Effect of 2.3 Cr% and Austempering Parameters on Properties of Carbidic Austempered Ductile Iron (CADI)

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Abstract— The objective of the present research work is to improve the wear resistance by addition 2.3% of chromium in ductile iron and examined other properties of carbidic austempered Ductile Iron (CADI) with changing austempering parameters. Two variants of CADI were austenized at 975°C temperature for the period of 1hr, quenched in salt bath at 325°C austempered temperature for the period of 2hr, 4hr respectively. The hardness of these two variants is between 44 to 46 HRc. Scanning electron microscope shows images of CADI variants at 5000X magnification and microstructure images at 500X magnification. The X-Ray diffractometer graph shows the peak value of austenite, ferrite, iron carbide, chromium iron carbide. The wear resistance was evaluated in accordance with ASTMG99 standard. It concluded that CE and chromium content increases in CADI, the volume fraction of carbides is increases which attribute to wear resistance will be more.

Key words: Austempering, carbide, SEM, XRD, Hardness and wear

I. INTRODUCTION

Austempered Ductile Iron (ADI) has been long recognized for its high tensile strength (over 1600MPa for grades 5 and 1 according to ASTM A-834-95), replaced forged steel in many application. It is also well known ability of this material to perform very well under different wear mechanisms such as rolling contact fatigue, adhesion and abrasion [1][2][3].The presence of carbides in the typical matrix of Ductile Iron a new type Carbidic Ductile Iron (CDI) has been developed. Carbidic Austempered Ductile Iron (CADI) has been recently introduced in the market which containing carbides immersed in the typical ausferrite matrix.

The abrasion wear resistance is increases due to presence of carbides. The different methods for development of carbides include: As-cast carbides Internal (chemical or inverse), chill: surface chill (limited depth, directional). Mechanically introduced carbides: Cast-in, crushed MxCy carbides cast-in engineered carbides (shapes). Welded: Hard face weldment, weldment with MxCy grains [4][5].The available literature of CADI shows application examples and data about the response to abrasive wear, very few literature on the development of carbidic austempered ductile iron (CADI).

The objective of the present research work is to developed carbides in ADI with addition of 2.3Cr% and improves the wear resistance of CADI. Numbers of two CADI variants are heated to austenization temperature of 975°C for the period of 1hr and austempered by quenching in salt bath at 325°C for the period of 2hr, 4hr respectively. The results are obtained from microstructure examination, scanning electron microscope images, X-ray diffractometer analysis, hardness (Bulk & Micro) assessment, wear analysis on pin on Disc wear testing machine in accordance with ASTM G99 standard.

II. EXPERIMENTAL DETAILS

A. Sample Preparation:

The charge material is made from the steel scrap and foundry returns with addition of Fe, Cr, Ni, Cu additives. The charge was heated to a temperature of 1500°C, the molten charge was transferred into the ladle containing Ferro-silicon magnesium alloy using standard sandwich method of treatment. The molten charge inoculated with Ferro-silicon (75Wt Si %). After this addition molten charge was stirred well using a thin steel rod for about 10 seconds then poured in green sand mould cavity. Fig1, Fig.2 the square sample of 15X15X200mm is prepared by using green sand mould casting in which the mould cavity made with the help of wooden pattern having standard allowance and proper finishing. The green sand consisting of silica sand as base sand with sub angular shapes and having grain fineness number of AFS 35 to 40 was used for molding (along with bentonite and 3.4% water for molding). Sand mix was prepared using a Muller type of sand mixer. The green sand has 1050 to 1280 N/mm^2 compression strength and 115 to 135 permeability.

Alloying element %	C	Si	Mn	S	P	Cr	Cu	Ni	Ti	Mg	CE
C2	2.7	1.90	0.58	0.0092	0.0266	2.30	0.600	0.488	0.011	0.045	3.34

Table 1: Chemical Composition of as cast CDI

B. Austenization and Austempering:

The two CADI variants were austenized at temperature of 975°C for period of 1hr and austempered with quenching in salt bath at temperature of 325°C for the period of 2hr, 4hr respectively.Fig.3,after soaking duration CADI variants were taken out from the salt bath and cool to room temperature. As the retain austenite is rich in carbon content, so the Ms temperature goes below room temperature and austenite is made stable at room temperature. Fig.4, austenization and austempering were carried out in an austempering furnace.

C. Test Assessment:

As per Indian standard specification using appropriate testing facilities the following experimentation was carried out for obtaining the result of present research work.

- Chemical analysis by Spark Emission Optic Spectrometer with a DV6 Excitation Source
- Scanning Electron Microscope and Microstructure Images
- X-Ray Diffractometer analysis
- Hardness Test
- Wear test on Dry Sliding Pin On Disc as per ASTM G-99 STD

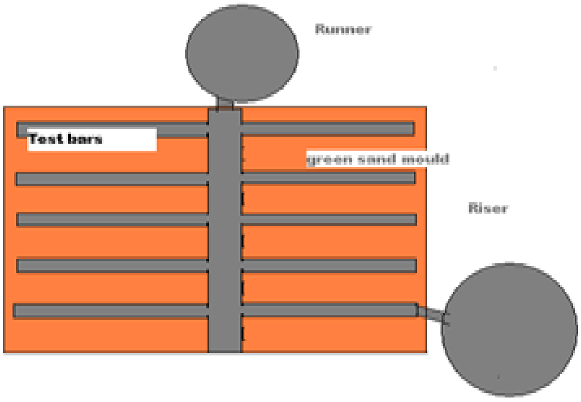


Fig. 1: Green sand mould casting

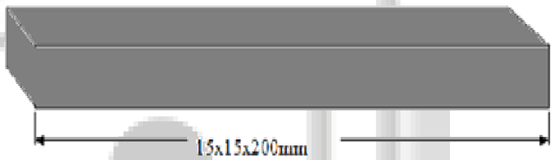


Fig. 2: Sample Test Bar

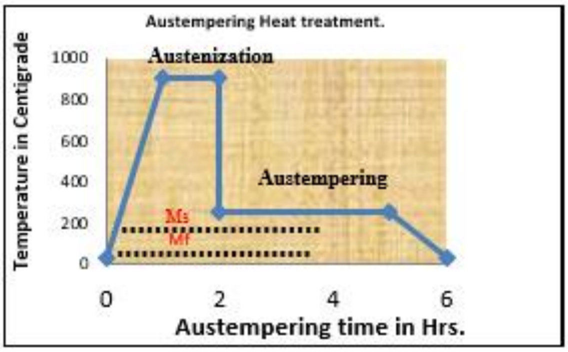


Fig. 3: Austempering cycle used for CADI" Samples

Fig. 4: Austempering Furnace

III. RESULT AND DISCUSSION

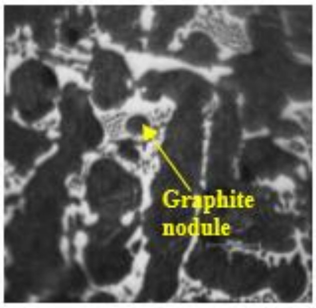
A. Chemical Composition:

The samples were cut by EDM wire cutting from the heat treated bars of CADI for metallographic investigation and mechanical assessment. The metallographic samples were prepared by using standard polishing techniques, etching with 2% Nital for optical microscopy examination. Table1, the chemical composition of as cast CDI. The Baird Spark Emission optic spectrometer with a DV6 Excitation source was used to determine the chemical composition of the casting.

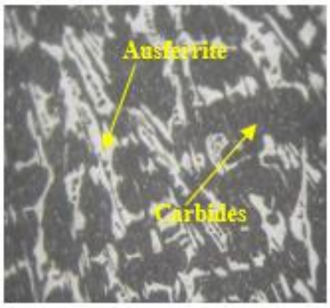
B. Microstructure and Scanning Electron Microscope Images:

Fig.5 the microstructure of as cast C2 the carbides in the lamellar net form, in between the carbide spacing the ferrite and pearlite is accumulated. Fig.6 the microstructure of C2 975°C-1 hr, 325°C-2hr, the dense portions of white phases which is of ausferrite distributed randomly in various profile and the dark portion which is of carbides. Some dense portion of lines and dots of ferrite distributed in dark portion.

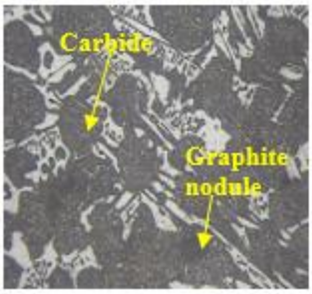
Fig.7 the microstructure of C2 975°C-1hr, 325°C-4hr, the dense portion of white phase which is of ausferrite distributed randomly in various profile and dark portion which is of carbides. The graphite nodules are present in carbide portion.



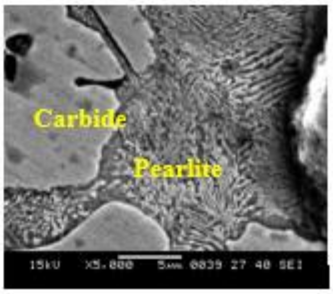
"Fig.5 Microstructure as-cast of C2 at 500X magnification"



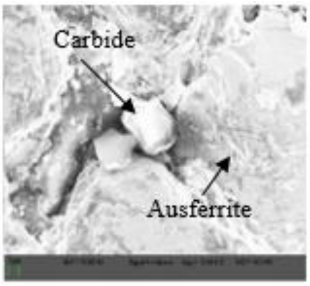
"Fig. 6 Microstructure of C2 975°C-1hr,325°C-2hr at 500X magnification"



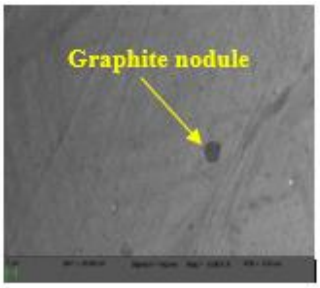
"Fig.7 Microstructure of C2 975°C-1hr, 325°C-4hr at 500X magnification"



"Fig.8 SEM of As-cast C2 at 5000X magnification"



"Fig.9 SEM image of C2 975°C-1hr, 325°C-2hr at 5000X magnification"



"Fig.10 SEM image of C2 975°C-1hr, 325°C-4hr at 5000X magnification"

Fig.8, 9, 10 SEM Is Done SCANNING ELECTRON MICROSCOPE (SEM), (JEOL 6380A), JEOL JSM-6380A Analytical Scanning Electron Microscope On CADI Variants At 5000X Magnification.

C. X-Ray Diffractometer Analysis:

XRD is done on the machine X-RAY DIFFRACTO METER (XRD) with online UPS-15KVA MODEL MAKE: PHILIPS X-PERT PAN ANLYTICAL, SUPPLIER: M/s SPECTRA TECH (P) LTD MUMBAI, on CADI sample. Fig.11, XRD of as-cast C2, the ferrite peak is at 110,211, 220 and iron carbide peaks at 022, 103 and the peak of chromium iron carbide at 600 and there is no Austenite peaks in as- cast CDI, C2. Due to alloying with Cr, the graphite nodule formation is poor [6]. Fig.12, XRD of C2 975°C-1hr, 325°C-2hr,the chromium iron carbide peaks at 420, 511, 733, 751 and iron carbide peaks at 321 and ferrite peaks at 220, 310 and matensite peaks at 103 and austenite peaks at 111. Fig.13, XRD of C2 975°C-1hr, 325°C-4hr, the Chromium iron carbide peaks at 420, 511, 751 and the iron carbide peaks at 210, 103 and the ferrite peaks at 220, 310 and austenite peaks at 200 and martensite peaks at 103.

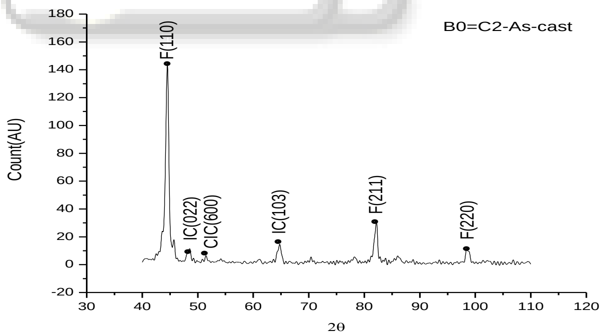


Fig. 11: XRD of as-cast C2

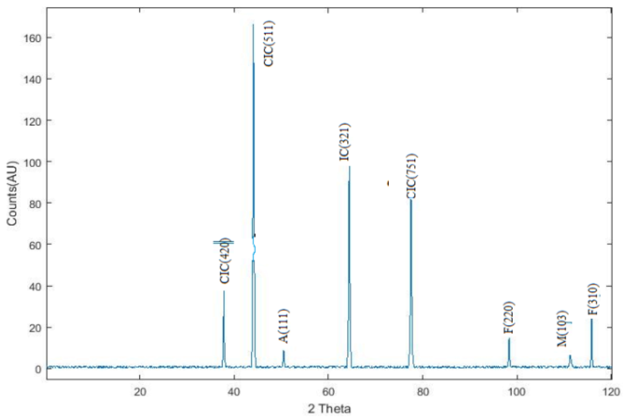


Fig. 12: XRD of C2 975°C-1hr, 325°C-2hr

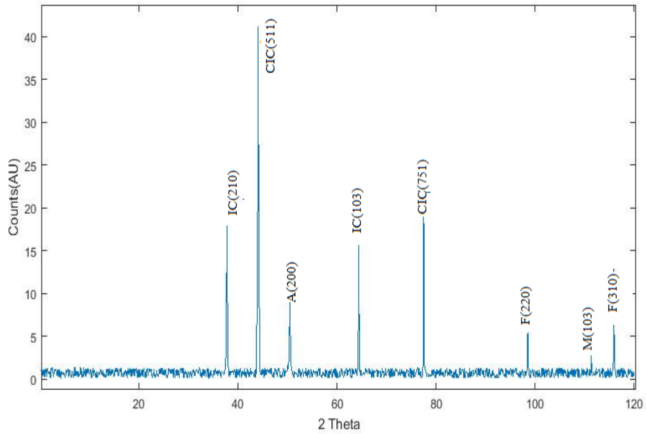


Fig. 13: XRD of C2 975°C-1hr, 325°C-4hr

D. Hardness Test:

The Rockwell (Bulk) hardness was measured at 150kg load (HRc) on C-scale. The micro hardness of the Carbides and matrix separately is measured by micro identification test were carried out by using a Vickers indenter at a 200g load (HV200) The average value of five measurements at different location across the cross sectional area was considered for the analysis. Fig.14, the Bulk hardness of as-cast C2 is 49 HRc,C2 975°C-1hr, 325°C-2hr and C2 975°C-1hr, 325°C-4hr is between 44 to 46 HRc .The reinforcing effect of carbide increases with the chromium content and the reinforcing effect of carbides on hardness was varies with the austempering temperature. The Vickers micro hardness was determined as the average of five measurements in each alloy. Carbides and ausferrite are randomly precipitated throughout the sample. Micro hardness on carbides is found around 602, 630Hv for 2hr sample and 628, 635Hv for 4hr.micro hardness on ausferrite is found around 346, 360Hv for 2hr sample and 396, 410Hv for 4hr sample.

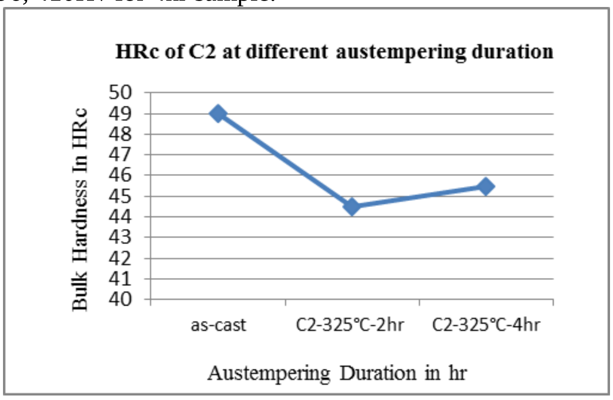


Fig.14: Bulk Hardness of as cast C2 975°C-1hr, 325°C-2hr &325°C-4hr

E. Wear Assessment:

Wear test carried on Pin on Disc wear testing machine in accordance with ASTM G-99 standard [11].Fig.15 the test on pin of 8mm diameter 40mm long and diamond coated ring having hardness of around 3000HV and width of 10mm.Table 2, the weight loss ratio of as cast C2, C2 975°C-1hr, 325°C-2hr and C2 975°C-1hr, 325°C-4hr CADI variants. According to the ASTM G-99 standard, and using the procedure A (test load 20N, distance travelled for 14325 meter, at 400rpm and track radius 57mm) .The minimum wear resistance is obtained in as cast C2 as compared to C2

325°C-4hr and C2 325°C-2hr due to the presence of more ferrite at the boundaries of carbide it gives more strength as compared to C2 325°C-4hr.

Fig. 15: The Diamond Coated Disc and Samples of CADI

Sr. No	Sample	Weight loss in g
1	As cast	0.1518
2	C2-325°C-2hr	0.0081
3	C2-325°C-4hr	0.0086

Table 2: Weight Loss in g of CADI Variants

IV. Application of CADI

The application of CADI under ideal conditions, Material handling equipments, like conveyor, chute, In power plant Ash handling equipment, cattle feed extruder, cam shaft of IC Engine, Earth mover component, soil aerator, centrifugal pump component, cylinder liner, agricultural and mining machinery [7]. Equipment bucket loader, pipes the use of a material for a new application should be evaluated through field tests, even with their associated difficulties such as higher cost, sample tracking, machine shut downs, etc. The performance of wheel loader bucket protection plates made of CADI containing 1.0 and 2.0% Cr and austempered at 300°C is currently being assessed by field tests, using a conventional

ADI also austempered at 300°C as reference material. This type of solicitation was deliberately chosen in order to get abrasive conditions different to that evaluated in the lab [7].

V. Conclusion

It is possible to obtain Carbidic ADI (CADI) with different amount of carbides using Chromium as the main alloying element. The carbide contents are obtained by alloying with Cr 2.3%. The presence of carbides in the microstructure increase the wear resistance, at the austempering stage carbon is rejected from the carbides starts nucleation of ferrite. The softness property of ferrite gives more strength to carbides hence the wear resistance was increased as compared to as cast CADI sample. The highest wear resistance was obtained for sample C4 975ºC-1h 325ºC-2h, with the chromium content (2.3%Cr) and (CE=3.34%) the austempering temperature (325ºC-2hr).The hardness of the material is relative to the wear resistance properties.

References

[1] L. Magalh˜aes, J. Seabra, ―Wear and scuffing of Austempered ductile iron gears‖, Wear 215 (1998) 237–246.
[2] R. Dommarco, I. Galarreta, H. Ortiz, P. David, G. Maglieri, ―The use of ductile iron for wheel loader bucket tips‖, Wear 249 (2001) 101–108.
[3] R. Dommarco, J. Salvande, ―Contact fatigue resistance of austempered and partially chilled ductile irons‖, Wear 254(2003) 230–236.
[4] J.R. Keough, K.L. Hayrynen, ―Carbidic austempered Ductile iron (CADI)‖, Ductile Iron News 3 (2000).
[5] K.L. Hayrynen, K.R. Brandenberg, ―Carbidi austempered ductile iron (CADI)—the new wear material‖, Am. Foundry Soc. 111 (2003) 845–850.
[6] S A Patil, S U Pathak, Ajay Likhite―development and wear analysis of carbidic austempered ductile iron (CADI) Vol. 3, Issue 2, February 2014
[7] S. Laino, J.A. Sikora, R.C. Dommarco, ―Development of wear resistant carbidic austempered ductile iron‖ (CADI) Wear 265 (2008) 1–7.

