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EFFECT OF WALL THICKNESS AND HEAT TREATMENT VARIABLES ON STRUCTURAL PROPERTIE OF AUSTEMPERED DUCTILE IRONS

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Abstract: The most rapidly growing area of cast technology is that of ADI or Austempered Ductile Iron. ADI is a heat treated Ductile Iron or S.G. iron with a unique micro-structure: Ausferrite which consists of high carbon Austenite and Bainitic ferrite with graphite nodules dispersed in it. This unique microstructure yields excellent properties: high strength, toughness, good wear resistance, good machinability and all that at low cost. The use of this type of cast iron as an engineering material has been increasing day by day since its discovery. These properties can be achieved upon adequate heat treatment which yields optimum microstructure for a given chemical composition. But this type of treatment is bit tricky, since it requires controlled heating and isothermal holding of the material.

In this work an investigation has been conducted on ductile iron without additions of any alloying elements and austempered in a range of time and temperature. An attempt has been made to study the effect of austempering time and temperature on the mechanical properties of Thin wall ADI. The samples of 2, 4,6 and 8 mm thickness were austenitized at 9000 C for 30 minutes followed by holding in salt bath maintained at 3500 C, 4000 C and 4500 C for 5, 10 and 15 minutes for each temperature. The tensile strength was found to increase with decreasing austempering temperature and time. Maximum tensile strength found in 2mm samples austempered at lower temperatures, 350°C and 5 minute and minimum tensile strength found in 8mm sample austempered at 4500C and 15 minute time. Maximum ductility was obtained after austempering for 15 minute. An increase in the ductility of ADI was found by increase of wall thickness, time and temperature. Hardness was found to be decreasing with increasing austempering time and temperature, and found minimum in 8mm at 4500C and 15 minute. Hardness found maximum at 3500C and 5 minute.

INTRODUCTION

The materials which offer the design engineer the best combination of low cost, design flexibility, good machinability, high strength to weight ratio & good toughness, wear resistance is Austempered Ductile Iron (ADI) [1]. Austempered Ductile Irons are an interesting class of materials because of their unique microstructure and interesting properties. When subjected to austempering treatment, ductile iron transforms to a microstructure consisting of ferrite and stabilized austenite rather than ferrite and carbide as in austempered steels. Because of the presence of stabilized austenite, ADI exhibits excellent combination of strength and ductility, together with good fatigue and wear properties [2, 3]. Compared to the conventional grades of Ductile Iron, ADI delivers twice the strength for a given level of ductility. But achieving excellent mechanical properties of the ADI material is not an easy task as they depend on austempered microstructure which is a function of its processing window. The optimum combination of high carbon austenite and bainitic ferrite of ADI makes it possible to compete against steel forgings and other engineering alloys in terms of mechanical properties, physical properties, weight saving and all that at low cost. ADI offers superior combination of properties because it can be cast like any other member of the Ductile Iron family, thus offering all the production advantages of a conventional Ductile Iron casting. The ductile Iron casting is subsequently subjected to the austempering process to produce mechanical properties that are superior to conventional ductile iron and forged steel. Due to its vast area of applications, extensive works are being carried out now-a-days to study the processing and characterization of this material.

The ADI market has been continuously growing with a rate estimated at 16% per year [4]. There are numerous studies on ADI, particularly on the kinetics of austempered of cast iron, microstructural characterization and mechanical properties [4-13]. While the parameters for a successful production of high quality ADI are well established, the same cannot be said of thin wall austempered ductile iron (TWADI). Thin wall ductile iron castings are characterized by an extremely large nodule count and hence with relatively small interparticle spacing. High nodule count, homogeneous structure and high cooling rate of the thin wall castings make it possible to eliminate the use of alloying elements such as Ni and Cu for increasing austemperability. Accordingly, thin wall ductile iron castings can be as an ideal material in producing thin walled austempered ductile iron castings.

EXPERIMENTAL WORK

Pattern and gating system of different castings plates A (128mm×77mm×2mm), B (128mm×77mm×4mm), C (128mm×77mm×6mm) and D (128mm×77mm×8mm) without riser was made. Green sand was prepared by using Silica sand, bentonite and water. Firstly Sand is mixed with bentonite in Sand Mixer and then bentonite coating is carried out in Sand Muller with addition of water. Sand mix was rammed by hand. Graphite powder was applied to the pattern for clean stripping and to act as mould coating.
A 31 kg charge, which consists of 20 kg pig iron, 3kg steel scrap, foundry return 7 kg and Fe-Si (50%) 1 kg, was melted in an induction furnace and then Mg-treated by using Sandwich method with FeSiMg alloy. The molten metal was inoculated by foundry grade Fe-Si in two steps, half of Fe-Si quantity was added in the vortex and the rest was added in ladle. The chemical composition of the test casting expressed in mass content of the alloying elements was 3.69% C, 2.6% Si, 0.36% Mn, 0.016% P, 0.005% S, 0.29% Cu and 0.064% Mg. The austempering treatment process was carried out by austenitizing at 900 ºC for 30 minutes and then austempering at different temperatures of 350 °C, 400^0C and 450 °C for 5,10 and15 minutes at each temperature. Tensile properties of the material were determined as per ASTM E8.The hardness values obtained from Brinell hardness tests.

RESULT AND DISCUSSION

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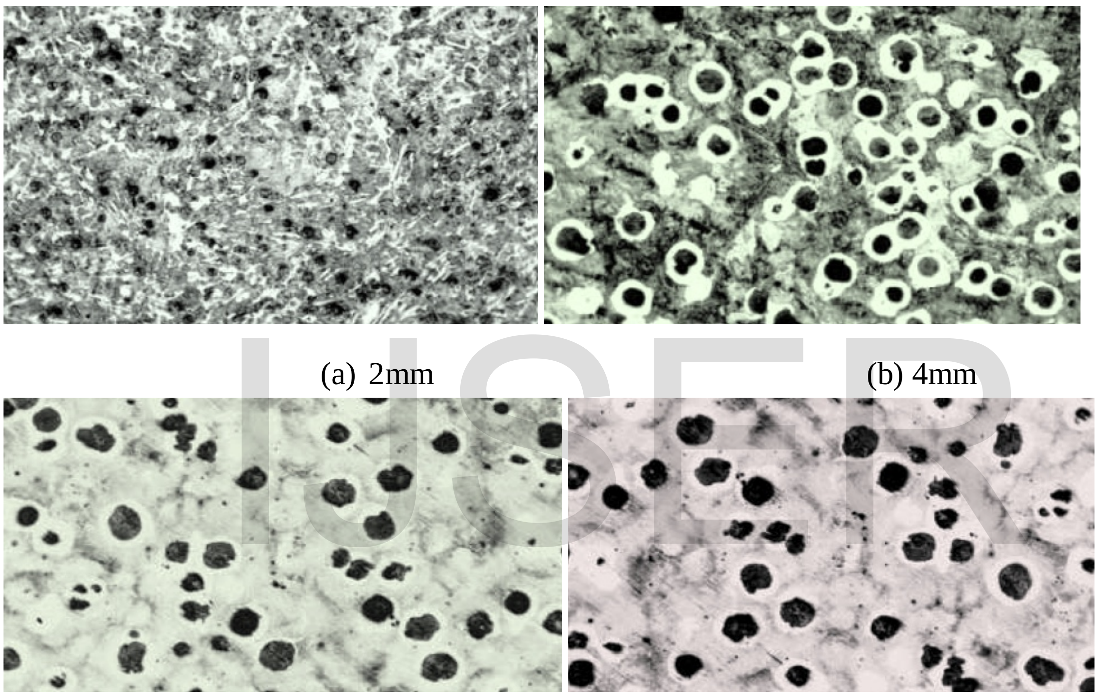
Thin wall ductile iron (TWDI)

The microstructures of the as-cast DI castings with different wall thicknesses are shown in Fig. 1. It is clear that the structure of 2-mm wall thickness contains a considerable amount of carbides, whereas the 4-mm wall thickness contains only traces of carbides. Increasing the wall thickness to 6 and 8 mm resulted in complete disappearance of carbides. The nodule count decreased with increasing the wall thickness with maximum count of nodules/mm^2 in the 2-mm sections.



(a) 2mm (b) 4mm

(a) 6mm (d) 8mm

Fig.1 Microstructure of as-cast ductile iron castings

Hardness and tensile test value of as-cast ductile iron in different thickness is depicted in Table 1 and the variation of hardness and UTS with section thickness is shown in figure.2 and Figure 3 respectively. It is clear that the hardness and UTS decreases with increase in section thickness. In thin section nodule counts is more compare to thick section, around 1800 nodule/mm^2 is found in 2mm section thickness and interparticle spacing is minimum. This is in agreement with the microstructure shown in Fig. 1 where the pearlite volume fraction increases with decrease in section thickness.

Table.1 Hardness and Tensile test results of as cast Ductile Iron samples

Sample Thickness (mm)	Hardness BHN(10 mm, 1000kgf)	Tensile Strength(MPa)
2	262	620
4	250	605
6	238	590
8	227	580

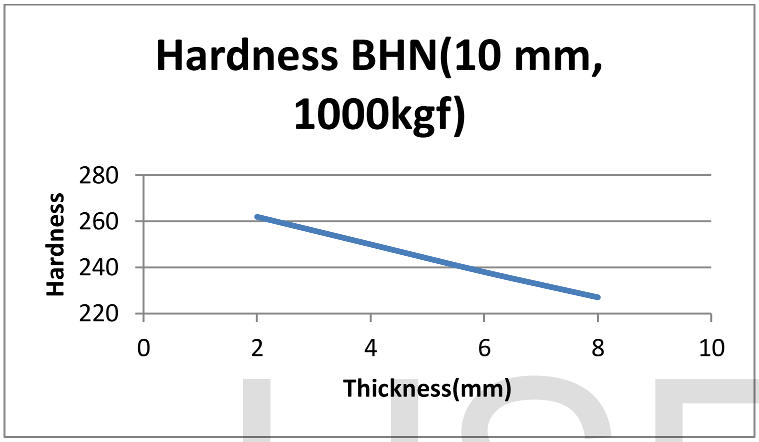


Figure.2 Hardnessvs section thickness of as-cast Ductile Iron

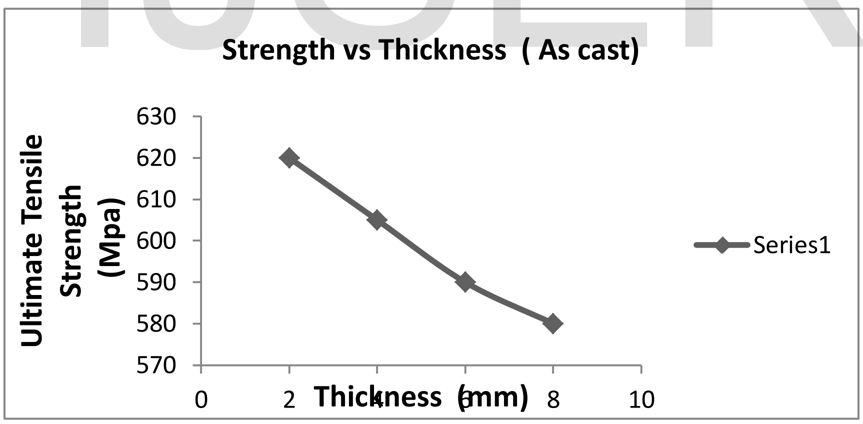


Figure.3: UTS vs section thickness of as-cast Ductile Iron

Thin walled Austempered ductile iron (TWADI)

Effect of Austempering time

The hardness and UTS data of samples austempered at 350^0 C for different times is included in Table 2 and the nature of variation of these data is shown in Fig.4 and Fig 5. From these figures, it is evident that the 2mm section thickness plate austempered for 5 minute has maximum

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hardnessand UTS and minimum hardness and UTS is found in 8mm plate austempered for 15 mm. It is clearly shown that the hardness increases with decreasing the wall thickness due to the structure refinement effect and increasing the bainitic transformation rate.

Table.2 Hardness and Tensile test results of TWADI in different time.

Austenitizing Temperature (^{0}C)	Austempering Temperature (^{0}C)	Plate Thickness, mm	Austempering Time (Minute)	Hardness BHN(10mm, 1000kgf)	Ultimate Tensile Strength (MPa)
900	350	2	5	328	1015
			10	307	995
			15	295	990
900	350	4	5	312	975
			10	311	960
			15	304	950
900	350	6	5	302	930
			10	308	920
			15	297	900
900	350	8	5	302	915
			10	298	920
			15	285	910

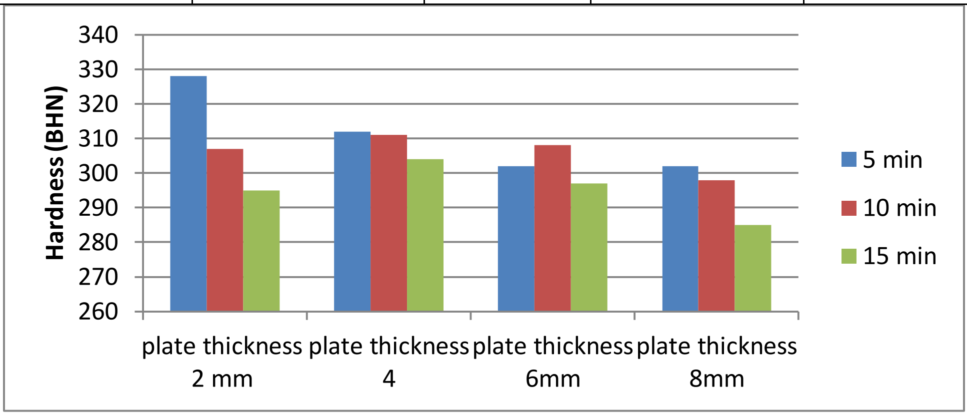

Fig.4: Hardness value of TWADI for different austempering time

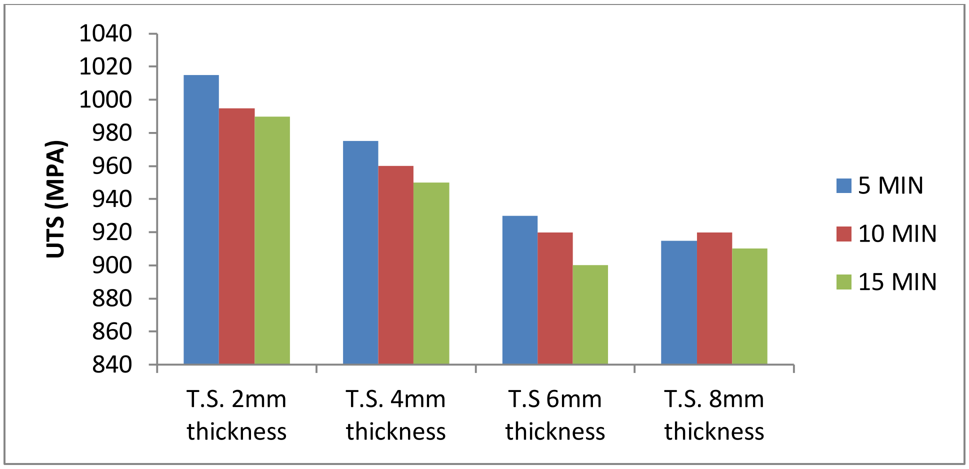

Fig.5: UTS value of TWADI for different austempering time

Table 3 shows the hardness and tensile data of plate austempered for 10 minutes time at different austempering temperature. This hardness and UTS data presented in figure 6 and Figure 7 clearly reflect maximum hardness and UTS in 2 mm thickness plate austempered at 350^0 C for 10 minute time and also the hardness and UTS decreases with increase in austempering temperature. Lowering the austempering temperature to 350 ºC, both diffusion and growth rates are decreased and the structure consists of fine needles of bainitic ferrite. The ADI samples austempered at 350 ºC were noticed to contain higher amount of unreacted austenite, which may be attributed to the incomplete transformation at 350 C, where the initiation and completion of transformation are retarded with decreasing the austempering temperature and time

Table.3: Hardness and UTS value of plate austempered at different austempering temperature.

Austenitizing Temperature	Austempering Time (Minute)	Plate Thickness, mm	Austempering Temperature	Hardness BHN(10mm, 1000kgf)	UTS (MPa)
900	10	2	350	315	1000
			400	305	820
			450	302	680
900	10	4	350	310	970
			400	305	805

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			450	302	640
900	10	6	350	301	940
			400	309	790
			450	296	615
900	10	8	350	302	920
			400	300	780
			450	298	590

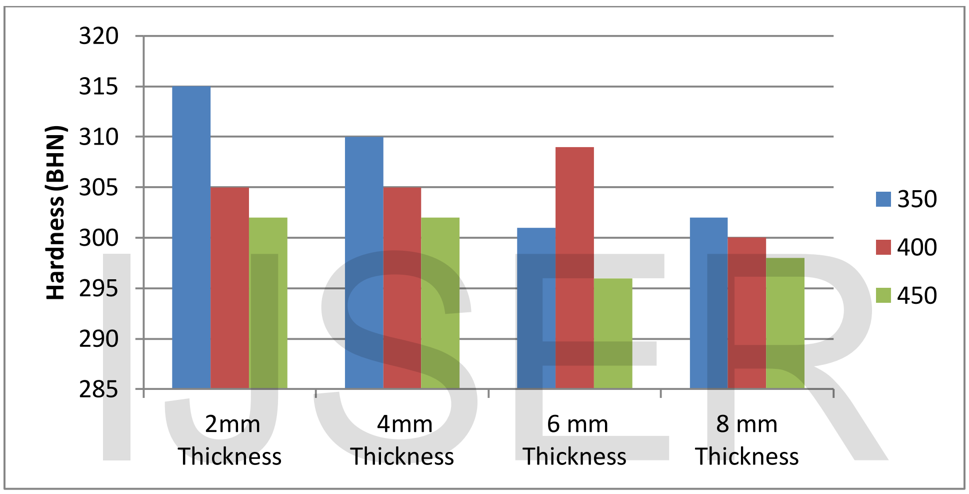

Figure.6: Hardness value for samples austempered at different temperatures for 10 minute.

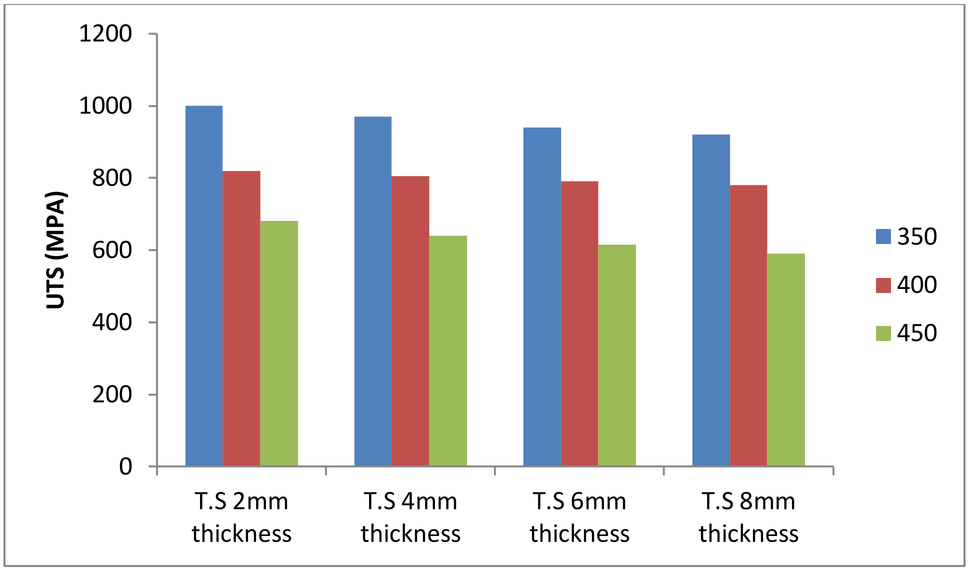

Figure.7: UTS value for samples austempered at different temperatures for 10 minute.

In figure.7, the samples austempered at 350 ºC for 10 minute showed higher tensile properties than those austempered at 400 ºC for 10 minute mainly due to the structural refinement effect and the existence of less amounts of retained austenite associated with lower austempering temperatures. In addition, a slight decrease in tensile properties was noticed with increasing the plate thickness from 2-mm to 8-mm. Whereas the tensile strength values showed low sensitivity to the wall thickness, the elongation percentage increased dramatically with increasing the wall thickness. Moreover, the higher amounts of retained austenite in thicker sections may as well play an important role in increasing ductility and toughness values of these plates. From Fig. 7, it is shown that elongation increases with increasing the austempering temperature from 350 ºC to 450 ºC, which is expected due to the higher retained austenite fraction in plates austempered at higher temperature. Whereas retained austenite and consequently elongation increases with increasing the wall thickness of the plates. It is well established that the austempering reaction starts by nucleation of ferritic platelets at the graphite/matrix interface. With the rather high nodule count encountered in the structures of 2-mm plates, it is expected that the transformation will proceed at rather high speed, independent on the austempering temperature. In other words, it may be assumed that the enhanced transformation rate due to the high nodule count will mask the influence of austempering temperature on diffusion and the structure and the elongation of the 2-mm thick plate will be almost the same.

Conclusions:

1. The Thin wall ductile iron castings plates were obtained up to 2mm by selecting suitable gating and feeding design.

2. In thinner plates, the fine size nodules are uniformly distributed and distance between two nodules were less compare to thicker section.

3. The hardness and strength decreases with increase in section thickness of DI plates.

4. The hardness and strength found higher in ADI comparatively to DI.

5. The Hardness and Tensile strength of ADI samples were found to increase with decreasing austempering temperature and time.

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