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Study of Mechanical Properties of Dual Phase EN19 Steel (AISI4140)

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Abstract

Medium carbon steels are high strength steels which include AISI4140 as an important member in low alloy category. These steels show positive response to all variety of heat treatments. The present work aims to experimentally investigate the properties like Tensile, Hardness and Impact Strength on AISI4140 steel. The as-bought properties of AISI4140 steel have good ductility, shock resistance but low wear resistance and shorter service life. However such properties can be further improved through various heat treatment processes. In the present investigation the effect of dual phase heat treatment and mechanical property analysis of AISI 4140 are studied. The effect of normalizing as pretreatments on dual phase structure and property at different inter-ctitical temperatures holding for 2 hours followed by water quenching are investigated in view of improvement in mechanical properties like hardness, impact toughness and tensile. Test specimens are prepared and subjected to preliminary heat treatment. The dual phase structures (Ferrite-Martensite) by heating to three different inter-critical temperatures are obtained by rapid quenching in water medium. The resultant dual phase microstructure is also studied. Then tensile, impact and hardness tests are conducted and compared with as-bought condition results. The dual phase steels find applications widely in automobile parts and general constructional applications where wear resistance is of the serious concern.

Keywords: Austempering, Annealing, Dual Phase Ferrite, Martensite, Steels

1. Introduction

Heat treatment is a process of combination of different operations involving heating and cooling of metal to alter its mechanical properties. Heat treatment is used to enhance the properties of steel. The required property may be enhanced with or without the phase changes or change in room temperature. Steel is defined as an alloy of iron and carbon with the carbon content between a few hundredths of a percent up to about 2% by wt. Other alloying elements can amount in total to about 5% by wt in low alloy steels and higher in more highly alloyed. The desire mechanical properties for a certain application can be achieved by alloy steels which contain variety of elements in total amounts between 1% and 50% by weight and also improving its mechanical properties by heat treatment. Heat treatment is often used to alter mechanical properties of an alloy, manipulating properties such as hardness, toughness, ductility and elasticity[1]. Now our interest is to test the properties of AISI4140 steel in its as-bought and in dual phase ferrite-martensite structure after which is attained after subjecting to a series of heat treatment processes. It is used in machine tools and in motor industry for shafts, spindles and gears. It is mainly used in diesel engine camshafts, which requires design of suitable heat treatment cycle and also has provision to improve toughness[2]. Dual phase steel is currently a material of commercial interest for certain automotive application. The interest originates from the demand for lighter, more fuel efficient vehicles and the fact that the dual phase steels have superior ductility with good tensile strength. The present work is an effort to improve the

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tensile and impact strength of medium carbon low alloy steel with potentials for use as engine seat and bumper protectors[3], and for machine body parts too. The working conditions are such that the parts are often subjected to static and dynamic stresses which make tensile and fatigue stress considerations crucial for investigation if the use of current steel grade among other alternative materials is to be endorsed[4]. A representative chemical composition of the steel grade is used as test material for this research work.

2. Materials and Methods

2.1 Material used and its Composition (AISI4140)

A representative composition of AISI4140 steel also known as EN19 (medium carbon low alloy steel) is utilized to produce ferrite martensite dual phases of varied proportions by inter critical annealing treatment followed by heat treatment to different temperatures and rapid quenching. Mechanical test is essential part of any engineering activity. Mechanical test is applied to the materials, components and assemblies. It consists of measurement of fundamental properties or measurement of responses to particular influences such as load[5], temperature, etc. Types of mechanical tests carried out in EN19 (AISI4140) material are tensile test, Impact test and Hardness test. Table 1 shows the chemical composition of the material.

Table 1. Composition of AISI4140 steel

Chemical	Composition
Fe	96.86%
C	0.38%
Si	0.21%
Mn	0.91%
Ni	0.23%
Cr	1.04%
Mo	0.23%

2.2 Tensile Test Specimen Preparation and Methodology

Specimen Preparation

The required code was written and uploaded in the CNC machine. A rod of diameter 16mm is clamped into the chuck of CNC and 80mm length of the rod is protruded from the chuck. From the Figure 1 and 2 shows the tensile specimen of the EN 19 steel. The operation parameters are defined and the machine carries out the machining operation and specimens are prepared as per the requirements.

Figure 1. Tensile specimen.

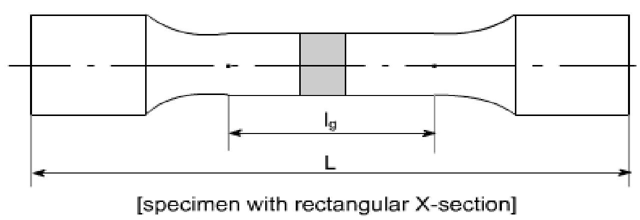

Figure 2. Orthographic view of tensile specimen.

Methodology

The tensile test is carried out using a Universal Testing Machine (UTM) with 50 KN capacity. To get a good grip when withheld in the machine, very coarse sandpaper is used to roughen the specimen surface. Load is applied at a rate of 0.05 KN/sec until the specimen was broken. As the test is performed as per ASTM standards Load vs Displacement graph is plotted. The test is same for both as bought and normalized dual phase attained specimens.

2.3 Hardness Test Specimen Preparation and Methodology

Specimen Preparation

As bought 16 mm diameter rod is cut into required dimensions i.e., 16x25 mm and is faced to get a fine surface finish.

Methodology

Rockwell hardness test is performed to determine the hardness of the specimen which shows in Figure 3 and 4. According to the standards hardness of EN19 steel is tested on C-scale and a diamond indenter is used in this process[6]. Firstly, indenter is made to touch surface of specimen by applying a minor load and needle is set to C-0. Now the crank lever is pushed from position A to position B which applies the major load for a dwell time to allow elastic recovery. Upon removal of major load the depth of indentation is measured giving us the hardness value. The test is same for both as bought and normalized dual phase attained specimens.

Figure 3. Hardness specimen.

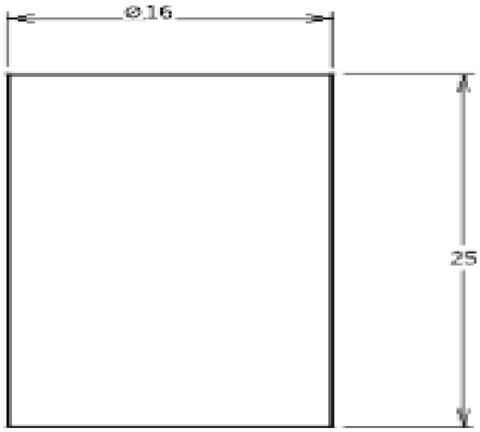

Figure 4. Orthographic view of hardness specimen.

2.4 Impact Test Specimen Preparation and Methodology

Specimen Preparation

As bought 16 mm rod is cut into cylindrical rod of length 55 mm. Further the diameter of the rod is reduced to 14.2 mm which is approximately equal to the diagonal length of a 10 mm x 10 mm square cross section. Using a VMC with the required code uploaded to get the required dimensions, the specimens are further machined to get a square rod of 10 mm x 10 mm x 55 mm. A V-notch is then made at the center on any one of the sides of the specimen using a Shaper machine. The notch must be 2 mm deep with an angle of 45 degrees and 0.25 mm radius along the base of the tool.

Figure 5. Impact test specimen.

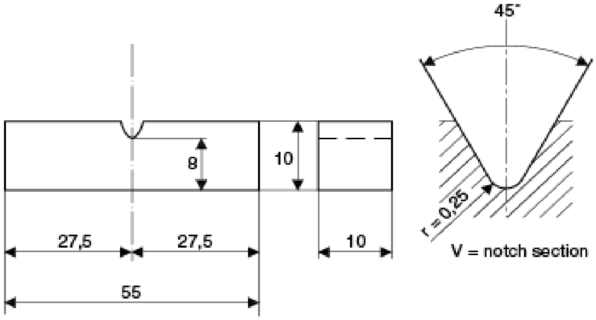

Figure 6. Orthographic view of impact specimen.

Methodology

Charpy Impact test is conducted to determine the impact strength of the specimens. Charpy Impact test involves striking a specimen with a striker. Figure 5 and 6 shows the impact specimen of EN 19 steel. The specimen is mounted at the end of a pendulum. The specimen is fixed at both the ends. Before releasing the striker, dial reading is set to zero. The striker strikes specimen immediately behind the notch which breaks it at the same while dial give us its impact strength.

3. Results and Discussions

3.1 Effect of Heat Treatment on Tensile Specimen

Tensile strength of a material is measurement of a force required to pull or deform the material in order to expand or fracture. Higher the ductility higher is the tensile strength of a material. EN19 steels have high tensile strength[7]. Normalizing of the specimen only removes internal stresses there isn't much change in the ductility of the material. The inter critical annealing performed at different temperatures i.e., 760^0, 780^0 and 800^0 and holding specimens at same for two hours and water quenched at room temperature in each case. Due to the formation of the dual phase ferrite-martensite structure the ducitility of the material is increased. From the results, in the asbought condition as observed there is no certain yield point as the specimen is initially hard and has low yield strength according to the graph. In Normalized dual phase condition as the inter critical temperature is increased it shows a continuous yielding and yield strength goes on increasing. Also from the comparison in the chart the higher the temperature the more closer it is to ideal stress-strain curve of ductile materials is observed. The test is same for both as bought and normalized dual phase attained specimens. Test for as bought condition is done and the results of the same are included in the Figure 7 for comparison.

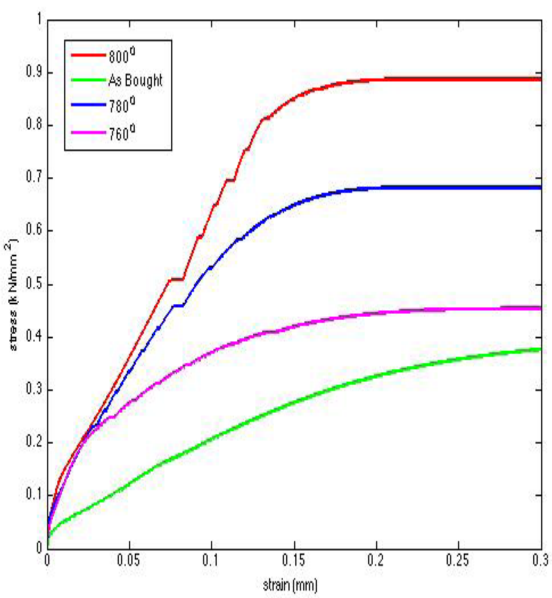

Figure 7. Stress-strain curve.

3.2 Effect of Heat Treatment on Impact specimen

Impact strength is the resistance of the material to withstand an impact or a sudden load that is applied and is measured in terms of energy which in our case, joules. Results observed, the asbought condition seems to have the least impact strength and the results after the heat treatment[8] i.e., normalization followed by the inter critical annealing at different temperatures and holding for 2 hours followed by rapid water quenching the toughness of the material increased giving us higher energy values at 760^0 being the least and at 800^0 being the highest. The ferrite-martensite dual phase structure with increasing volumes of martensite increased the ductility of the steel givng it higher resistance to oppose the impact applied[9] i.e., increasing energy values at increasing temperatures. This being one of the reason EN19 steel is used in machine parts, automotive parts especially in Cam shafts.

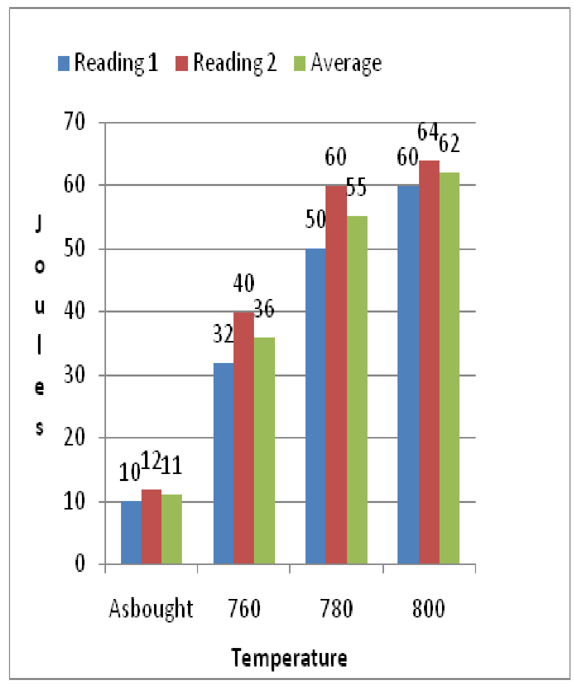

Chart 1. Impact test.

3.2 Effect of Heat Treatment on Hardness specimen

Hardness of the EN19 steel in asbought condition is comparatively high. Initially normalizing is done to remove the internal stress which does not affect the hardness much[10]. Later intercritical annealing at three different temperatures 760^0, 780^0 and 800^0 is performed and held for about 2 hours followed by rapid water quenching at to attain ferrite-martensite dual phase structure. After dual phase (ferrite-martensite) is attained it is observed that due to annealing, hardness of the specimen is decreased but the hardness of the steel is gradually increasing as the temperature at which the steel specimen is annealed increases. This is because as the temperature is increased the dual phase structure witnesses an increase in the volume of martensite. We know martensite is the hardest structure of the steel.

Hence as temperature increases the volume of the martensite increases thus causing an increase in the hardness. The following figure shows us the result obtained and variation of the hardness in asbought condition, 760^0, 780^0 and 800^0. Test for asbought condition is done and the results of the same are included in the Figure 7 for comparison

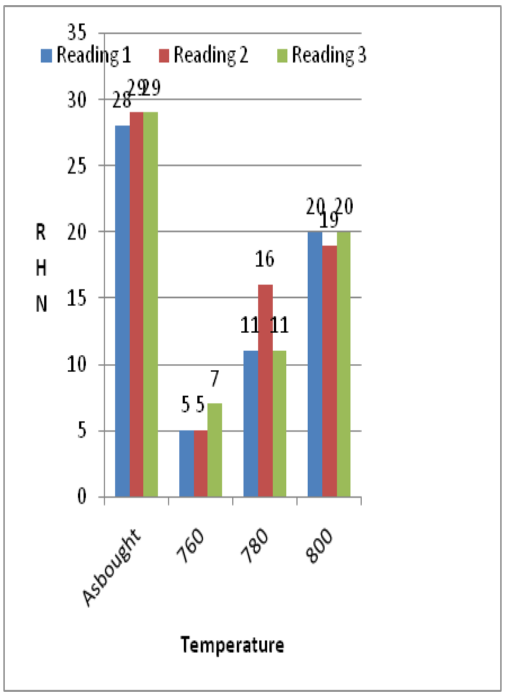

Chart 2. Hardness test.

3.4 Effect of Heat Treatment of Microstructure

From the pictures , Figure 8, 9 and 10 it can be observed that as the ICT temperature increases the density of the martensite increases which is the black spots that can be observed in the below given microstructural images at 500x magnification.

4. Conclusions

- Medium carbon low alloy steels exhibited better mechanical properties after heat treatment to attain dual phase ferrite-martensite structure[11].

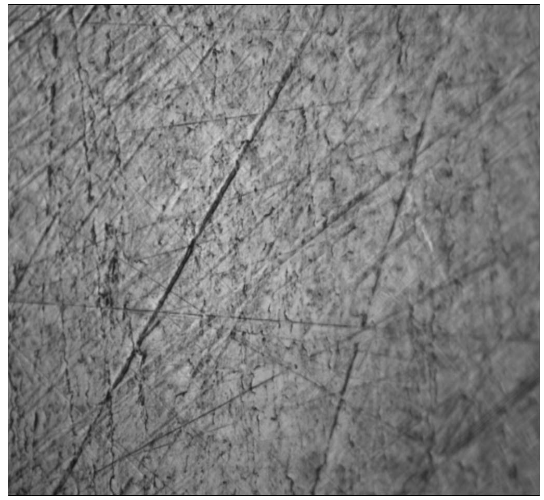

Figure 8. Normalisized ferrite-martensite microstructure [500x] at 760^oC.

Figure 9. Normalised ferrite-martensite microstructure [500x] at 780^oC.

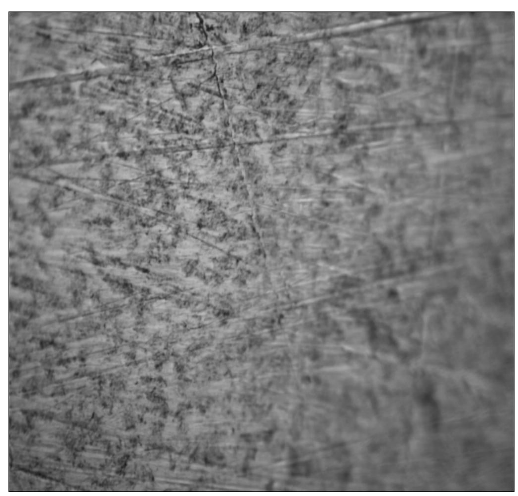

Figure 10. Normalized ferrite-martensite microstructure [500x] at 800^oC.

- Thus giving us a better hope to increase its use in various industrial and non industrial applications for improved customer satisfaction and safety.
- The tensile properties after normalized dual phase structure of ferrite-martensite is attained have increased giving it better ductility and tensile strength. The dual phase steels also exhibited high yielding with increase in annealing temperature.
- The hardness of the as-bought condition is higher than normalized and annealed dual phase structure but increased with increase in the martensitic structure which increased with temperature.
- Impact strengths of dual phase steel attained after normalizing are higher than that of the asbought condition with increasing toughness with increase in the temperature[12] i.e., increase in the martensite volume in ferrite-martensite phase.

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