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# EFFECT OF DIFFERENT PHASE PROPORTIONS OF MARTENSITE ON THE MECHANICAL PROPERTIES OF A DUAL PHASE STEEL

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***Abstract:*** In 0.38% C steel, different amounts of martensite were produced by intercritically annealing the specimens in a range of temperatures in the two phase (ferrite + austenite) region. The specimens which were annealed at temperatures 750 °C and above followed by quenching exhibited better hardness values as compared to the normalized specimens. The specimens annealed at 790 °C and 800 °C followed by water quenching exhibited higher hardness as compared to the oil quenched specimens which were completely austenitized. The specimens corresponding to all intercritical annealing temperatures showed higher hardness as compared to specimens of the same steel which were first austenitized and then annealed.. The yield strength and ultimate tensile strength of the specimens corresponding to all intercritical annealing temperatures followed by water quenching, were also found to be higher when compared with furnace cooled, air cooled and oil quenched specimens.

## 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 applications. Medium carbon steels are used extensively for construction of buildings and bridges. In construction work they are mostly used as reinforcing roads in concrete. They are also used for making diesel pump injection parts and automated packing machinery parts. Other applications includes railroad tracks, pressure vessels and ships. 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 steels provide tremendous load carrying ability. Such heat treatment of the steels for the purpose of improvement in mechanical properties have been studied previously by many workers [1,2]. Different amounts of martensite in a dual phase steel were produced by intercritically annealing at 760 °C and 775 °C and mechanical properties were determined after tempering in the range 200 °C-600 °C [4].

As the plain carbon steels are almost always tempered after quenching before they are used in any structural application, the most of the previous work including that described above has focused on the characterization of these steels in the quenched and tempered condition. Also, dual phase steels have mostly been developed from low carbon low alloys steels [5,6,7].However in present work, improvement in mechanical properties of a medium plain carbon steel instead of a low carbon steel have been studied by developing different proportions of ferrite and martensite phases, without attempting tempering of these structures.

1-For Proof and Correspondence: **S. Zahid**

## Material and Experimental Techniques

The material studied in this work was a 0.38 percent plain carbon steel. Specimens for heat treatment and subsequent mechanical testing, were obtained and machined from the bar material in standard dimensions. The specimens were heated for one hour at different temperatures in the austenite and ferrite region, in a muffle furnace and then water quenched. The specimens were also austenitized and then subsequently furnace cooled, air cooled, and oil quenched separately. The hardness testing of the specimens was carried out by using a Brinell hardness testing machine and a tensometer was used for the purpose of determining the tensile properties. The yield strength, tensile strength and toughness were determined from the stress-strain graphs plotted from the load-extension data.

## Results and Discussion

All the specimens of this particular alloy were heated in the two phase (ferrite + austenite) region, at temperatures 730 °C, 740 °C, 750 °C, 760 °C, 780 °C, 790 °C and 800 °C for one hour and then water quenched. As a result, the specimens having microstructures containing different proportions of ferrite and martensite were obtained. After heat treatment, the specimens were tested for Brinell hardness results of which are given in Table1.

It may be seen that Brinell hardness is very high at 800 °C (555.5HB) and then decreases to a much smaller value at 730 °C (242 HB) suggesting that the decrease in the temperature of heat treatment results in a smaller martensite content and subsequently giving rise to a smaller hardness value.

Specimens were also austenitized at 840 °C and subsequently water quenched, furnace cooled, air cooled and oil quenched. The results are given in Table 2.

Now on comparing the data with the specimens which were austenitized and then subsequently furnace cooled, air cooled, and oil quenched separately, it may be seen that the hardness of the specimen which was heat treated at the lowest temperature of 730 °C (242HB) is higher than the specimen which has been furnace cooled (217HB). This shows that the specimen which is expected to contain approximately 50% ferrite and 50% martensite has a high hardness as compared to the one which contains 50% ferrite and 50% pearlite. This would be expected because of high strength of martensite as compared to pearlite. Also the specimens heat treated at 750 °C and higher temperatures show a higher hardness value than the specimens which are normalized. Also the specimens which are heat treated at 800 °C and 790 °C show higher hardness value than the specimen which was oil quenched. In general, most of the specimens heat treated in the present work exhibit better hardness values than those which are either annealed, normalized or oil quenched from an austinizing temperature. These results provide us with an alternate method of inducing better hardness as compared to furnace cooled, air cooled or oil quenched specimens. However such heat treatment could be useful in those applications of this particular medium carbon steel where the prime requirement is only the hardness. This is due to the brittle nature of the martensite phase present in the specimen. Tensile properties of the specimen determined after heat treating in the temperature range 730 °C 800 °C are given in Table 3. It may be seen that with decrease in heat treatment temperature the decrease in ultimate tensile strength and yield strength is not seen. However on comparing the tensile properties of these specimens which are partially martensitic with those which were first austenized and then furnace cooled, air cooled, and oil quenched separately all the specimens exhibited higher ultimate tensile strength and yield strength values at all heat treatment temperatures.

**Conclusions:**

On the basis of present work in which the ferrite and matensite structures in different proportions were produced in a 0.38% °C steel by heat treating the specimens at different temperatures in the ferrite + austenite region and then quenching, following conclusions may be drawn.

i. The specimens heat treated at temperatures 750 °C, and above exhibited better hardness values as compared to the normalized specimens.

ii. The specimens heat treated at 790 °C, and 800 °C, exhibited higher hardness as compared to oil quenched specimens.

iii. The specimens corresponding to all heat treatment temperatures showed higher hardness as compared to the annealed specimens of the same steel.

iv. The specimens tested for tensile properties corresponding to all intercritical annealing tempertures possessed higher yield strength and ultimate tensile strength values when compared with those which were first austinized and then furnace cooled, normalized or oil quenched. However the accompanying toughness values of the specimens were not high in almost all cases.

**References:**

1. Avner, S.H. *Physical Metallurgy* McGraw Hills, 2nd Edition.

2. Honey Comb, R.W.K., Bhadeshia, H.K.D.H. 2000, *Steels*, Second Edition Butterworth-Heinemann Publishing Ltd.Oxford, U.K.

3. Samuel, F.H. and Hussein, A.A. 1982 Tempering of Medium and High Carbon Martensites. *Metallography*.15: 391-408.

4. Joarder, A. Jha, J. N. Ojha, S. N. and Sarma, D.S. 1990 the tempering behaviour of a plain carbon dual phase steel. *Materials Characterization* **25:** 199

5. S.S.M. Tavares, P.D. Pedroza, J.R.Teodorio and T. Gurova, 1999, Mechanical Properties of a quenched and tempered dual phase steel. *Scripta Materiala* **40:887**

6. A. Bayram, A. Uzuz and M.Ula, 1999 Effects of Microstructure and Notches on the Mechanical Properties of Dual Phase Steels. *Material Characterization* **43:259**

7. A.K. Bello, S.B.Hassan and M. Abdulwahab 2007 Effects of Tempering on the Microstructure and Mechanical Properties of low Carbon, low alloy Martensitic Steel **3:1719**

**Table-1**

| Temperature $^oC$ | Heat Treatment | Brinell Hardness (BH) |
|---|---|---|
| 800 | Water Quenched | 555.5 |
| 790 | Water Quenched | 516 |
| 780 | Water Quenched | 360.53 |
| 770 | Water Quenched | 318.47 |
| 760 | Water Quenched | 303.30 |
| 750 | Water Quenched | 303.31 |
| 740 | Water Quenched | 230.22 |
| 730 | Water Quenched | 241.87 |

**Table-2**

| Temperature $^oC$ | Heat Treatment | Brinell Hardness (BH) |
|---|---|---|
| 840 | Furnace Cooled | 217 |
| 840 | Air Cooled | 285 |
| 840 | Oil Quenched | 415 |

**Table-3**

| Temperature $^oC$ | Heat Treatment | Tensile Properties | | |
|---|---|---|---|---|
| | | UTS Kg/mn$^2$ | Y.S. Kg/mm$^2$ | Toughness Kg.mm |
| 800 | Water Quenched | 64.1 | 55.1 | 29.204 |
| 790 | Water Quenched | 71.7 | 63 | 22.89 |
| 780 | Water Quenched | 95.5 | 81.4 | 35.38 |
| 760 | Water Quenched | 73.4 | 60 | 26.68 |
| 750 | Water Quenched | 74.11 | 58 | 29.6 |
| 740 | Water Quenched | 81.9 | 57.5 | 23.91 |
| 730 | Water Quenched | 63.9 | 55 | 20.81 |

**Table-4**

| **Temperature °C** | **Heat Treatment** | **Tensile Properties** | | |
|---|---|---|---|---|
| | | **UTS Kg/mn²** | **Y.S. Kg/mm²** | **Toughness Kg.mm** |
| 840 | Oil Quenched | 61.5 | 46.7 | 30.296 |
| 840 | Air Cooled | 51.5 | 35 | 26.39 |
| 840 | Furnace Cooled | 46.7 | 35.5 | 30.414 |

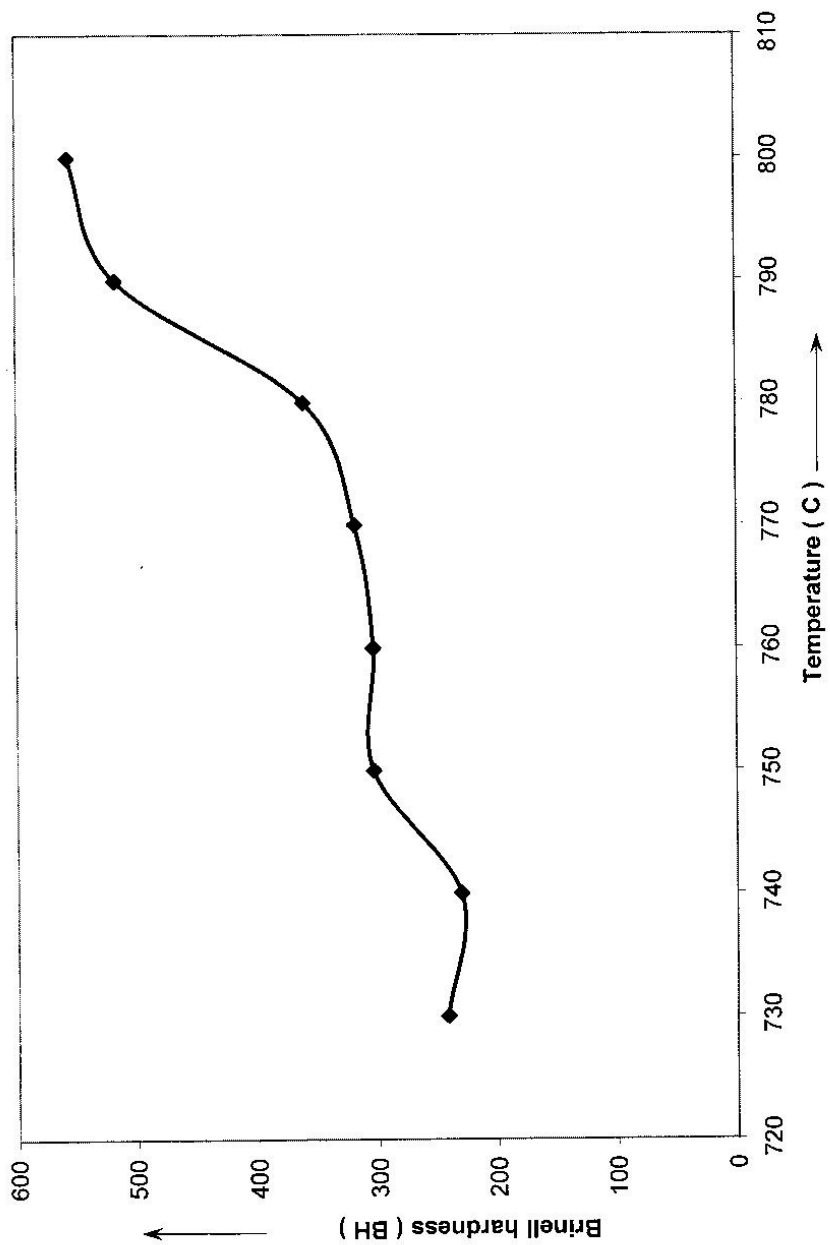


Figure I: Effect of heat treatment temperature on hardness.