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# COMPARISON OF MECHANICAL PROPERTIES OF MEDIUM CARBON STEEL WITH DUAL PHASE STEEL

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## ABSTRACT

In this research work investigations were carried out to study the effects of heat treatment on the mechanical properties (toughness, hardness) of medium carbon steel and on Dual phase steel development from Medium carbon steel. Dual phase steel is developed by intercritical annealing in order to improve the hardness and impact toughness. Medium carbon steel of 0.46% carbon content is first inter critically heated in furnace and then rapid cooling in water is done to obtain the martensite steels and named as Dual phase steel. Different samples of Dual Phase steels are prepared by the intercritical annealing process for holding time of 2, 4 and 6 minutes for temperature ranging from 740°C to 840°C. The heating temperature and different time of heating (holding time) of the steel is used to make different percentage of Martensite steel. Dual phase steel so obtained is now tested and properties of the Dual Phase steel are evaluated. Rockwell Hardness test and Charpy toughness test for each Dual phase steel specimen is conducted to compare its hardness and toughness with untreated medium carbon steel. The result indicates that the specimen hardness and toughness increased with the increment in the heating temperature and holding time. The increase in heating temperature and holding time followed by quenching will convert austenite into martensite.

**KEYWORDS:** Austenite, Dual Phase Steel, Intercritical Annealing, Martensite, Medium Carbon Steel

## INTRODUCTION

Medium carbon steel is the most common form of steel. Due to its relatively low price and superior mechanical properties such as high strength and toughness, it is acceptable for many engineering application. Medium carbon steel is used extensively for construction of buildings and bridges. They are also use for making diesel pump injection parts and automated packing machinery parts; other application includes railroad tracks, pressure vessels and ships. Steels whose structures consist of mixtures of ferrite and martensite are often referred as Dual phase steel. Medium carbon steel may be heat treated by austenitizing, quenching and then tempering to improve their mechanical properties, on strength to cost basis, medium carbon steel provide tremendous load carrying ability. Such heat treatments of the steels for the purpose of improvement in mechanical properties have been studied previously by many workers. The mechanical properties of the Dual phase steels can be enhanced by changing the amount of martensite in the structure, by carrying out intercritical annealing heat treatment for different holding times followed by water quenching. The amount of martensite present in ferrite-martensite steel depends on the intercritical annealing temperature in the ferrite plus austenite region. Different amounts of martensite in a dual phase steel were produced by intercritically annealing at 760 $^0$C, 800 $^0$C and 840 $^0$C for different holding times of 2, 4 and 6 minutes and there mechanical property were determine after quenching in water. The knowledge base generated through this study is expected to provide a better understanding of this unique class of steels and help utilize its potential as a future material.

## MATERIALS AND METHODS

The test sample used in the present work is 10 mm thick medium carbon steel square rod. The main chemical composition of the material is shown in the table.

**Table 1: Chemical Composition**

| Element | C | Si | Mn | S | P | Ni | Cr | Mo | Al | Cu | Ti | Co |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wt% | 0.46 | 0.34 | 1.00 | 0.31 | 0.03 | 0.035 | 0.042 | 0.001 | 0.030 | 0.17 | 0.005 | 0.001 |

The material studied in this work was medium carbon steel of 0.46% carbon. Specimen are made for heat treatment and subsequent mechanical testing, were obtained and machined from the bar material in standard dimension. The specimens were heated for different temperature in the austenite and ferrite region in a muffle furnace and then water quenched. The hardness testing of the specimen was carried out by using a Rockwell hardness testing machine and toughness testing of the specimen was carried out by using Charpy test on impact testing machine.

### Development of Dual Phase Steel

Dual phase steels are developed by heating medium carbon steel of 0.46% carbon content into two phase ferrite-austenite ($\alpha$ + ϒ) region of Fe-C phase diagram, followed by rapid cooling to transform austenite (ϒ) into martensite, resulting in a structure of ferrite and martensite that is known as dual phase steel. Method mainly used for developing dual phase microstructure in steels, namely intercritical annealing.

### Process for intercritical Annealing

**Step 1.** Switch ON the furnace and set 740 °C temperature in the controller which controls the voltage, current and the temperature inside the furnace.

**Step 2.** Gradually the temperature of the furnace reaches 740 °C in 45 min approximately.

**Step 3.** Temperature will fluctuate between 739°c to 741°C due to error in the thermocouple used so wait for the stable value.

**Step 4.** Now put the work piece on ceramic plate.

**Step 5.** Set timer in the mobile for required time (Holding Time).

**Step 6.** In the end of set time, open the lid of the furnace Remove the material and drop the work piece in the water pool.

**Step 7.** Use asbestos plate to cover the furnace to avoid heat loss.

**Step 8.** Remove the material and repeat steps for other material.

The production route for intercritical annealed Dual Phase steels is schematically shown in Figure 1, where, Ac1 and Ac3 are the start and finish temperatures of austenite formation during heating.

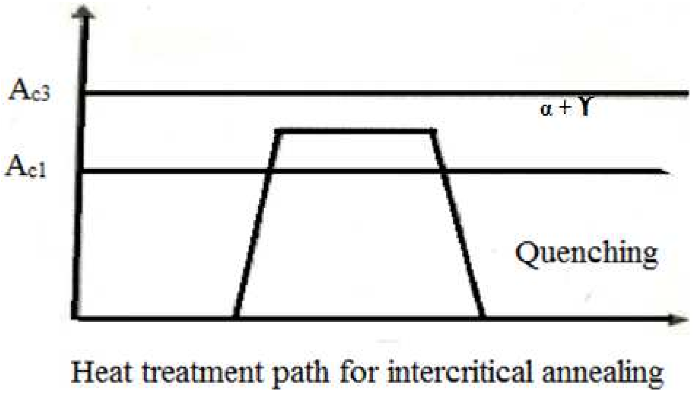



**Figure 1**

**Table 2: Different Heating Temperature and Holding Time Selected as Shown**

| Specimen | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Temperature($^0$C) | 0 | 760 | 800 | 840 |
| Holding time(min) | 0 | 2,4,6 | 2,4,6 | 2,4,6 |

### Charpy Impact Test

Charpy impact is practical for the assessment of brittle fracture of metals. An impact test signifies toughness of material that is ability of material to absorb energy during the plastic deformation. The Charpy test sample has (10 × 10 × 55) mm$^3$ dimensions, 45$^0$ V notch angle of 2 mm depth and 0.25 mm root radius will be hit by a pendulum attach opposite end of the notch as shown in Figure2

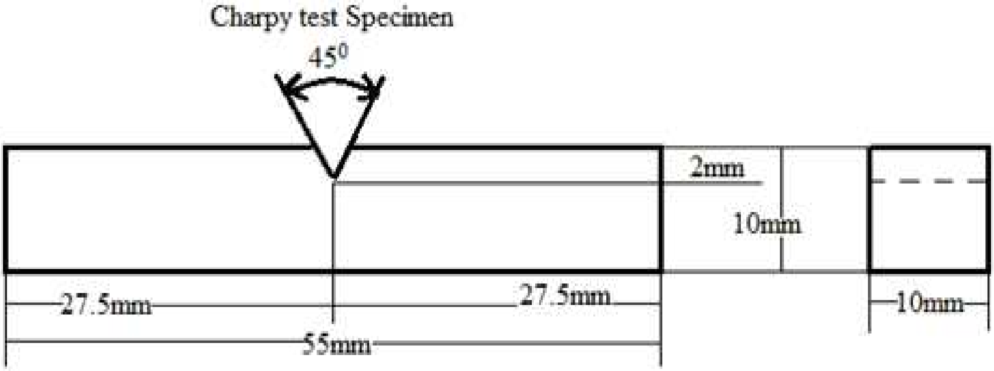



**Figure 2**

### Hardness Test

The hardness of heat treated and untreated samples are determined using Rockwell Hardness testing machine using C scale (HRC). The purpose of this test is to make comparison of the hardness properties between the specimen with the medium carbon steel.

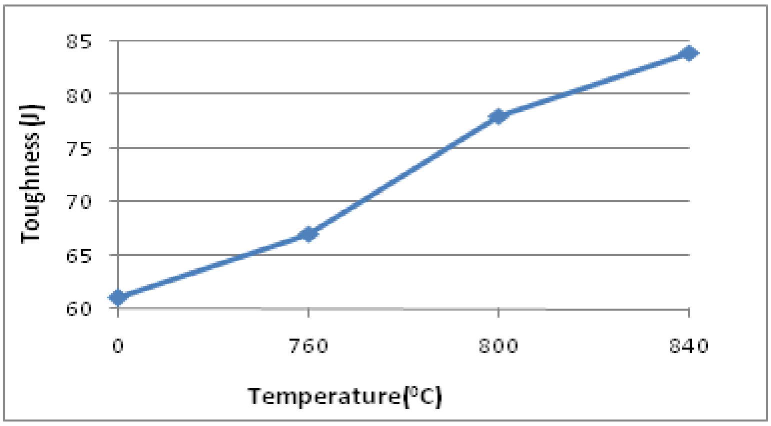
## RESULT AND DISCUSSIONS

The experimental results show that dual phase steels have excellent mechanical properties in terms of hardness and toughness.

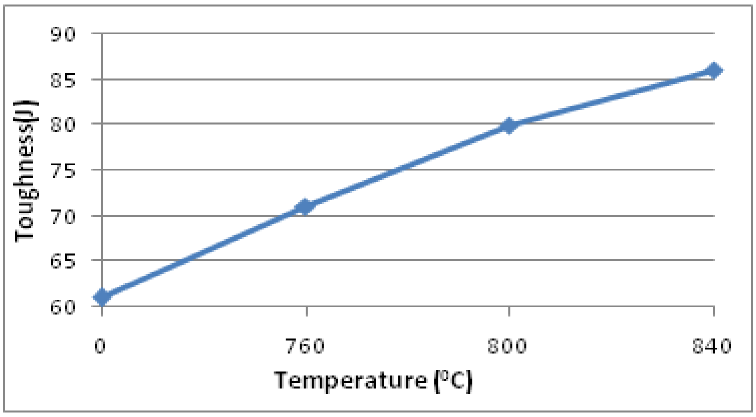
**Table 3: Mechanical Properties of Heat Treated and Untreated Steel**

| Temp. ($^0$C) | 0 | 760 | | | 800 | | | 840 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Holding time (min) | 0 | 2 | 4 | 6 | 2 | 4 | 6 | 2 | 4 | 6 |
| Toughness (J) | 61 | 67 | 71 | 73 | 78 | 80 | 82 | 84 | 86 | 87 |
| Hardness (HRC) | 18 | 21 | 23 | 25 | 27 | 28 | 30 | 31 | 33 | 34 |

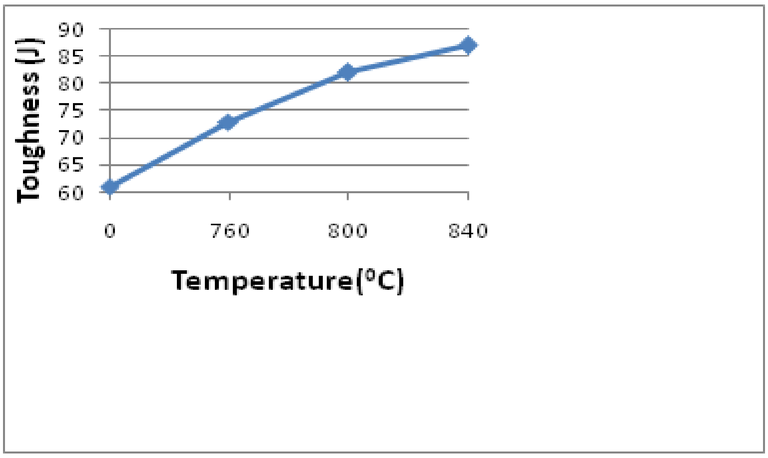
**Temperature vs Toughness**




**Graph 1: Shows Increase in Toughness for Holding Time 2 Minutes**

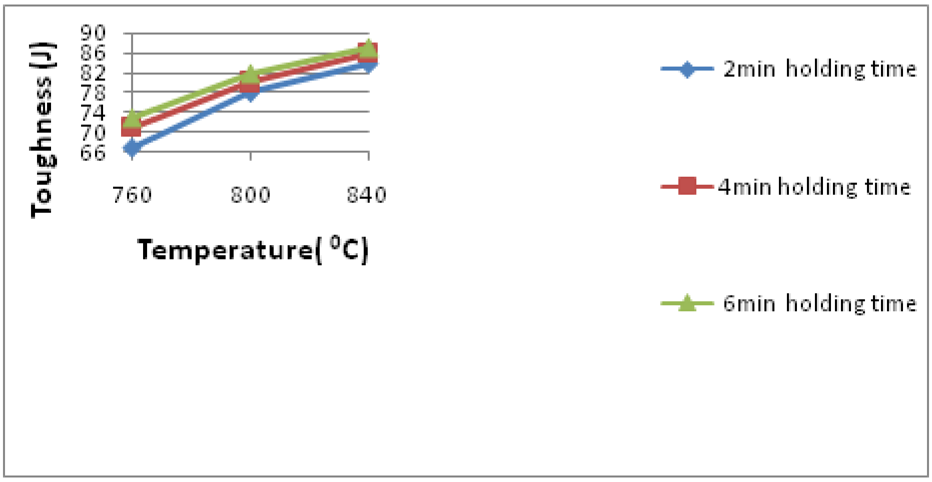



**Graph 2: Shows Increase in Toughness for Holding Time 4 Minutes**



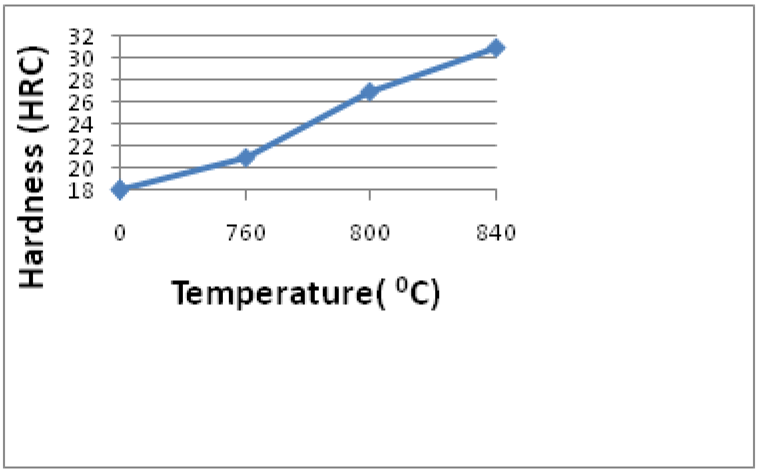

**Graph 3: Shows Increase in Toughness for Holding Time 6 Minutes**

**Temperature vs Toughness**

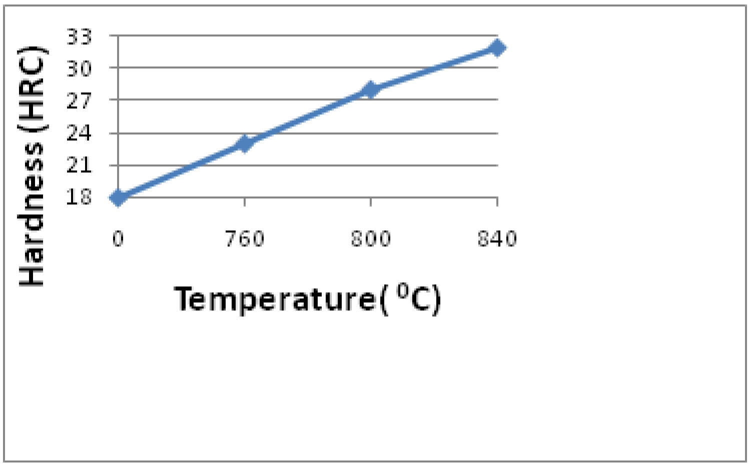



**Graph 4: Shows Increase in Toughness for Holding Time 2, 4 and 6 Minutes**

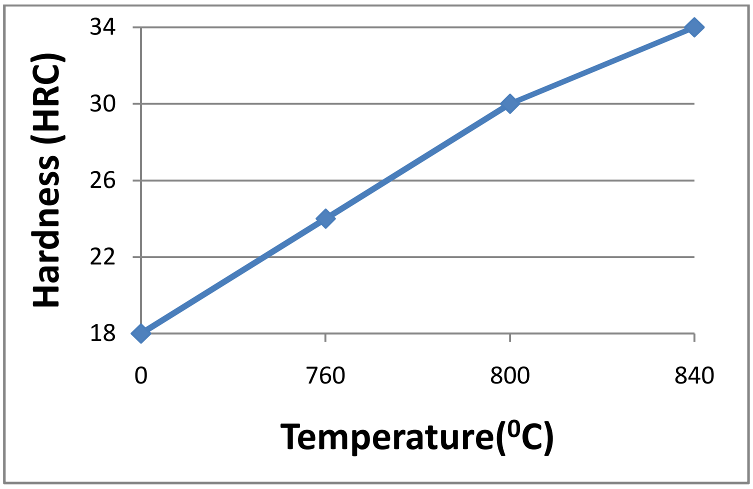
**Temperature vs Hardness**



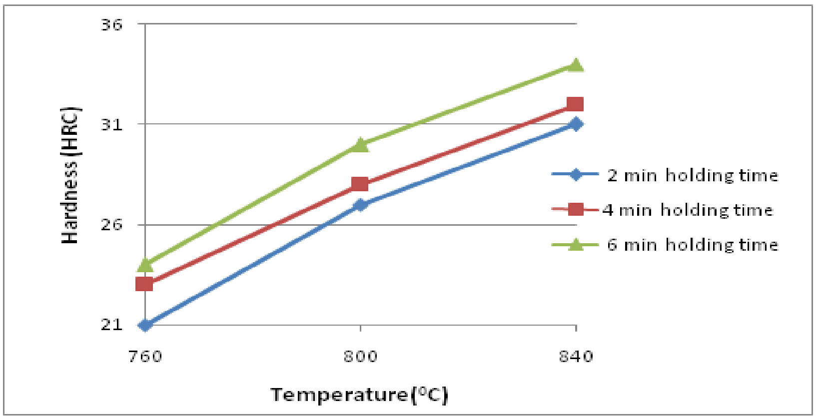

**Graph 5: Shows Increase in Hardness for Holding Time 2 Minutes**




**Graph 6: Shows Increase in Hardness for Holding Time 4 Minutes**




**Graph 7: Shows Increase in Hardness for Holding Time 6 Minutes**




**Graph 8: Shows Increase in Hardness for Holding Time 2, 4, 6 Minutes**

The above table 3 and graph 1 to 8 show that the hardness and toughness value of dual phase steel and medium carbon steel. In all these 8 Graphs, the graph no 4 and 8 show comparison of toughness and hardness for 2, 4, 6 minutes holding time for treated samples and remaining graph show that the hardness and toughness of untreated and treated sample with different holding time period. So from these table and graph it is clear that hardness and toughness of dual phase steels are higher than the medium carbon steel. The hardness and toughness value of dual phase steels increase with growing intercritical annealing temperature and heating time. The increase is due to increasing martensite volume. The increases intercritical annealing temperature changes more pearlite to austenite. Austenite then transform to martensite by rapid cooling. Hence the percentage of martensite in Dual Phase steel is increased. Tougher martensite formed at higher temperature. The dual phase steels have better hardness and toughness properties as it consists of ferrite and martensite structures. The experimental results show that dual phase steels have excellent mechanical properties in term of hardness, toughness.

## CONCLUSIONS

Dual phase steel can be developed from medium carbon steel by intercritical annealing process. The investigations are carried out on various samples to study the effect of temperature and time in the martensite phase of dual phase steel. As the content of martensite in the Dual Phase steel increases by increasing the heating temperature and time the hardness and toughness of Dual Phase steel increases. It is clear that hardness and toughness of dual phase steels are higher than the medium carbon steel. The result obtained confirmed that improvement in the mechanical properties that can be obtained by subjecting medium carbon steel to intercritical annealing heat treatment and then testing it on Charpy test for toughness and Rockwell test for hardness. Dual Phase steels have better mechanical properties as it consists of ferrite and martensite structure. By simply heat treatment of steel, the mechanical properties are improved and cost adding costly material is saved.

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