

Experimental Analysis of Mechanical Properties, Wear and Corrosion Characteristics of IS500/7 Grade Ductile Iron Casting



Mohit Kumar Agarwal, Vineet Kumar

Abstract: In the present research investigation, ductile iron castings conforming to IS500/7 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. Based on the earlier investigation by the above group the castings were austenitised at 900°C for 120 minutes and quenched in a salt bath consisting of potassium nitrate and sodium nitrate in the ratio of 55:45 and maintained at 310°C 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 [13,14] and wear characteristics were studied and compared with the as-cast condition. Mechanical properties such as ultimate tensile strength, % 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. Corrosion tests were carried out to determine corrosion rate at different viz. 35°C & 45°C temperature for increasing duration viz. 2 hours to 24 hours. The results of the research investigation indicate that the heat treated castings shows higher Ultimate Tensile Setength values (54.86% increase), elongation values (64.32% increase) and Brinell hardness values (19.03% increases) as compared to the ascast condition of casting. From the dry sliding wear studies, it is seen that heat treated specimen's shows higher resistance to wear compared to the ascast specimens and corrosion rate & weight loss due to corrosion in heat treated condition is less compared to ascast ones.

Key Words: Austempered Ductile Iron (ADI), Corrosion, Ductile Iron (DI), Heat Treatment (HT), Wear,

I. INTRODUCTION

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. For improving mechanical properties of the material can be heat-treated to make change in the properties of ductile iron. 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 [10,11]. 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 [12].

However, the production of ADI in India is still in infant stages. Hence, in the present investigation ductile iron conforming to IS7500/7 grade was produced and austempered for the best conditions hence, in the present research investigation different experimentation was done for evaluation of mechanical properties, and wear properties for different loads and speed level [1,2].

II. EXPERIMENTAL DETAILS

A. 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 [3,4].

B. 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].

C. 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 [7] 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.

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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 (as-cast or heat treated) [8,9].

D. Corrosion test:

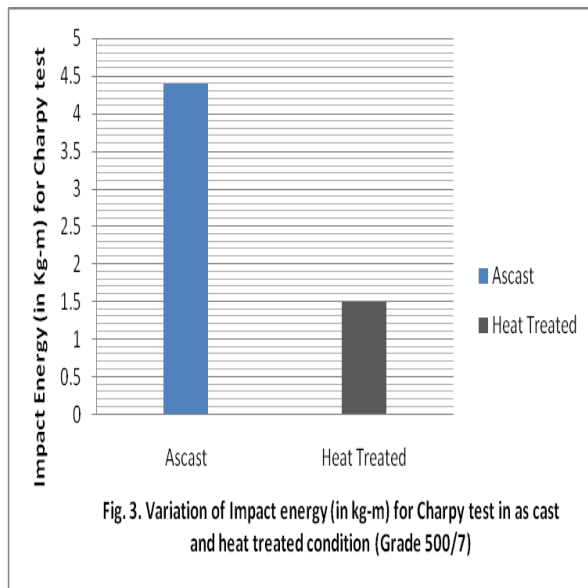
Corrosion studies carried out using standard salt spray fog type corrosion testing apparatus conforming to ASTM standard B117 specification. The corrosion rate of the specimen was calculated using the formula.

$$\text{Corrosion rate (mpy)} = \frac{534 \times w}{d \cdot a \cdot t}$$

Where

w = Weight loss in mg,

d = Density of the specimen in gm/cc,



a = Area in square mm,

t = Exposure time in hours.

Also, weight loss method was used to assess the corrosion of the specimen[15].

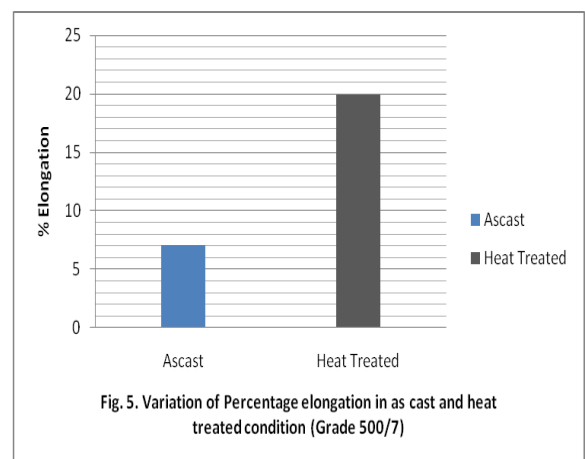
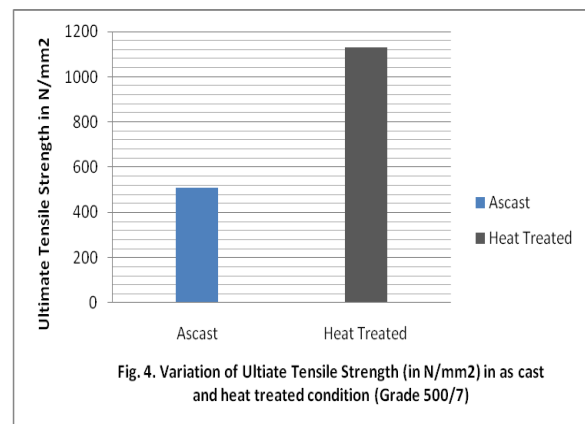
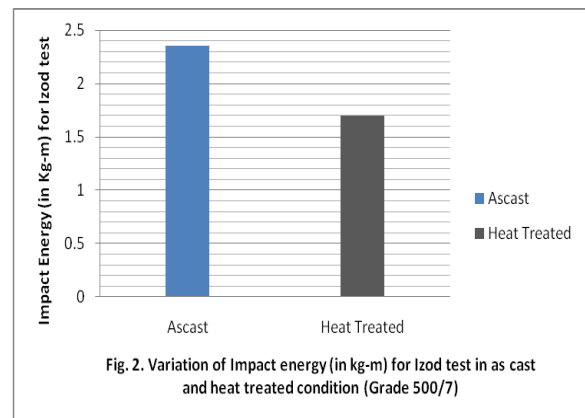
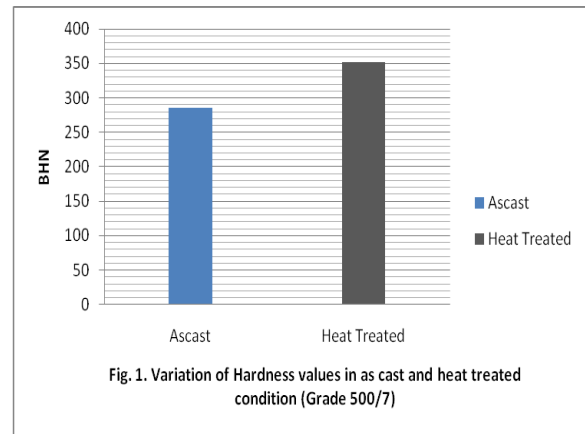
III. RESULTS AND DISCUSSION

A. Mechanical Properties:

The variation of Ultimate Tensile Strength, % 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 are higher than the as cast 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)	285	352	19.03
Impact Energy values (kg-m), Izod test	2.35	1.7	27.65
Impact Energy values(kg-m), Charpy test	4.4	1.5	65.90
UTS (N/mm2)	510	1130	54.86
% Elongation	7.1	19.9	64.32



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-1 and figure 3.

Charpy result shows that the impact energy decreases on heat treatment. But there is a tendency to show sudden drop. 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.

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 any given normal load condition. Dry sliding wear increases with increase in time of testing. Decrease in wear for heat-treated specimen, varies from 12 to 16% with respect to as cast specimen as shows in Table 2 to Table 9 and fig. 6 to fig. 13.

Table-2 Effect of speeds on dry sliding wear at constant load 300 gm in As-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	0.15	0.13
2130	0.18	0.15

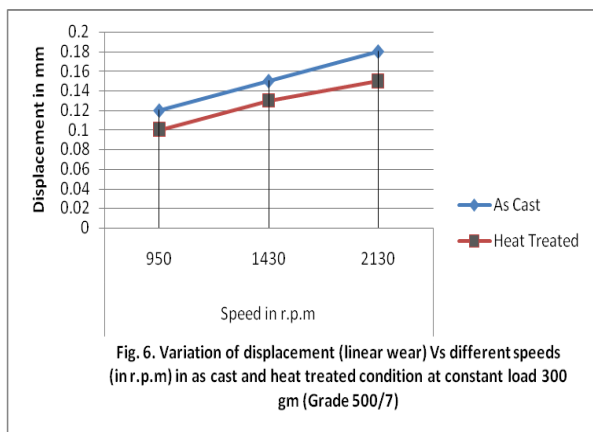


Fig. 6. Variation of displacement (linear wear) Vs different speeds (in r.p.m) in as cast and heat treated condition at constant load 300 gm (Grade 500/7)

Table-3 Effect of speeds on dry sliding wear at constant load 400 gm in As-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	0.18	0.15
1430	0.24	0.2
2130	0.3	0.28

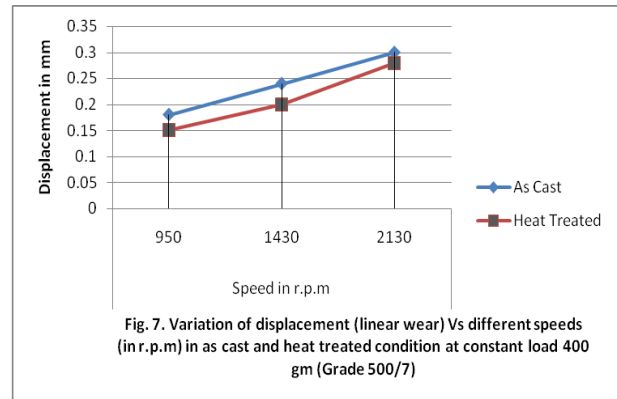


Fig. 7. Variation of displacement (linear wear) Vs different speeds (in r.p.m) in as cast and heat treated condition at constant load 400 gm (Grade 500/7)

Table-4 Effect of speeds on dry sliding wear at constant load 500 gm in As-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	0.29	0.26
1430	0.33	0.29
2130	0.38	0.35

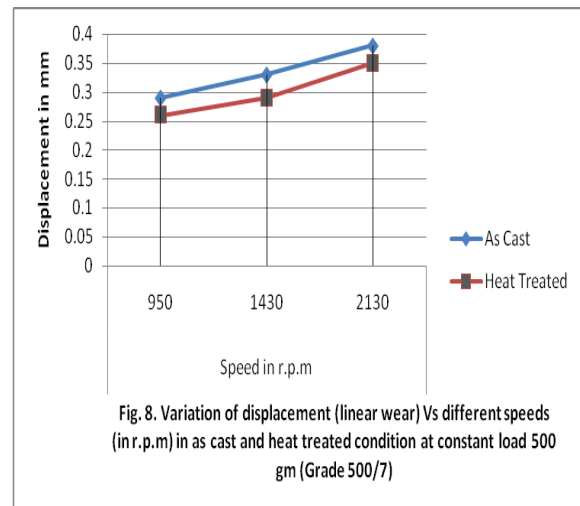


Fig. 8. Variation of displacement (linear wear) Vs different speeds (in r.p.m) in as cast and heat treated condition at constant load 500 gm (Grade 500/7)

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

Load (in gms)	Speed (in rpm)	Condition-Wear	
		Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	950	0.12	0.1
	1430	0.15	0.13
	2130	0.18	0.15
400	950	0.18	0.15
	1430	0.24	0.2
	2130	0.3	0.28
500	950	0.29	0.26
	1430	0.33	0.29
	2130	0.38	0.35

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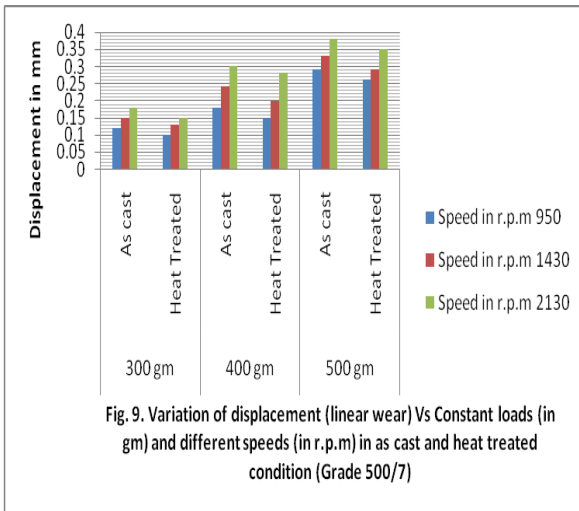


Table-6 Effect of loads on dry sliding wear at constant speed 950 r.p.m in As-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.31	0.27
400	0.35	0.32
500	0.37	0.34

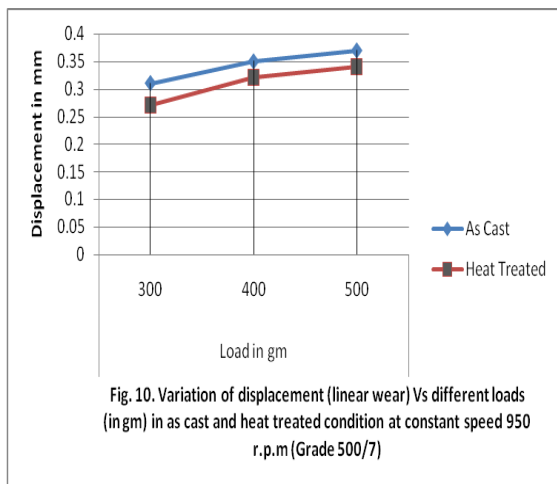


Table-7 Effect of loads on dry sliding wear at constant speed 1430 r.p.m in As-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.32	0.28
400	0.37	0.33
500	0.4	0.37

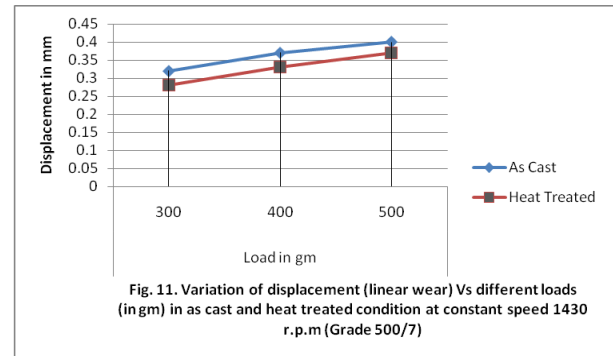


Table-8 Effect of loads on dry sliding wear at constant speed 2130 r.p.m in As-Cast and Heat – Treated condition (at the end of 20 minutes).

Loads in gm	Condition-Wear	
	Ascast, wear (in mm)	Heat Treated, Wear (in mm)
300	0.37	0.34
400	0.41	0.37
500	0.44	0.4

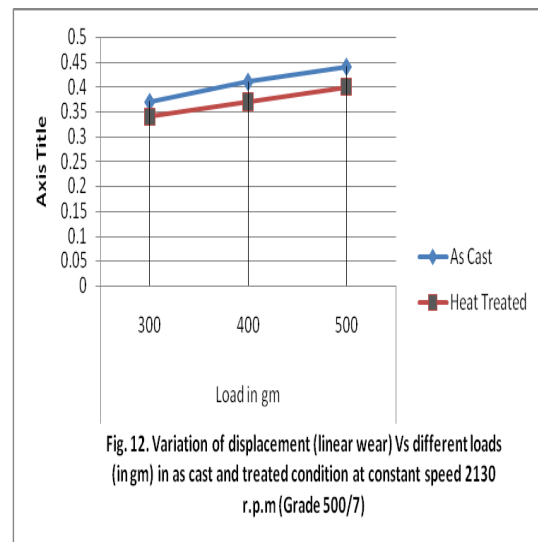


Table-9 Wear of As-Cast and Heat-Treated specimens for different loads and speeds

Speed (in rpm)	Load (in gm)	Condition-Wear	
		Ascast, wear (in mm)	Heat Treated, Wear (in mm)
950	300	0.31	0.27
	400	0.35	0.32
	500	0.37	0.34
1430	300	0.32	0.28
	400	0.37	0.33
	500	0.4	0.37
2130	300	0.37	0.34
	400	0.41	0.37
	500	0.44	0.4

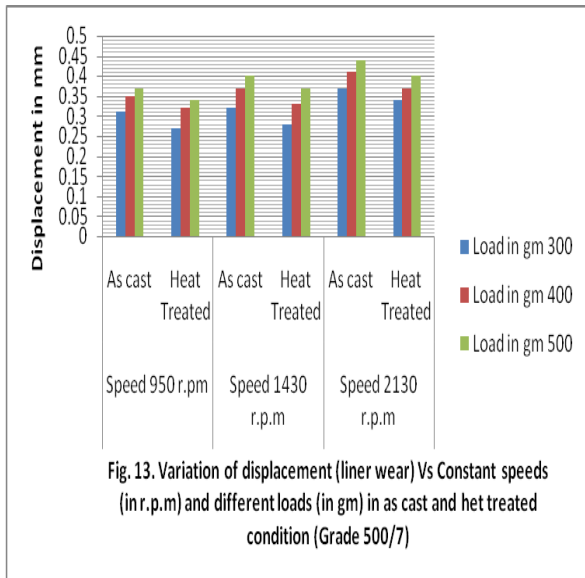


Fig. 13. Variation of displacement (liner wear) Vs Constant speeds (in r.p.m) and different loads (in gm) in as cast and heat treated condition (Grade 500/7)

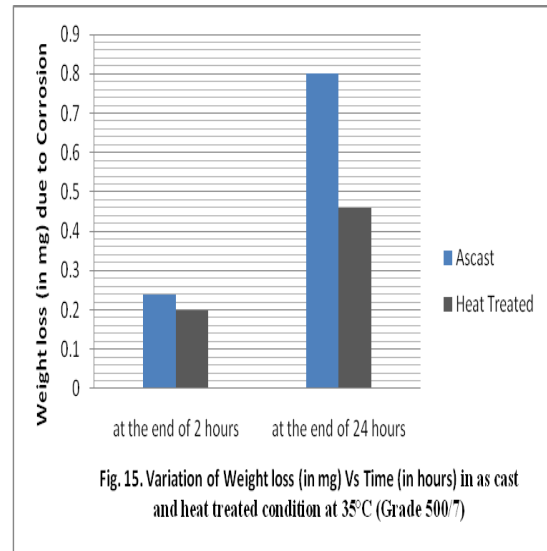


Fig. 15. Variation of Weight loss (in mg) Vs Time (in hours) in as cast and heat treated condition at 35°C (Grade 500/7)

D. Corrosion:

The variation of corrosion rate and variation of loss of weight at different temperatures conditions (i.e. 35°C & 45°C) for duration of 2 hours and 124 hours respectively were evaluated. Corrosion rate is higher for ascast specimen as compared to heat treated specimen.

Corrosion rate and weight loss of, ascast specimen is higher than heat-treated condition for any given temperature and duration. Corrosion rate decreases with increase in time of testing. Decrease in corrosion for heat-treated specimen, varies from 12.5 to 33.33% at temperature 35°C and 12.36 to 26.41% at temperature 45°C respect to ascast specimen for duration 2 hours to 24 hours as shows in Table 10, 12, 14, 15 and Figure 14, 16, 18, 19.

Weight loss decreases with increase in time of testing. Decrease in weight loss due to corrosion for heat-treated specimen varies from 16.66 to 42.50% at temperature 35°C and 3.86 to 31.14% at temperature 45°C respect to ascast specimen for duration of 2 hours to 24 hours as shown in Table 11, 13, 16, 17 and Figure 15, 17, 20, 21.

Table-10 Corrosion rate(in mpy) in ascast and Heat Treated condition at 35°C

Condition	Corrosion rate (in mpy) - Time in hours	
	Corrosion rate at the end of 2 hours	Corrosion rate at the end of 24 hours
As cast	200	60
Heat Treated	175	40

Table-11 Weight loss(in mg) due to corrosion in ascast and Heat Treated condition at 35°C

Condition	Weight Loss (in mg) - Time in hours	
	Weight loss at the end of 2 hours	Weight Loss at the end of 24 hours
As cast	0.24	0.8
Heat Treated	0.2	0.46

Table-12 Corrosion rate(in mpy) in ascast and Heat Treated condition at 45°C

Condition	Corrosion rate (in mpy) - Time in hours	
	Corrosion rate at the end of 2 ours	Corrosion rate at the end of 24 hours
As cast	542	265
Heat Treated	475	195

Table-13 Weight loss(in mg) due to corrosion in ascast and Heat Treated condition at 45°C

Condition	Weight Loss (in mg) - Time in hours	
	Weight loss at the end of 2 hours	Weight Loss at the end of 24 hours
As cast	0.52	3.5
Heat Treated	0.5	2.41

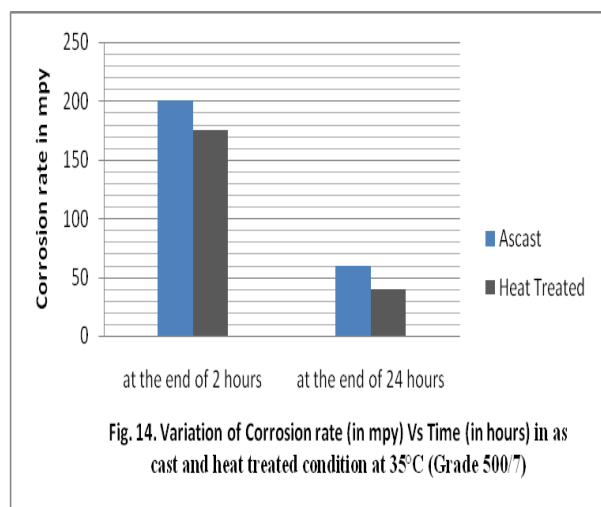


Fig. 14. Variation of Corrosion rate (in mpy) Vs Time (in hours) in as cast and heat treated condition at 35°C (Grade 500/7)

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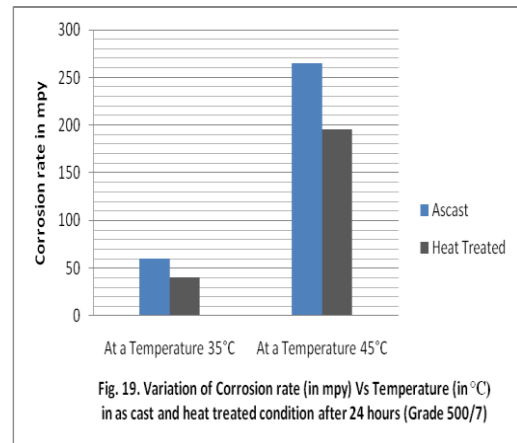
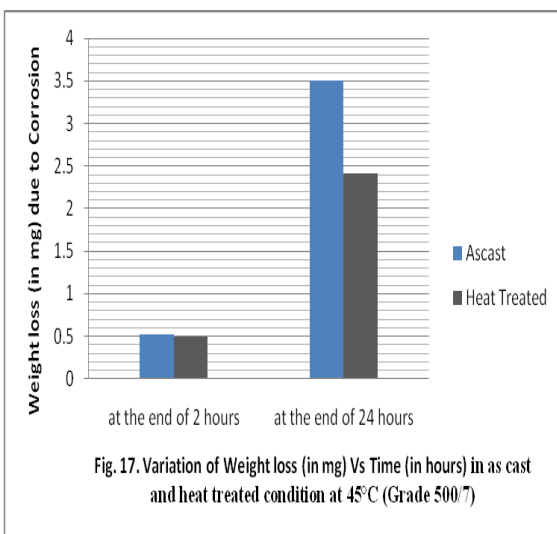
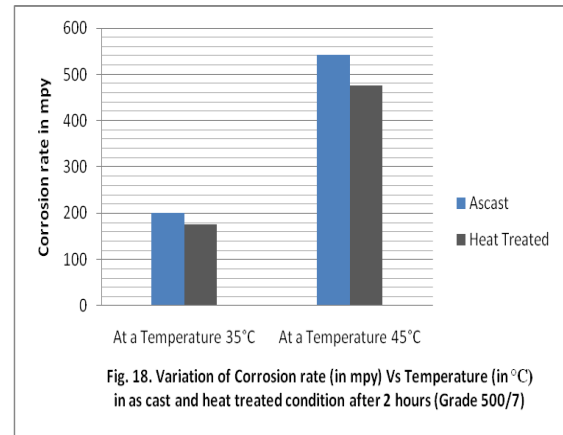
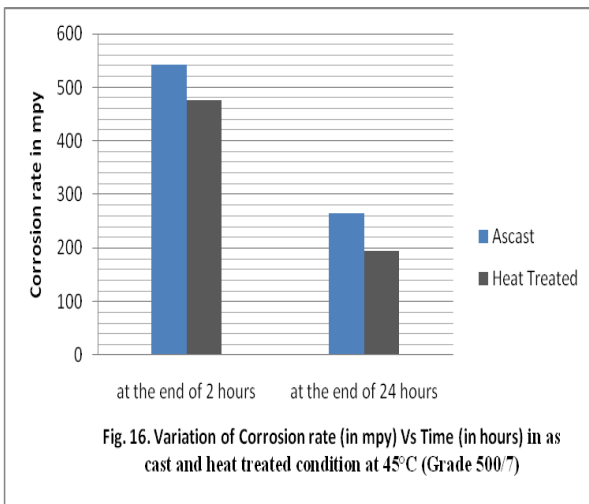


Table 16 Weight loss at a temperature 35°C and 45°C in ascast and heat treated condition for 2hours duration

Condition	Temperature in Dgree Centigrade-Weight loss (in mg)	
	At a Temperature 35°C	At a Temperature 45°C
As cast	0.24	0.52
Heat Treated	0.2	0.5

Table 14 Corrosion rate at a temperature 35°C and 45°C in ascast and heat treated condition for 2hours duration

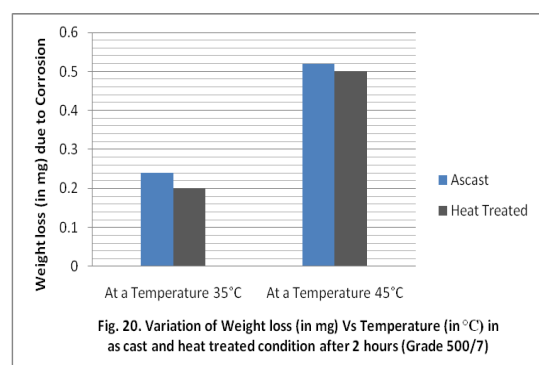
Condition	Temperature in Dgree Centigrade-Corrosion Rate (in mpy)	
	At a Temperature 35°C	At a Temperature 45°C
As cast	200	542
Heat Treated	175	475

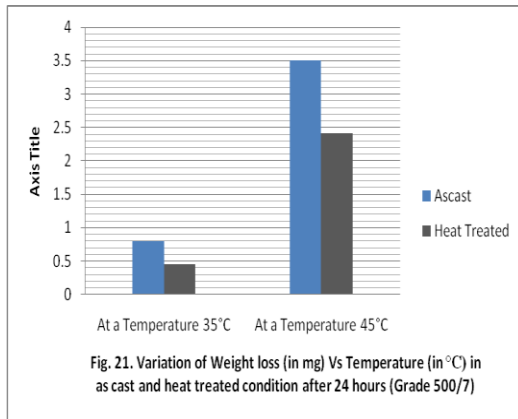
Table 17 Weight loss at a temperature 35°C and 45°C in ascast and heat treated condition for 24hours duration

Condition	Temperature in Dgree Centigrade-Weight loss (in mg)	
	At a Temperature 35°C	At a Temperature 45°C
As cast	0.8	3.5
Heat Treated	0.46	2.41

Table 15 Corrosion rate at a temperature 35°C and 45°C in ascast and heat treated condition for 24hours duration

Condition	Temperature in Dgree Centigrade-Corrosion Rate (in mpy)	
	At a Temperature 35°C	At a Temperature 45°C
As cast	60	265
Heat Treated	40	195





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 (54.86% increase), % elongation (64.32% increase) and Brinell hardness values (19.03% 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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