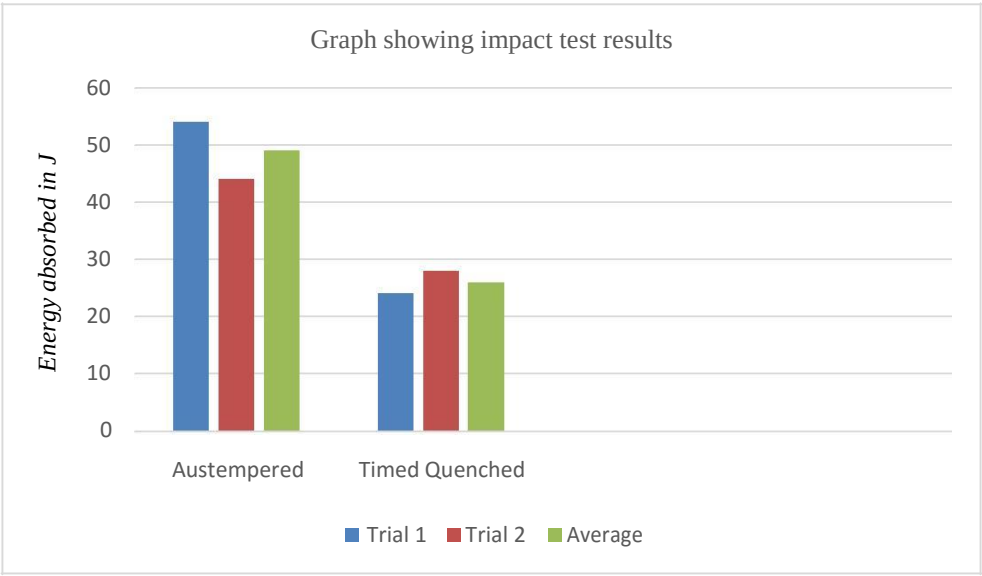

Fig 6: graph showing impact test results

Table 1: Chemical composition of AISI 4340 steel

Carbon	0.40
Silicon	0.25
Manganese	0.70
Nickel	1.85
Chromium	0.80
Molybdenum	0.25

Table 2: Hardness test results

Condition	Trial 1	Trial 2	Trial 3	Average VHN
Austempered	285	279	259	274
Time Quenched	372	335	362	356

Table 3: impact test results

Condition	Trial 1	Trial 2	Trial 3	Average VHN
Austempered	285	279	259	274
Time Quenched	372	335	362	356

5. CONCLUSION

Austempering method to the heat treatment of AISI4340 steel has been presented and has been compared with the timed quenching method.

- It is found that hardness of the timed quenched specimen is higher than the austempered specimen. But this hardness is surface hardness only.
- Grain size of austempered specimen is finer than that of the timed quenched specimen that makes it finer than the time-quenched specimen.
- Austempered specimen has got good impact resistance as compared to that of the timed quenched specimen.
- The austempered specimen shows faced structure whereas time quenched specimen shows single phase band like martensic structure.

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BIOGRAPHIES

Mr. Shivaprakash Y.M is the corresponding author and working as Assistant Professor(sr.scale) in the Department of Mechanical and Manufacturing Engineering, MIT, Manipal,Karnataka,India. He did his B.E in Mechanical Engineering from Gulbarga University and M.E in Machine design from Bangalore University. Presently he is pursuing the Ph.D (composite materials) under the supervision of Dr.K.V.Sreenivasa Prasad at SJCE, Mysore, affiliated to VTU, Belgaum. www.manipal.edu

Mr.Gurumurthy.B.M First author Mechanical received his Bachelor's Degree in Engineering (VTU, Belgaum, India 2008) and Master's Degree in Mechatronics Engg (NIT K Surathkal, India 2010). He has four years in teaching and research. His area of interest includes Mechatronics, Manufacturing, Heat treatment and Metallurgy. He is a faculty member at Manipal Institute of Technology, Manipal and. He has published 3 research papers in journalsconferences. www.manipal.edu

Mr. Gowri shankar M. C received his Bachelor's Degree in Mechanical Engineering (Mysore University, India 1998) and Master's Degree in Precision and Quality Engg (IIT Kharagpur, India 2006). He has to his credit 7 years of professional experience in industry and more than six years in teaching and research. His area of interest includes Manufacturing, Heat treatment and Metallurgy. He is a faculty member at Manipal Institute of Technology, Manipal and carrying his research in the area of heat treatment of composites from Manipal University. He has published 3 research papers in journals and presented 5 research papers in conferences. www.manipal.edu

Dr. S. S. Sharma holds Bachelor's degree in Industrial & Production Engineering (Mysore University, India 1987), Master's degree in Materials Engineering (Mangalore University, India 1996) and PhD degree in Materials Engineering (Manipal University, India 2007). He has 24 years of teaching experience. His area of interest includes Heat Treatment, Deformation of Metals, Material Characterization, Composite Materials. He has published 28 research papers in journals and presented 47 research papers in conferences.www.manipal.edu

Dr. Achutha Kini holds Bachelor's degree in Mechanical Engineering (Mysore University, India 1985), Master's degree in Engineering Management (Mangalore University, India 1991) and PhD degree in Corrosion Engineering (Manipal University, India 2012). He has 24 years of teaching experience. His area of interest includes Corrosion Science and Engineering, Composite Materials. He has published 19 research papers in journals and presented 34 research papers in conferences.www.manipal.edu