EFFECT OF AUSTENIZING TEMPERATURE ON CHEMICAL PROPERTIES AND THE WEAR PROPERTIES OF CADI

Swapnil Turepatil[1], Dr. Sunil Patil[2], Prof. Madhavi Harne[3]

[1,2,3] Department of Mechanical Engineering, Government college of Engineering, Aurangabad, Maharashtra, (India)

ABSTRACT

By the addition of an extra phase in the matrix maily of carbides, the abrasion wear of ductile cast iron can be improved. This paper aims to produce carbides in a ductile cast iron which is subsequently austempered, to obtain the carbidicaustempered ductile iron (CADI). When the carbidic ductile iron (CDI)was heated to a austenitization temperature of 1000˚C for the period of one hour and then followed by quenching in salt bath at temperature range 325˚C for a period of two hours and four hours respectively. Then by using optical microscope the characteristics of the produced CADI were evaluated. The abrasion wear resistance was evaluated by testing in accordance with ASTM G 99 standard. Carbidic ductile iron (CDI) as-cast samples were taken as reference material to determine the relative wear resistance index E.The microstructures of carbidicaustempered ductile cast iron are affected by the heat treatment parameters which can be characterized by optical microscope, XRD and SEM.

Keywords*: *Carbidicaustempered Ductile Iron, Optical Microscope, XRD, SEM, Austempering, Microstructure, Abrasion Wear.

I. INTRODUCTION

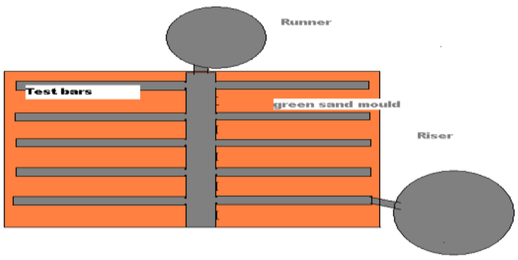
Due to high tensile strength (over 1600MPa for grades 5 and 1, according to the ASTM A-834-95), Austempered Ductile Iron (ADI) has been long recognized. Under different wear mechanism such as rolling contact fatigue, adhesion and abrasion [1],[2],[3] ADI performs very well. It has proved to behave in a different manner under abrasive conditions, depending on the tribo system (lower high stress abrasion), if proper heat treatment parameters have been selected it is always possible to obtain a good performance in wear.by immersing carbides in typical matrix, a new type of DI, called Carbidic DI or CDI has been developed. A new type of CDI, containing carbides immersed in the typical ausferriticmatrix, called carbidic ADI or CADI has been recently introduced in the market. It is expected to promote increase in abrasion wear resistance due to presence of carbides, but on other hand toughness is expected to decrease. There is no such procedure for formation of CADI but available literature of CADIshows only application examples and data about the response to abrasive wear.CADI is a ductile cast iron containing carbides, (that are induced either thermally or mechanically), that is subsequently austempered to produce an ausferritic matrix with an engineered amount of carbides. Methods of carbide introductioninclude: As-Cast Carbides: Internal (chemical or inverse) chill:

Surface chill (limited depth, directional). MechanicallyIntroduced Carbides: Cast-in, crushed MxCy carbides; Cast-in, engineered carbides (shapes).Welded: Hard faceWeldment; Weldment with MxCy grains.[4],[5]. The presence of carbides promotes an increase in the abrasion wear resistance. The development of this material is possible; if heat treatment parameters, microstructure is controlled properly in order to obtain the maximum abrasion resistance. The objective of this work is to produce two variants of CADI, studying their microstructural characteristics and evaluating the abrasion resistance.

II. EXPERIMENTAL PROCEDURE

2.1 Material and Sample Preparation

The details of the pattern used in the present experiment is shown in figure 1(a) which was made from wooden with standard allowances with proper finishing, then by using the prepared wooden pattern a mold is prepared in the specified sand in the mold box then after removing the pattern from sand and drying the mold and removing the loose sand from mold, then the mold is finished and the mold is ready to pour the molten metal in it, thus the standard square casting of 15x15x200mm long, were produced in the green sand mold table1 gives the chemical composition of the carbidic ductile iron. Figure 1(a) shows the schematic diagram of the prepared sand mold used in the present investigation. The shape and dimensions of the model used to make the moulds for casting are shown in Fig. 1(a), it is of near net shape casting test bars of size 15x15x200mm. CADI samples were obtained from the same two heats alloyed with Cr after a heat treatment involving an austenitizing stage of temperature 1000°C in a muffle furnace for Tg-1h, followed by an austempering step in a salt bath at Ta-325°C during quenching time ta-2h,4h. Thus obtained test bars are sliced in 15mm long to test sample for microstructural characterization and hardness measurement. The wear samples Sliced of about 15x15x40mm long of 8mm diameter cut with EDM wire cut for as-cast, as well as for CADI wear samples preparation, CDI samples used as reference material.



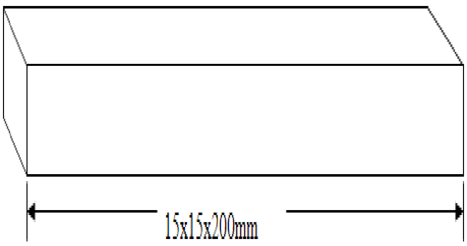


Figure 1(a). Sample Casting Green Sand Mould   Figure 1(b). Sample Test Bars

Table1. Chemical composition of As-cast CDI

Alloying element %	C	Si	Mn	S	P	Cr	Cu	Ni	Ti	Mg	CE
C4	3.6	1.9	0.64	0.0122	0.0294	4.3	0.610	0.431	0.016	0.044	4.23

2.2 Chemical and Micro structural Examination

The chemical composition of the alloys was measured by means of a spark emission optic spectrometer with a DV6excitation source. Metallographic sample preparation for optical microscopy examination was conducted by usingstandard cutting and polishing techniques, and etching with 2% Nital. The volume fraction of carbides was measuredby image analyzer. For this purpose, carbides were revealed by etching with 10% ammonium persulfate in aqueoussolution. The magnification used to obtain data from a sufficiently large area was X20.Each reported value is theaverage of four measurements.

2.3 Mechanical Tests

Rockwell hardness was measured at 150 kg load (HRC) on C-scale. A hardness profile was obtained for each alloy. Inorder to determine the hardness of the carbides and the matrix separately, micro indentation tests were carried out byusing a Vickers indenter at a 200g load (HV200). The abrasion wear resistance was evaluated by performing the ―Pinon disc Abrasion Test‖ the disc is of diamond ring having hardness of around 3000Hv and width of 10mm. Accordingto the ASTM G-99 standard, and using the procedure A (test load 20N, distance travelled for 14450meter, at 400rpmand track radius 58mm). The Relative Wear Resistance index, E, was obtained as the ratio between the weight lossexperienced by the Carbidic Ductile Iron (CDI) samples, used as reference material (WLR), and the CADI samples(WLS), according to Eq. (1). The weight loss values were measured by means of a 0.1 mg precision scale.

E=WLR / WLS ------ (1)

2.4 SEM of CADI Sample

SEM is done SCANNING ELECTRON MICROSCOPE (SEM),(JEOL 6380A), JEOL JSM-6380A Analytical Scanning Electron Microscope on sample at different magnification, by secondary electron and photo micrographs are presented in the result.

2.5 XRD of CADI Sample

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 with excitation sources of copper k-α at 2θ position and various peaks of ferrite, Chromium iron carbide, Iron carbide and austenite are found which are indicated in the results.

III. RESULT AND DISSCUSSIONS

3.1 Chemical and Microstructural Characterization

Microstructure in Fig.2(c) shows rare white portion is carbide traces along the grain matrix, Dark spot shows the graphite nodule, Dark portion shows Ausferrite, which is conformed through hardness values, White portion in dark phase indicate retain austenite and dark line indicate free ferrite. While microstructure in Fig.2(a) shows large amount of carbides is formed and dark portion is Ausferrite. Fig.2(b) shows microstructure in which carbides are formed in circle form with thick boundries and dark portion is Ausferrite.

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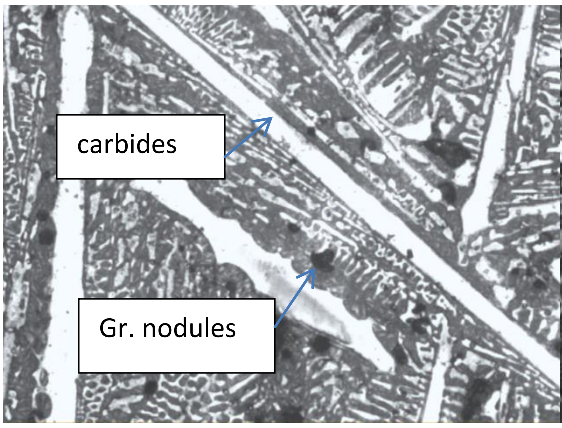

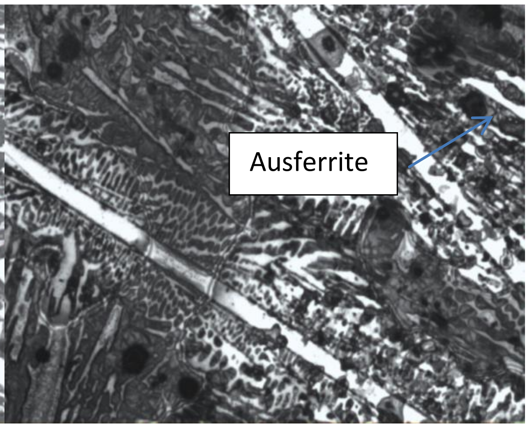

Fig 2(a) C4 1000ºC-1h 325ºC-2h-200X **Fig 2(b) C4 1000ºC-1h325ºC-4h-200X**

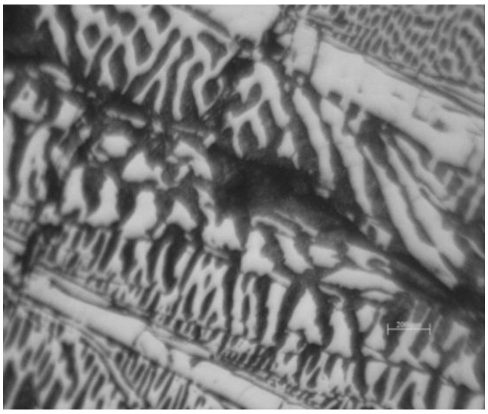

Fig 2(c) C4 900ºC-1h 325ºC-2h-500X

3.2 Mechanical Properties

3.2.1 Hardness Tests

The Rockwell hardness for 150 kg laod on C-scale was determined for samples C4-325^0c-2hr and C4-325^0c-4hr bulk hardness was determined as average of three measurements. The bulk hardness of 2 hr sample is 55 HRC and bulk hardness of 4 hr sample is 57 HRC.The results of the one austempering temperature and two quenching durations in salt bath are determined. The reinforcing effect of carbides 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 three measurements in each alloy. Carbides are randomly precipitated throughout the sample. Micro-hardness on of Carbide phase is found around 700.2HV200 to 836.2HV200 for 2 hr sample and 684.2HV200 to 753.4HV200 for 4 hr sample. From the wear resistance results, it is observed as the hardness decreased the wear increased and hardness increased the wear decreased.

3.2.2 Scanning Electron Microscope

SEM of Fig.3(a) shows more grey portion is carbides while grey portion in small pieces is austenite and dark line indicates ferrite. In Fig3(b) the amount of carbides is reduced and this carbides are induced into Ausferrite. Fig.3(c) large amount of carbides are formed and dark spot is grapfite nodules.

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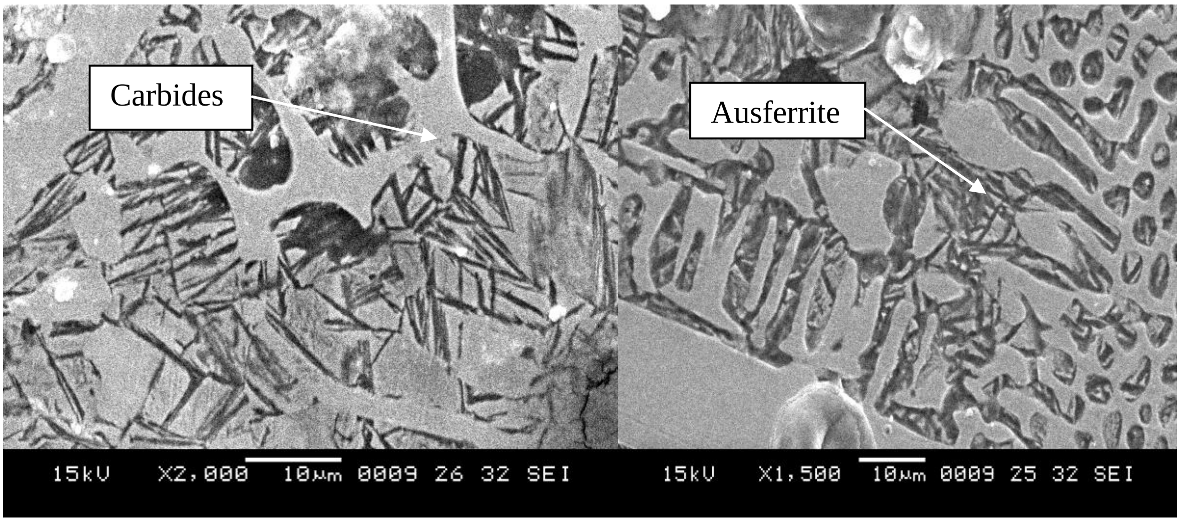


Fig 3(a) C4 1000ºC-1h 325ºC-2h-2000XFig 3(b) C4 1000ºC-1h 325ºC-4h-1500X

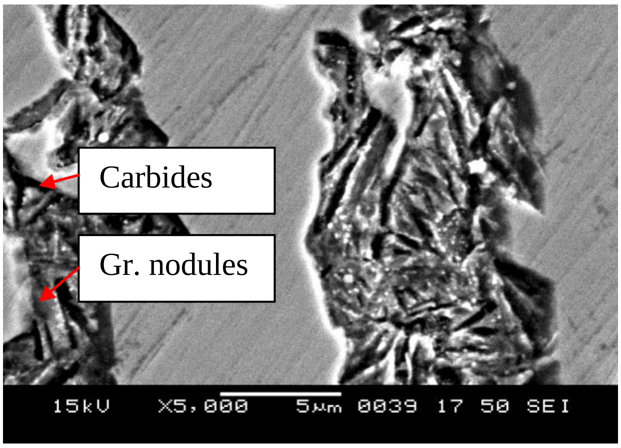
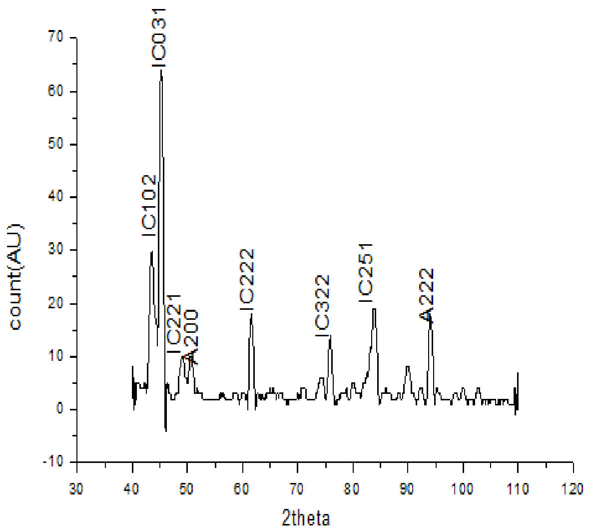


Fig 3(c) C1 900ºC-1h 325ºC-2h-5000X

3.2.3 X-Ray Differaction

XRD of Fig.4(a) shows the peak of Austenite at 200, 222. Iron carbide at 102,031, 221, 222, 322, 251. While Fig.4(b) shows the peak of iron carbide at 102,221,400,303,430 and chromium iron carbide at 531 planes. The XRD in Fig.4(c) shows that the peaks of Austenite at 111,220,311, and ferrite peaks at 110,211,220, and iron carbide peaks at 112, 600,103,662, and chromium iron carbide peaks at 600,662 plane.



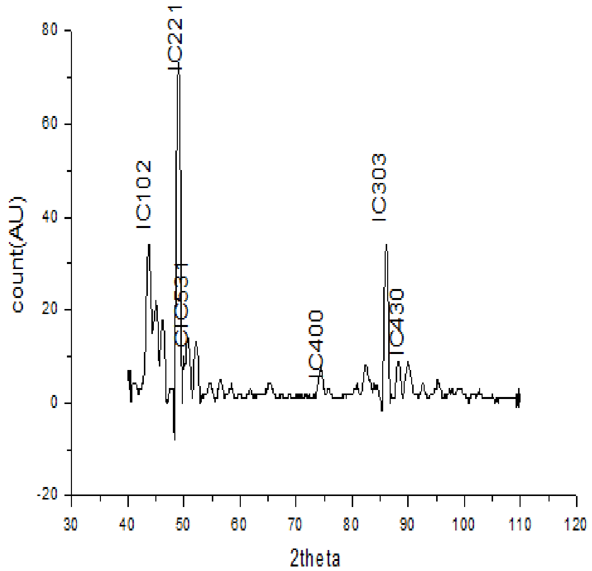


Fig 4(a) C4 1000ºC-1h 325ºC-2hFig 4(b) C4 1000ºC-1h 325ºC-4h

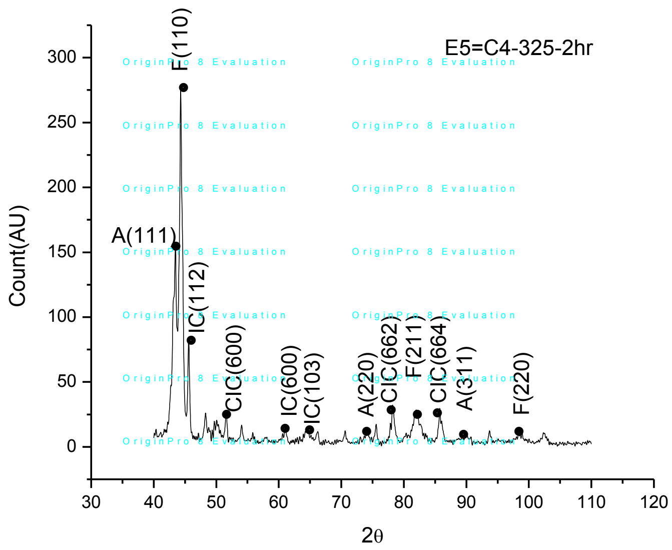


Fig 4(c) C4 900ºC-1h 325ºC-2h

3.2.4 Wear Resistance

The Pin on disc wear test is conducted in accordance with ASTM G-99 standard. The weight loss values for CADI samples measured on pin of 8mm diameter 40mm long and Diamond ring Disc.Weight loss is the functions of the chromium content, carbon equivalent, austempering heat treatment parameters and microstructure matrix .The Maximum wear resistance is obtained on sample C4 1000ºC-1h 325ºC-4h as its weight loss is minimum.Austempering at 325ºC-4h the reinforcement effect of carbide and ausferrite is matched to the hardness values which are higher, reported in the graph of figure 5 and accordingly the wear resistance is more, which is indicated in Table 2.

Table 2, Pin on disc Wear testing results of various CADI

Sample Name	Weight loss in gram
C4 900 °C -1h 325 °C -2h	0.052
C4 1000 °C-1h 325 °C-2h	0.078
C4 1000 °C-1h 325 °C-4h	0.013

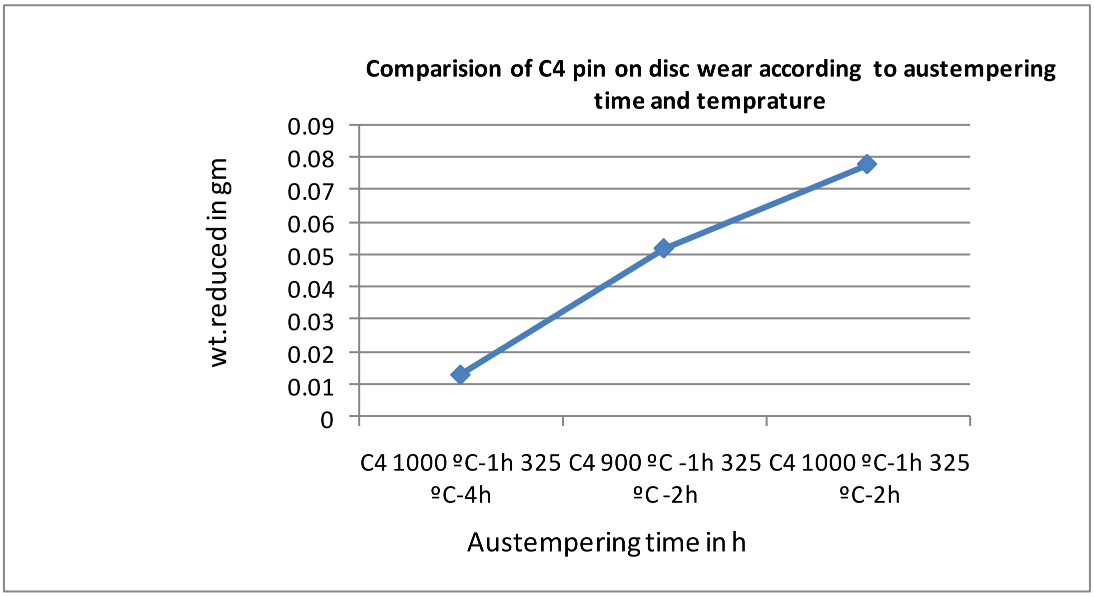


Fig.5 Wear Resistance is Maximum at C4 1000 °C-1h 325 °C-2h

IV. APPLICATIONS OF CADI IN REAL PARTS

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[13], 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 300ºC as reference material. This type of solicitation was deliberately chosen in order to get abrasive conditions different to that evaluated in the lab[13].

V. CONCLUSION

It is possible to obtain Carbidic ADI (CADI) with different amount of carbides using Cr as the main alloying element. The carbide contents are obtained by alloying with Cr between 2 and 2.5%. All most all carbide was stable during the austenitizing stage of the austempering and the amount of dissolved carbides was nil and negligible. The presence of carbides in the microstructure increase the wear resistance, after austempering the wear resistance was increased, this is due to reinforced matrix of three phase’s ferrite, ausferrite and carbides. Under the present experimental conditions in the alloys containing 2.17% Cr precipitates the thick circular form carbides significant reinforcement of the matrix with respect to abrasion. The highest wear resistance was obtained for sample C1 1000ºC-1h 325ºC-4h, with the chromium content (2.17% Cr) and CE=2.29 the austempering temperature (325ºC-4hr).

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