Analysis of Tensile strength and Hardness of IS 500/7 Grade Ductile Iron Subjected to Austempering Heat treatment

Shakir K.A, Ahamed Aahraf, Vijaykumar H.K

***Abstract*—Austempered Ductile Iron (ADI) is replacing steel and it is finding applications in agriculture, mining construction and automotive sector due to its superior mechanical properties and cost-effectiveness in manufacturing. In this study IS500/7 grade ductile iron castings were made subjected to austempering heat treatment to get ADI i.e., to bring about changes in microstructure and hence therefore mechanical properties. Austempering heat treatment involves austenisation at 900^0C temperature for 2 hours duration, austempering temperatures selected was 360^0C and 430^0C and austempering duration selected were 50,100,150,200 and 250 minutes. Ultimate Tensile strength and Hardness of the ADI specimens were analysed and compared with as cast condition specimen. The results of the investigation indicate that the ADI castings possess better tensile strength and hardness compared to as cast specimens.**

***Index Terms*—Austempered ductile iron (ADI), Ductile Iron, Ultimate tensile strength, Hardness.**

I.INTRODUCTION

Austempering is a special heat treatment process [1] .Initially austempering heat treatment was applied to steel, resulting microstructure obtained in steel is known as Bainite.Later on austempering heat treatment process was extended to ductile iron, resulting microstructure obtained in ductile iron is known as Ausferrite [2], [8], [10]. Ausferrite microstructure in ADI exhibits remarkable mechanical properties [3], [4], [5].Austempering heat treatment is a two stage treatment involves subjecting the material i.e., specimens to austenitisation treatment (850^0C-960^0C) and then suddenly quenching to austempering baths (250^0C-450^0C).

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Factor that affect austempering process and subsequent microstructures as well as mechanical properties are chemical composition, alloying elements, austenitizing temperature austenitizing time, casting quality, alloy segregation and section size of castings [6],[7],[9].In the present investigation IS500/7 grade ductile iron castings were subjected to standard austempering heat treatment cycle. Mechanical properties such as ultimate tensile strength, Brinell hardness tests were carried out for ADI and as cast condition and compared.

II.EXPERIMENTAL METHOD

A. Moulding

Moulding sand used for production of casting possessed American Foundry man's Society (AFS No.) 60 in the present analysis. Sand moulding was used for obtaining castings with permeability and compression strength of the sand being 120 and 1250 N/mm^2 respectively. Fig. 1 shows the sand moulds. Mould sizes were prepared such that castings obtained were as per specifications of ASTM A897 standard.

Fig.1 Sand Moulds as per ASTM A897

B. Melting and Pouring

Melting of the charge was carried out using 200Kg capacity, 200Hz frequency induction furnace. Figure 2 shows the preparation of IS500/7 grade ductile iron melt. The charge consisting of ductile Iron, Grey Iron returns, pig iron, and mild steel punching were melted and superheated to a

ISSN: 2278 – 7798

temperature range 1450°C-1560°C. After removing off the impurities and slag the molten metal was poured into the prepared sand moulds. The carbon equivalent of the iron was aimed to meet specification of IS 500/7 grade ductile iron.

Fig. 2 Preparation of IS500/7 ductile iron by melt

The chemical composition of IS 500/7 grade ductile iron is as shown in the Table I. The molten metal was poured in the mould cavity as shown in the Figure 3.Then molten metal was allowed to cool in the moulds and solidified castings taken out were used for preparation of test specimen.

Table I. Chemical composition of IS 500/7 grade ductile iron specimens

Elements	Percentage by weight
C	3.45
Si	2.53
Mn	0.183
S	0.0086
P	0.016
Cu	0.390
Sn	0.0410
Fe	Remaining

Fig. 3 Pouring of IS 500/7 ductile iron molten metal

C. Heat treatment

Standard austempering heat treatment cycle as shown in the Figure.4 was employed in the present analysis. Initially IS500/7 grade ductile iron specimens were transferred to a salt bath furnace maintained at 900^{0}C.The specimens were dipped completely in the salt bath and maintained at the same temperature for 120minutes.The samples at the end of austenitisation were then quenched into austempering salt baths held at 360^{0}C and 430^{0}c.The specimens were then held at this austempering temperature for 50,100,150,200 and 250 minutes duration in order to bring about isothermal transformation to bainite stabilized austenite matrix. Later the specimens were removed from the furnace and cooled in air till room temperature is reached.

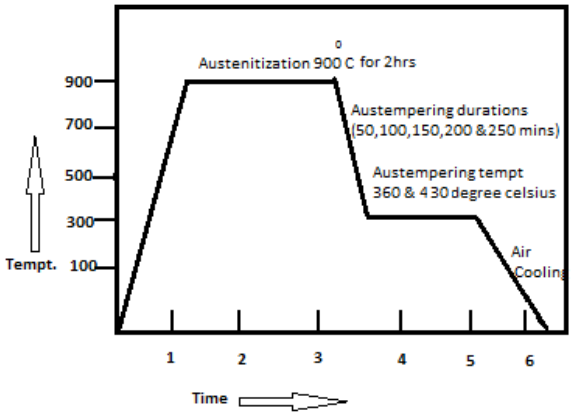

Fig.4 Austempering Heat treatment cycle

II. TESTING OF SPECIMENS AND RESULTS

Mechanical properties such as Ultimate tensile strength and hardness are considered for analysis since these properties plays an important role in applications of ADI in many fields.

A. Tensile test

The tensile specimens were prepared as per ASTM A370 standards. Figure 5 shows the tensile specimens of ADI held at different austempering durations. The tensile test was carried out on Universal testing machine for all the five different specimens at each austempering temperature i.e., at 360^{0}C and 400^{0}C and finally ultimate tensile strength results were tabulated.

ISSN: 2278 – 7798

Fig. 5 Tensile specimens of ADI held at different austempering durations.

These results of ADI specimens were then compared with as cast IS500/7 grade ductile iron specimen. The Ultimate tensile strength values obtained for ADI specimens and as cast are as shown in Table II.

Table II. Ultimate tensile strength values obtained for ADI specimens and as cast specimens

Ultimate Tensile Strength of as cast and Austempered specimens held at 360^0C&430^0C			
Sl.No.	Austempering Duration	Austempering Temperature	UTS N/mm^2
1	As cast	360^0C	479.3
2	50 minutes	360^0C	1136.9
3	100 minutes	360^0C	1149.7
4	150 minutes	360^0C	986.5
5	200 minutes	360^0C	954.7
6	250 minutes	360^0C	1079.2
7	50 minutes	430^0C	1088.6
8	100 minutes	430^0C	1096.5
9	150 minutes	430^0C	1120.7
10	200 minutes	430^0C	1105.3
11	250 minutes	430^0C	989.8

B. Hardness test

Brinell hardness test was conducted on the as cast and ADI specimens. Figure 6 shows the hardness specimens held at different austempering duration.

Fig. 6 Hardness specimens held at different austempering duration

An average of five readings has been considered for the test. The values of Brinell hardness number are as shown in the table III.

Table III. Hardness (BHN) values obtained for ADI specimens and as cast specimens

Hardness of as cast and Austempered specimens held at 360^0C&430^0C			
Sl. No.	Austempering duration	Austempering Temperature	Hardness (BHN)
1	As cast	360^0C	284
2	50 minutes	360^0C	346
3	100 minutes	360^0C	362
4	150 minutes	360^0C	371
5	200 minutes	360^0C	356
6	250 minutes	360^0C	343
7	50 minutes	430^0C	351
8	100 minutes	430^0C	368
9	150 minutes	430^0C	379
10	200 minutes	430^0C	360
11	250 minutes	430^0C	349

C. Microstructure

Microstructure analysis is carried out on the specimens using metallurgical microscope. Specimens are polished by following standard metallographic procedures, etched in 10% Nital (10% Nitric acid and 90% Ethanol) and examined under optical microscope equipped with digital camera. Figure 7 shows microstructure consisting of Ausferrite which consists of high carbon Austenite and Bainitic ferrite with graphite nodules dispersed in it. Figure 8 shows Photomicrograph of as cast IS500/7 grade ductile iron with graphite nodules distributed uniformly.

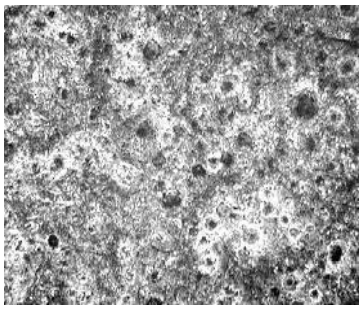

Fig.7 Microstructure of ADI at 100X

ISSN: 2278 – 7798

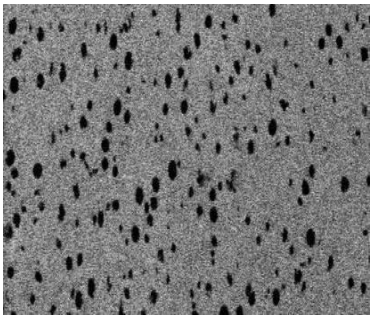

Fig.8 Microstructure of as cast IS500/7 ductile iron at 100X

III. CONCLUSION

From the analysis the following conclusions are drawn:

- By subjecting IS500/7 ductile iron casting to austempering heat treatment transformation in the microstructure is found**.**
- ADI specimens possess improved Ultimate tensile strength and hardness when compared with as cast ductile iron specimen.
- From experimental investigation it is found that Austempered specimen held at 360^0C for 100minutes duration possess higher Ultimate strength of 1149.7N/mm^2 comparatively with other specimens time durations at 360^0C.
- It is also found that Austempered specimen held at 430^0C for 150minutes duration possess better Ultimate tensile strength of 1120.7N/mm^2 comparatively with other specimen time durations at 430^0C.
- It is observed that Austempered specimen held at 360^0C for 150minutes duration possess better hardness of 371BHN comparatively with other time durations at 360^0C.
- It is also observed that Austempered specimen held at 430^0C for 150minutes duration possess better Hardness value of 379BHN comparatively with other time durations at 430^0C.

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ISSN: 2278 – 7798