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Experimental Analysis of Mechanical Properties, Wear and Corrosion Characteristics of IS400/12 Grade Ductile Iron Casting

Mohit Kumar Agarwal, Vineet Kumar

Abstract: ***In the present research investigation, ductile iron castings conforming to IS400/12 grade casting were produced using green sand moulds. The castings were produced in a regular production foundry using 1.25T Induction Furnace. The molten metal was subjected to standard desulphurisation and modularisation to get graphite in the nodular form. The molten metal was poured into the sand mould and allowed to solidify. Based on the earlier investigation by the above group the castings were austenitised at 900ºC for 120minutes and quenched in a salt bath consisting of potassium nitrate and sodium nitrate in the ratio of 55:45 and maintained at 310ºC for 120 minutes to bring about austempering treatment. The result in austempered ductile iron will consist of graphite nodules in a matrix of bainite[1,2]. The effect of austempering heat treatment on microstructure, mechanical properties and wear characteristics were studied and compared with the ascast condition. Mechanical properties such as ultimate tensile strength, percentage elongation, hardness and impact strength were determined. Wear tests were carried out to determine the weight loss of specimens; using pin on disc type machine. Wear test was held for different loads viz. 300 gm, 400 gm and 500 gm and different speeds conditions viz. 950 r.p.m, 1430 r.p.m and 2130 r.p.m. The results of the research investigation indicate that the heat treated castings shows higher Ultimate Tensile Setength values (35.93% increase), elongation values (24.2% increase) and Brinell hardness values (12.05% increases) as compared to the as-cast condition of casting. From the dry sliding wear studies, it is seen that heat treated specimens shows higher resistance to wear compared to the ascast specimens.***

Key Words: ***Austempered Ductile Iron (ADI), Corrosion, Ductile Iron (DI), Heat Treatment (HT), Wea.***

I. INTRODUCTION

Ductile Iron casting consists of graphite in the form of nodules or spheroids in a matrix of either ferrite or pearlite. The Mechanical properties of ductile iron combine the properties of cast iron and steel. Iron with different microstructure can be obtained by changing the treatment conditions during melting, after treatment and also by heat-treating the castings. By changing any one of the parameters, a suitable iron casting as per requirements and application can be obtained. In order to improve the Mechanical properties of ductile iron, the material can be treated with alloying elements or can be heat-treated to make change in the microstructure of the material.

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* Correspondence Author

Mr. Mohit Kumar Agrawal*, Associate Professor , Department of Mechanical Engineering, Vaish College of Engineering, (Haryana), India.

Dr. Vineet Kumar, Professor, Department of Mechanical Engineering, University Institute of Engineering and Technology, (Haryana), India.

Commonly, austempering heat treatment is carried out on ductile iron; hence the name "Austempered Ductile Iron" or "ADI". ADI has found its application in a wide range of components[5,6] for many engineering sectors as in gears, crank shafts, transmissions, suspensions, earth-moving and construction equipment, railways etc. Wear is an important property, which is evaluated in materials to find out its response to undergo loss of material. It is a progressive, unintentional loss of material when two surfaces come in contact under normal load and there is relative motion between the surfaces. Wet abrasive wear test is one method for evaluating the material behaviour to wet abrasive action. Many Indian foundries are producing ductile iron on a commercial scale since a few decades.

However, the production of ADI in India is still in infant stages. Hence, in the present investigation ductile iron conforming to IS400/12 grade was produced and austempered for the best conditions hence, in the present research investigation a systematic study was done for evaluation of mechanical properties, and wear properties for different loads and speed level [1,2].

II. EXPERIMENTAL DETAILS

A. **Mould Material Used:** Silica sand having a grain fineness of AFS61 was used for making the moulds. Greensand moulds were prepared using 5% bentonite and 3.5 % water. Cylindrical bar castings of 30mm diameter and 300mm length were produced using cope and drag type moulds.[3] .

B. **Melting, Casting and Treatment:** Charge consisting of Grey Cast Iron; foundry returns; ductile Iron, commercial pig iron (S<0.05%), mild steel punching was used. Conventional techniques of melt treatment and heat treatment were carried out as shown in the flowchart Fig.1 to produce ductile iron castings and ADI castings. The composition of IS400/12 was 3.6% C, 2.8% Si, 0.35% Mn, 0.03% P(max) and 0.03% S(max) with 0.03% Mg (min).

Metal charge (PigIron,CastIron,Steel punching,Soral PI)

↓

Induction Furnace
1.25T, 200HZ

↓

Melt was superheated
155ºC and Desulphurised with
1.9% CaC2 to reduce S level to <0.05%

↓

Desulphurised Iron was poured into a Ladle containing Fe-Si-Mg alloy using sandwich method

↓

Post inoculated with 0.3% Fe Si & the melt was stirred. Slag removed

↓

Molten metal poured into the moulds cavity and cooled

↓

Castings were heat treated by first austenitising at 900°C for 120 minutes

Quenched in salt bath containing KNO3: NaNO3- 55:45 maintained at a known temperature. level and held at this temp. for 120 minutes

↓

Castings were cooled

↓

The resulting Iron is ADI

Fig.1 Flow chart for production of ADI casting [15].

C. Evaluation of Properties

Standard metallographic procedures like grinding and polishing were done for microstructure examination. Standard test procedures were employed for structure examination and mechanical property assessments [4,14].

D. Impact Studies

Impact test was carried out using standard Izod (cantilever type) and standard Charpy (simply supported) specimens and evaluation of impact on specimen in as-cast condition and heat-treated condition. It is absorbed on heat treatment, the impact values will come down appreciably[5-6].

E. Dry Sliding Wear Test

The specimens in the form of 5 mm pins were prepared in a lathe and used as a sample for dry wear test. A hardened circular disc having hardness of 64 HRC was used as counter face. The testing was carried out by allowing the specimen to rub against hardened disc for a given normal load and speed condition. Making use of pin on disc machine test was carried out[7]. The specimens were taken out at regular intervals and the weight was recorded. The experiment was conducted for different load, speeds and different conditions of metal (ascast or heat treated) [8].

III. RESULTS AND DISCUSSION

A. Mechanical Properties

The variation of Ultimate Tensile Strength, percentage elongation and hardness values of the specimen are shown in Table-1. It can be seen that the UTS values, percentage elongation values and hardness values of the heat-treated specimen or higher than the ascast ones. This may be due to the formation of bainite in the heat-treated condition.

Table-1 details of Mechanical properties under As-Cast and Heat-Treated condition.

Mechanical Properties	Condition		% Increase
	As- Cast	Heat-Treated	
BHN (Hardness Values)	248	282	12.05
Impact Energy values (kg-m), Izod test	2.25	1.6	28.88
Impact Energy values(kg-m), Charpy test	4.2	1.2	71.42
UTS (N/mm2)	410	640	35.93
% Elongation	12.2	16.1	24.22

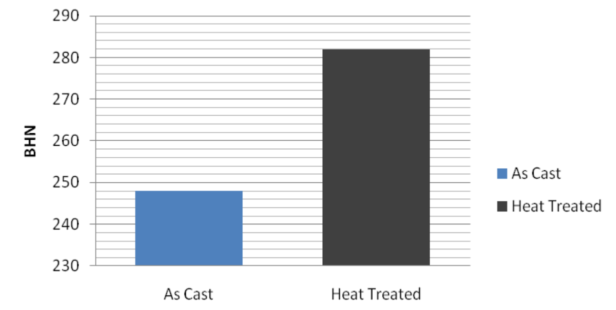

Fig. 2 shows the variation of hardness values in as cast and heat treated condition.

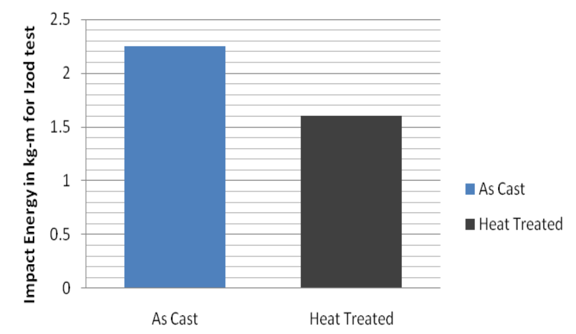

Fig. 3 shows the variation of Impact energy values (in kg-m) for Izod test in as cast and heat treated condition.

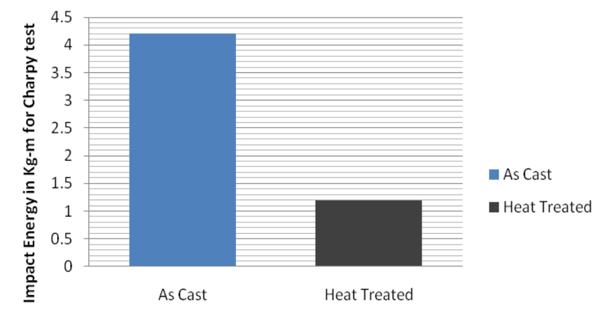

Fig. 4 shows the variation of Impact energy values (in Kg-m) for Charpy test in as cast and heat treated condition.

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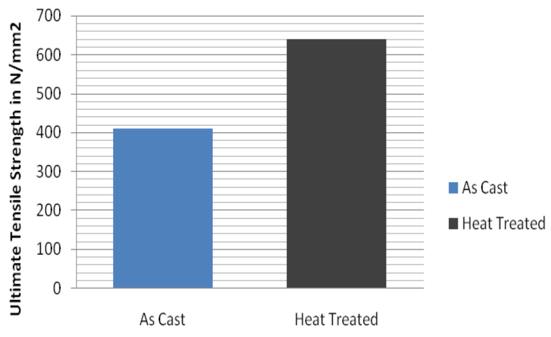

Fig. 5 shows variation of Ultimate Tensile Strength (in N/mm2) in as cast and heat treated condition.

B. Impact Test

The Izod impact results show that the impact energy decreases on heat treatment indicating that the specimen tends to become brittle. There is a decrease in energy level by nearly 29% as shown in Table-1and figure 3. [9]. Charpy result shows that the impact energy decreases on heat treatment. But there is a tendency to show sudden drop[10]. The decrease is as high as 71% as shown in Table-1 and figure 4 this may be attributed to the type of arrangement used for impact measurement and due to the specimen tending to become brittle[11]

Table-2 Effect of speeds on dry sliding wear at constant load 300 gm inAs-Cast and Heat-
Treated condition (at the end of 20 minutes).

Speed in rpm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
950	0.12	0.1
1430	0.14	0.13
2130	0.17	0.15

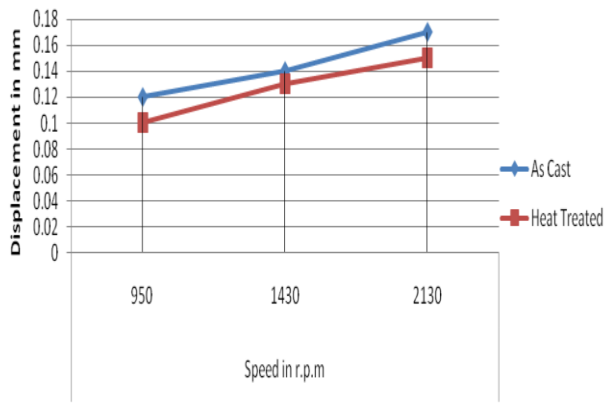

fig. 6 Variation of displacement (linear wear) at constant load 300 gm in as cast and heat treated condition

Table-3 Effect of speeds on dry sliding wear at constant load 400 gm inAs-Cast and Heat –Treated condition (at the end of 20 minutes).

Speed in rpm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
950	0.17	0.14
1430	0.22	0.18
2130	0.29	0.26

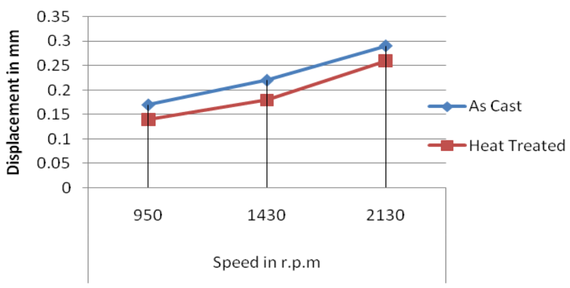

fig. 7 Variation of displacement (linear wear) at constant load 400 gm in as cast and heat treated condition

Table-4 Effect of speeds on dry sliding wear at constant load 500 gm inAs-Cast and Heat –
Treated condition (at the end of 20 minutes).[12]

Speed in rpm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
950	0.28	0.24
1430	0.32	0.28
2130	0.35	0.32

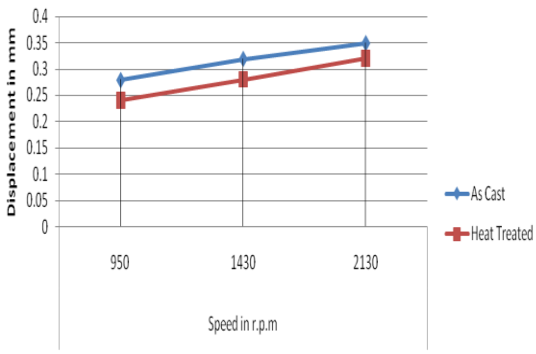

fig. 9 Variation of displacement (linear wear) at constant load 500 gm in as cast and heat treated condition

Table-5 Wear of As-Cast and Heat-Treated specimens for different loads and speeds[13]

Load (in gms)	Speed (in rpm)	Condition-Wear	
		Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	950	0.12	0.1
	1430	0.14	0.13
	2130	0.17	0.15
400	950	0.17	0.14
	1430	0.22	0.18
	2130	0.29	0.26
500	950	0.28	0.24
	1430	0.32	0.28
	2130	0.35	0.32

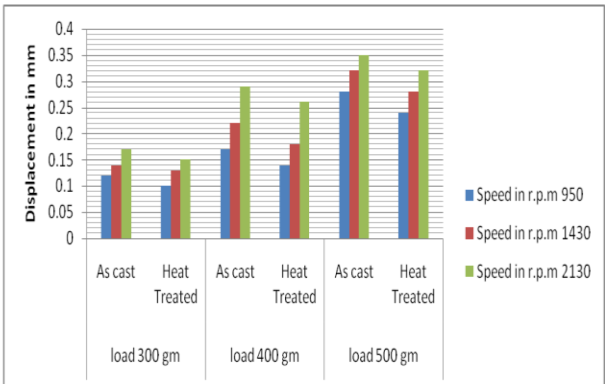

fig. 10 Variation of displacement (linear wear) at different loads and speeds in as cast and heat treated condition.

Table-6 Effect of loads on dry sliding wear at constant speed 950 r.p.m inAs-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.29	0.25
400	0.33	0.29
500	0.36	0.32

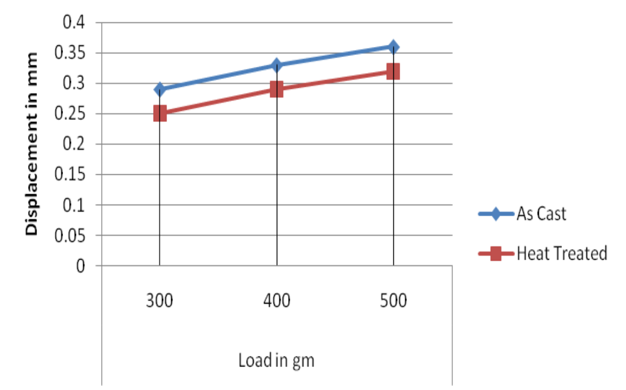

Fig. 11 Variation of displacement (linear wear) at constant speed 950 r.p.m in as cast and heat treated condition

Table-7 Effect of loads on dry sliding wear at constant speed 1430 r.p.m inAs-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.32	0.28
400	0.36	0.32
500	0.39	0.35

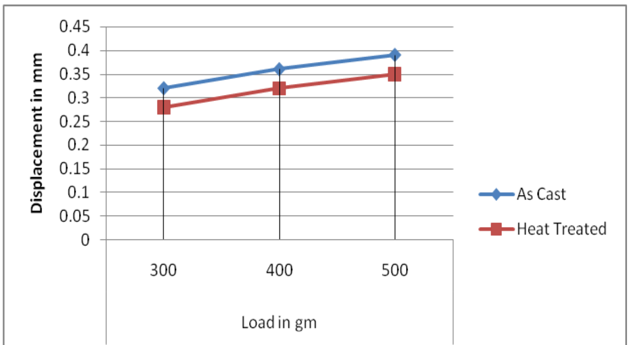

Fig. 12 Variation of displacement (linear wear) at constant speed 1430 r.p.m in as cast and heat treated condition.

Table-8 Effect of loads on dry sliding wear at constant speed 2130 r.p.m inAs-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.36	0.33
400	0.39	0.35
500	0.43	0.38

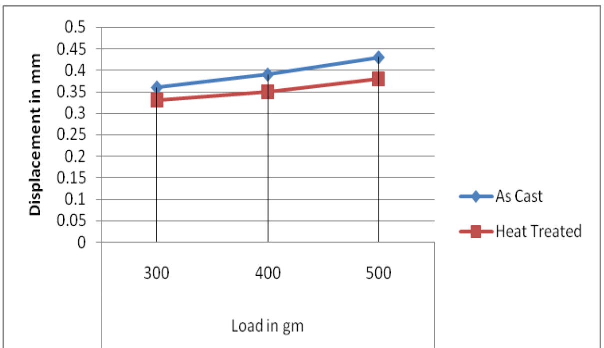

Fig. 13 Variation of displacement (linear wear) at constant speed 2130 r.p.m in as cast and heat treated condition.

Table-9 Wear of As-Cast and Heat-Treated specimens for different loads and speeds

Speed (in rpm)	Load (in gm)	Condition-Wear	
		Ascast, wear (in mm)	Heat Treated, Wear (in mm)
950	300	0.29	0.25
	400	0.33	0.29
	500	0.36	0.32
1430	300	0.32	0.28
	400	0.36	0.32
	500	0.39	0.35
2130	300	0.36	0.33
	400	0.39	0.35
	500	0.43	0.38

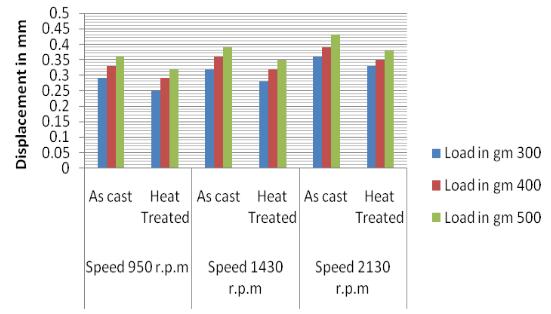

Fig. 14 Variation of displacement (linear wear) at different speeds and loads in as cast and heat treated condition

C. Dry Sliding Wear

The variation of loss of weight at 3 different speeds and 3 different loads were evaluated. Wear of, as cast specimen is higher than heat-treated condition for any given speed or [12]. any given normal load condition. Dry sliding wear increases with increase in time of testing. Decrease in wear for heat-treated specimen, varies from 15 to 20% with respect to as cast specimen as shows in Table 2 to Table 9 and fig. 6 to fig. 14.

IV. CONCLUSIONS

The result of present investigation was held on ascast and heat treated ductile iron specimens shown below:

1. Mechanical properties in heat treated condition such as Ultimate Tensile Strength (35.93% increase), % elongation (24.22% increase) and Brinell hardness values (12.05% increase) as compared to the ascast condition in present research investigation.
2. Impact test (Izod and Charpy) shows that impact energy decreases on heat-treating of the specimen as compared to as cast ones in present research investigation.
3. Dry sliding wear found less in heat treated condition as compared to as cast condition in present research investigation.
4. Corrosion rate and weight loss shows that on heat treating the specimen is less as compared to as cast specimen in both temperature conditions.

Hence, from above it has been noted that by heat treating the ductile iron castings provides better mechanical properties, wears and corrosion characteristics.

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AUTHORS PROFILE

Mr. Mohit Kumar Agrawal (B.E, M.Tech. in ME), currently doing Ph.D in Mechanical Engg. Deptt. from UIET, MDU, Rohtak, also working as a Associate Professor in Mechanical engg. deptt. VCE, Rohtak. He published 07 papers in International/National Journals and Conferences and also attended several workshops and FDPs. He is also working as Nodal officer AISHE (All India Survey on Higher Education, MHRD), also incharge of CM Grievence portal for college, worked as ISO Coordinator, time table incharge & working as admission Coordinator at VCE, Rohtak.

Dr. Vineet Kumar (Ph.D in ME), Current Academic Position, Dean (Faculty of Engineering & Technology, MDU, Rohtak) , Professor, Mechanical, UIET, MDU, Rohtak. Also worked as Principal, Dean, Professor and other faculty position in engineering colleges. He published about 50 papers indifferent International/National Journals and Conferences. Guided number of MTech. & Ph.D scholars and currently guiding PhD scholars. He was awarded university Merit Scholarship and Awarded with National Merit Scholarship in 10+2. He is also Principal Coordinator of AICTE funded projects. Also conducted and participated in several AICTE or sponsored conference/Session chair. Also worked as Head of Mechanical Engg. Deptt., worked as Chief Coordinator of ISO.