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# Influence of Austempering Heat Treatment on Ductile Iron

M. Ashraf Sheikh

[1]Department of Technology, The University of Lahore, Lahore, 54000, Pakistan
Corresponding author: First A. Author (e-mail: author@ee.uol.edu.pk).

***Abstract*-In this present work the influence of austempering heat treatment was studied on ductile iron. Medium frequency induction furnace was used to make casting samples. Austempered Ductile Iron (ADI), which is a relatively new material is produced by the process of austempering heat treatment. ADI material is a very valuable. The properties of ADI are equivalent to forged steel. This study was done to develop Austempered Ductile Iron and to find out the effect of heat treatment temperature. In this study samples were treated, one with higher heat treatment temperature i.e. 370 $^0$C and other in lower range of temperature i.e. 285 $^o$C were used. For austenitizing of samples, the furnace temperature was maintained at 900 $^o$C and the samples were heated for one hour. After austenitizing, the samples were dipped in a salt bath at temperatures i.e. 285 $^o$C and 370 $^o$C for one hour. The researcher found encouraging result. Almost double tensile strength was achieved with the same composition of the samples only with the heat treatment at lower temperature.**

***Index Terms*-- Austempering, Ductile iron, Induction furnace, Tensile strength, Astatized**

## I. Introduction

Ductile iron shows good ductility and toughness because the shape of graphite is spherical in the ductile iron [1]. Applications of ductile iron castings are many especially those requiring a material having good machinability and strength. Ductile iron is used mostly for the production of auto parts i.e. crankshafts, piston rings and cylinder lining. Cost of ductile parts are less than the cost of parts of steel or malleable iron [2].

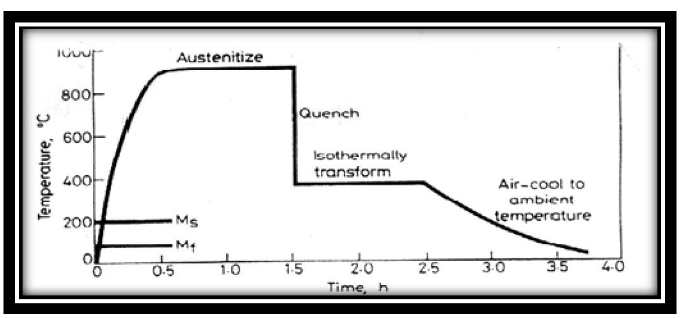


Figure 1. Heat treatment cycle for austempering [8]

If ductile iron is austempered at controlled temperature, it is changed to Austempered Ductile Iron (ADI) with unique properties comparable to forged steel. To convert the ductile iron to austempered ductile iron (ADI) is not a very hard job. Its primary requirement is that the ductile iron chosen for ADI should be of good quality [3]. Engineers are paying attention to ADI because of its attractive properties e.g. ductility, wear resistance, tensile strength and fatigue property [4]. Design engineers are preferring ADI material than steel due to its low cost and good machinability. It also has high strength-to-weight ratio of the material [5]. Due to its less weight and less price ADI has become a substitute material for aluminum alloys and steel [6]. ADI parts have replaced many castings of steel and forged parts [7].

ADI is made by special austempering heat treatment process [8]. The process is shown in figure 1 and it is summarized as follows:

1) To convert the simple ductile iron parts to ADI parts, these are heated to 850 $^o$C to 950 $^o$C, austenitizing temperature.
2) These parts are held at this temperature to saturate the austenite with carbon for requisite time.
3) Then the austenitised parts are quenched quickly to the range of 235 $^o$C to 400 $^o$C which is called austempering temperature.
4) The parts are held at this austempering temperature for required time to get the desired properties and microstructure of the parts.
5) The ADI parts produced are then cooled to room temperature.

## II. ADI Specifications

The ASTM has made five grades for ADI, which is mentioned in table 1 [9]. The grades are made considering their mechanical properties e.g. tensile strength and hardness. These grades are now used by engineers and professionals.

In recent years the ADI is the exceptional achievement in the material of cast iron. The simple heat treatment makes the material very useful for many applications with good strength and with sufficient ductility. The researchers are continuously working on different aspects of this unique material. The purpose of this study was to investigate the influence of heat treatment (austempering) on tensile strength. For this purpose, a high range and a low range austempering temperatures were chosen.

Table I

ASTM A897-90, ADI Specification.[9]

| Grade | Tensile Strength (Min) | | Yield Strength (Min) | | Elongation | Brinell Hardness |
|---|---|---|---|---|---|---|
| | Psi. | N/mm$^2$ | Psi. | N/mm$^2$ | % | Range |
| 1 | 125,000 | 850 | 80,000 | 550 | 10 | 269-321 |
| 2 | 150,000 | 1050 | 100,000 | 700 | 7 | 302-363 |
| 3 | 175,000 | 1200 | 125,000 | 850 | 4 | 341-444 |
| 4 | 200,000 | 1400 | 155,000 | 1200 | 1 | 388-477 |
| 5 | 230,000 | 1600 | 185,000 | 1300 | - | 444-555 |

## III. EXPERIMENTAL PROCEDURE

### *A. Research Methodology*

The purpose of this research was to find the influence on ductile iron of the heat treatment (austempering). For this purpose, medium frequency induction furnace was used to produce samples from as-cast pieces. The cast samples were machined and first heated for one hour in a muffle furnace at 900 $^0$C temperature. Then the samples were quickly submerged in a salt bath kept at temperature 285 ºC. Another batch of samples were dipped in salt bath maintained at temperature 370 $^0$C, i.e. at a higher range. After this heat treatment process (austempering), the tensile strength of samples was found using universal tensile strength machine.

### *B. Equipment*

**Induction Furnace:** Induction furnace of capacity 30 kg was used for the melting of charge. Good quality raw materials were used for the production of ductile iron. Twenty-four-kilogram melt was used for each experiment.

**Spheroidizing Treatment Ladle:** A special ladle with two pockets at the bottom was used to convert the cast iron into ductile iron. Ferro alloys of ferro-silicon 75 and ferro-silicon-magnesium were placed in one of the pockets at bottom and another pocket was empty. Now the melted metal was poured to this ladle. Using this method, the cast iron was converted to ductile iron.

**Heat Treatment Furnaces:** Two heat treatment furnaces were used; one for austenitizing and other for austempering. Austenitizing of castings were done in a muffle furnace. The maximum temperature of the furnace was1300 ºC.

**Vertical tube furnace:** The other heat treatment furnace was for austempering. It was a Carbolite vertical tube furnace with maximum temperature of 1200 ºC. The casting samples were immersed in salt bath for austempering heat treatment.

**Universal Testing Machine:** After the austenitizing and austempering heat treatment, the samples were subjected to tensile test. The maximum capacity of the universal testing machine was 100 kn.

### *C. Casting of Ductile Iron Samples*

The ductile iron tensile samples were cast in an induction furnace of medium frequency. The raw materials were iron from local market, Sorel metal and ferro-alloys. The method used for casting of tensile samples was sandwich method. In this process a special type of ladle was used in which the ladle was provided at the bottom two pockets. One of the pockets was filled with ferro-alloys while the other pocket was empty. The composition of casting samples was as follows:

Table II

Composition of Casting Samples Wt. %

| C | Si | S | P | Mg | Fe |
|---|---|---|---|---|---|
| 3.5 | 2.5 | 0.05 | 0.008 | 0.5 | Balance |

Table III

Effect of Heat Treatment on Ductile Iron

| Austenitizing Temperature $^0$C | Austempering Temperature $^0$C | Elongation % | UTS N/mm$^2$ |
|---|---|---|---|
| 900 | 285 | 3.2 | 1657 |
| 900 | 370 | 5.0 | 1154 |
| Without Heat Treatment | ------ | 12.3 | 714 |

## IV. RESULTS AND DISCUSSION

The tensile strength of the samples was found after the heating the samples for one hour at 900$^0$C and then dipping samples quickly to furnace for one hour at 285 $^0$C. The second batch of samples were heated at 900 $^0$C for one hour in a muffle furnace and then austempered at 370 $^0$C for one hour. The results are tabulated in table 3. Without any heat treatment the tensile strength was very low i.e. 714 N/mm$^2$. The elongation of samples was much higher i.e. 12.3%. The samples with the same composition were heated for one hour at temperature of 900 $^0$C and then immersed in a salt bath at temperature 285 $^0$C. The tensile strength was maximum i.e. 1657 N/mm$^2$. The elongation decreased to level of 3.2%. This was an amazing result. The other batch of samples with same composition was heated to 900 $^0$C for one hour and then heated to higher austempering temperature i.e. 370 $^0$C. Now the elongation was increased but the tensile strength decreased to 1154 N/mm$^2$. This experiment provides a choice for the design engineers to select the austempering temperature to get the desired properties. The engineers can get higher tensile strength with lower elongation or if they want higher elongation, they can choose lower austempering temperature.

In the present study, the ADI produced at austempering temperature 285 $^0$C matched the Grade 5 of ASTM Standard i.e.

ASTM A897-90 with tensile strength of 1657 N/mm$^2$ against minimum tensile strength of 1600 N/mm$^2$ of the standard. The second batch of ADI produced at austemperature temperature 370 $^0$C matched the Grade 2 of ASTM Standard with tensile strength of 1154 N/mm$^2$ against minimum tensile strength of 1050 N/mm$^2$ of the standard.

Similar results were found by other researchers, Prabhukumar Sellamuthu et al., heated the samples at two different austempering temperatures i.e. 300 $^0$C and 360 $^0$C. They found that the hardness and strength decreased with the rise of the austempering temperature [10]. Another researcher, M. Kaczorowski found that the ductility is increased when the austempering temperature was enhanced to 350 $^0$C [3]. In present study the elongation was 3.2 % at austemperating temperature 285 $^0$C but it was increased to 5.0 % when the temperature was increased to 370 $^0$C.

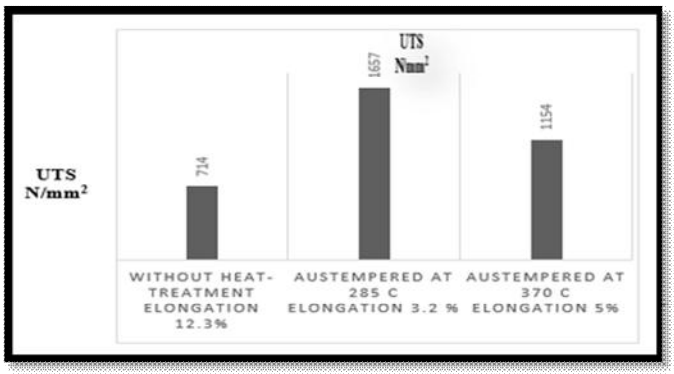


Figure 2. Results of austempering heat treatment of tensile test casting samples at low and high austempering temperatures.

The tensile strength results are represented graphically in figure 2. The maximum tensile strength was achieved when samples were austempered at lower heat treatment temperature i.e. 285 $^0$C. The engineers can use the lower austempering temperature to get the maximum tensile strength with lower ductility. In case the design engineers require increased elongation, they can select higher austempering temperature.

## V. Conclusion

1. The austempering process gave a choice to the engineers to increase the tensile strength by this process.
2. The tensile strength can be increased to double at lower austempering temperature e.g. 285 $^0$C.
3. The process gave the choice to get the desired elongation. If engineers require higher elongation, they can select the higher austempering temperature.

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