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Fatigue behavior of Nickel alloyed permanent moulded austempered ductile

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Abstract: **-- Laboratory low cycle fatigue tests were conducted on permanent moulded austempered ductile iron alloyed with 1.0% and 2.0% nickel content. Samples were austenitized at 9000C for 60 minutes and austempered at 300 and 3500C for 60 to 150 minutes in steps of 30 minutes. The results indicated that PMADI samples austempered at 3000C for 60 minutes showed superior fatigue strength than other test samples. 2% Nickel PMADI samples showed better fatigue strength than 1% Nickel PMADI samples. The results were analyzed based on structure property correlation and microstructure.**

Key words: **Austempered, Fatigue, Nickel content Permanent moulded.**

I. INTRODUCTION

Austermpered ductile iron (ADI) is most recent, construction material with good combination of toughnesss, strenth & platicity. ADI provides a material with superior wear resistance and fatigue strength to conventional ductile iron, cast and forged aluminium and many cast and forged steels. The mechanical properties of ductile iron and ADI are primarily determined by the metal matrix. The matrix in conventional ductile iron is a controlled mixture of pearlite and ferrite. The properties of ADI are due to its unique matrix of acicular ferrite and carbon stabilized austenite called ausferrite. Technical literature often descibes this matrix as bainite (although it does not contain carbides). The structure of ADI is obtained by exactly controlled process of heat treatment of nodular cast iron [1],[2,3]

Austempered ductile iron (ADI) is an engineering material which finds its use in agriculture, automative, mining and power plant applications due to its special properties such as wear resistance, toughness and high strength. Components made from ADI are used in liners in power plants, in automative sectors and in coal handling equipments such as gears and chutes. Uma et al. [4] have reported that sand casting are used for production of ADI, the application of permanent mould casting offers greater merits like better environmental cleanliness, better mechanical properties, improved dimensional stability and higher production rates.

Seetharamu et al. [5] have reported that dry sand abrasion and jet erosion wear resistance of ADI has been superior for castings poured into permanent moulds compared to sand moulded counterparts. Murthy et al. [6] have reported greater erosive and abrasive resistance and sterngth of permanent moulded austempered ductile iron (PMADI) castings alloyed with manganese.

II. HEAT TREATMENT

Standard austempering heat treatment cycle as shown in the Figure 1 was employed in the present analysis. Initially IS500/7 grade ductile iron specimens were transferred to a salt bath furnace maintained at 900oC.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 300oC and 350oC .The specimens were then held at this austempering temperature for 60, 90, 120 and 150 minutes duration in order to bring about isothermal transformation to bainite stabilized austenite matrix. Later the specimens were removed from the furnace and

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cooled in air till room temperature is reached. Fig.1 shows the austempering heat treatment cycle.

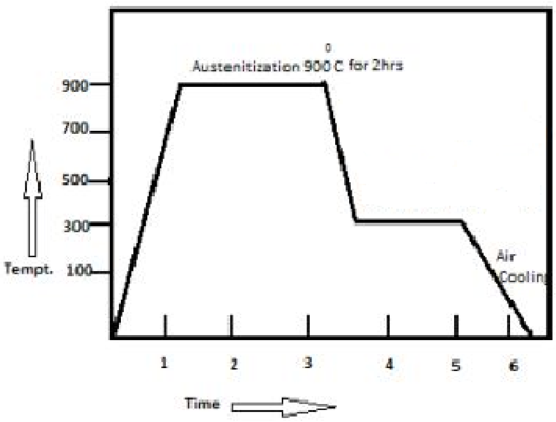

Fig 1. Austempering Heat Treatment Cycle

The application of ADI occurs in situations involving abrasive wear for example pieces of earth moving equipment and mining. Also in automotive industry mainly on parts subjected to mechanical stresses associated with impact requests, such as suspension parts for vehicles (Aranzabal et al., 2003)

Table 1- Standard ADI grades (USA) ASTM A897M-06.

Grade	Tensile Strenth (MPa)	Yeild Strength (MPa)	Elogation %	Typical Hardness (BHN)
1	850	550	10	269-321
2	1050	700	7	302-363
3	1200	850	4	341-444
4	1400	1100	1	388-477
5	1600	1300	-	444-555

Whereas the fatigue phenomena is ultimate responsibility for the most of the damage in gears,crack nucleation & crack propagation periods are directly related to the total number of cycles of these components. The stress concentrators are graphite nodules & are responsible for the crack nucleation.And also accelerate the propagation of these cracks.

III. EXPERIMENTAL DETAILS

Table 2- Percent weight composition of ADI

Materials	c	Si	Mn	Ni	Cu
ADI 1	3.3	3.0	0.5	1.0	1.0
ADI 2	3.3	3.0	0.5	2.0	1.0

Austempering is an isothermal process and offers various merits over Q&T. The formation of Martensite occurs immediately as the metal temperature drops below the Martensite start temperature. The surface of the part will transform before the centre, so distrotion or/and cracking can occur due to non-uniform transformation. This is further exacerbated by changes in section sizes. Since the formation of Ausferrite or Bainite occurs over minutes or hours at a single temperature, distortion is minimized and cracking does not occur.

Carbo-Austempering is a heat treat process used on certain steels where the surface of the part is carburized, followed by an isothermal quench at a temperature required to produce a high carbon, Bainitic case. The formation of a Bainitic case and a low carbon, tempered Martensite core occurs when this process is applied to low carbon steels. Bainite is formed throughout the cross-section of the part for medium carbon steels.

ADI can produce a quiet, low cost gear or shaft in its allowable loading range but it will not perform.

Carburized quenched & tempered alloyed, low carbon steel in bending or contact fatigue. Hence if a current product in carburized steel is failing in bending fatigue, ADI would not be a solution. However, if the contact & bending loads are in ADI's range, a considerable cost & noise advantage can be expected.

Fatigue: Various components in manufacturing equipment, such as tools, dies, gears, cams, shafts, and springs, are subjected to rapidly

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fluctuating (cyclic or periodic) loads, in addition to static loads, like (a) on gear teeth or reciprocating sliders, (b) by rotating machine elements under constant bending stresses, as is commonly encountered by shafts, or (c) by thermal stresses, as when a die comes into repeated contact with hot work pieces and cools between successive contacts. Under these conditions, the part fails at a stress level below that at which failure would occur under static loading. Upon inspection, failure is found to be associated with cracks that grow with every stress cycle and that propagate through the material until a critical crack length is reached, when the material fractures. Known as fatigue failure, this phenomenon is responsible for the majority of failures in mechanical components. Fatigue test methods involve testing specimens under various states of stress, usually in a combination of tension and bending. The maximum stress to which the material can be subjected without fatigue failure, regardless of the number of cycles, is known as the endurance limit or fatigue limit.

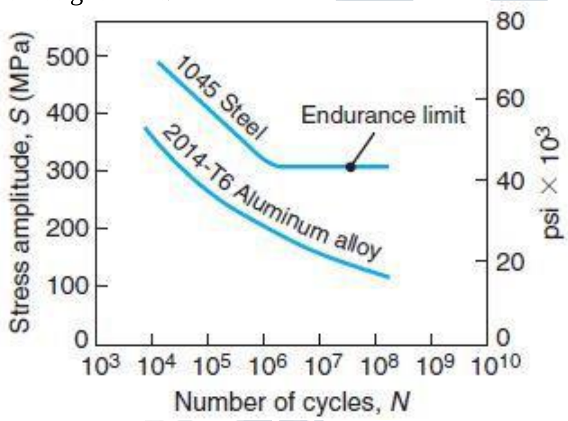

Fig. 2 Typical S–N curves for two metals. Note that, unlike steel, aluminum does not have an endurance limit

The fatigue test was conducted in the Lab and the results are tabulated in the table 3.

Table-3 Fatigue testing of sample

Sl No.	Specimen No.	Salt bath/time in ºC/min	Load in kg	No of cycles	Time in secs
1	10	350 / 60	40	5950	44
2	11	350 / 120	35	4188	5
3	13	350 / 60	75	304	3.98
4	21	350 / 120	50	5950	101
5	22	350 / 90	40	297	5
6	24	300 / 60	40	11225	155
7	25	300 / 90	50	6006	86

The SEM Structures:

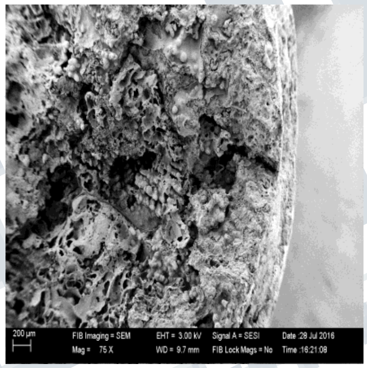

Fig. 3 Microstructure of ADI (Specimen no-11)

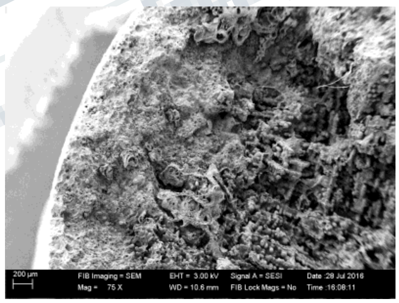

Fig. 4 Microstructure of ADI (Specimen no-21)

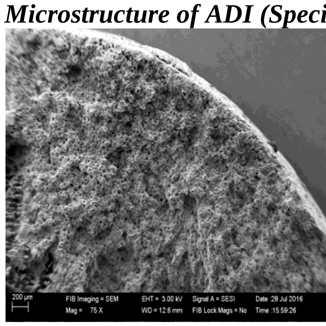

Fig. 5 Microstructure of ADI (Specimen no-24)

IV. CONCLUSION

• By subjecting IS500/7 ductail iron casting to austempering heat treatment transformation in the microstructure is formed.

• From the experimental investigation it is found that austempering specimen held at 300OC for 60 minutes posses better fatigue.

• ADI cast irons are increasingly used for the relavant parts of machines exposed to dynamic load changes. It is advisable to know the fatigue properties and crack mechanism to determine the safe operation service life.

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