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EFFECT OF PROCESSING PARAMETERS ON HARDNESS AND MICROSTRUCTURE OF AUSTEMPERED DUCTILE IRON

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ABSTRACT

In the present investigation the effect of copper along with the process variables (austempering temperature and austempering time) on hardness and microstructure of ductile iron is studied. With increasing austempering time hardness is increasing but with increasing austempering temperature it is decreasing. Austempered ductile iron with copper is showing some higher hardness than the austempered ductile iron without copper. In microstructure ferrite is increasing with increasing austempering time and austenite is increasing with increasing austempering temperature in both the grades

Keywords: Austempering, austempered ductile iron, austenite, ferrite and acicular.

INTRODUCTION

A ductile iron which subjected to a peculiar isothermal heat treatment process i.e. heating to the austenitizing temperature, followed by quenching into a salt or oil bath at a temperature in the range of 445^{o}C to 200^{o}C and holding for the time required for transformation to occur at this temperature, is known as austempered ductile iron (ADI) and the process is known as austempering [1]. It consists of high carbon austenite and ferrite as a matrix, which is called as ausferrite [2-4]. Due to this structure ADI exhibits a combination of high strength, hardness, ductility, damping capacity and toughness. So this material has application in various fields like automotive, agricultural, construction, military component etc. [5-8]. The abrasive wear resistance of ADI is much superior to that of the parent ductile iron and comparable to that of a steel whose hardness is approximately twice that of ADI. So that it is considered as an alternative material for earth moving components [9].

The mechanical properties of ADI strongly depend on the Ausferrite structure .So researchers mainly concentrate for the improvement of properties by varying the processing parameters i.e. austempering temperature and austempering time and alloying with various elements like Cupper, Nikel, Molybdenum, Silicon etc [10-15].

In this present investigation, the effect of copper alloying as well as the effect of processing parameters like austmpering time and austempering temperature on hardness and microstructure of ductile iron were studied.

MATERIALS AND METHODS

Two grades of ductile iron samples have used in the experiment which are produced from commercial foundry, L&T Kansbhal. The difference between these two grades were one contains copper and another without copper. Chemical composition of the two grades of ductile iron samples are given below in the Table 1. 12 numbers of samples with dimension 8×8×3 mm of each grade have taken and heated to 900^{o}C (austenisation) for 60 min and then transferred quickly to a salt bath at austempering temperatures 250, 300 and 350 ^{o}C, held for 30 min, 60 min, 90 min and 120 min and then air- cooled to room temperature. The heat treated samples were polished for hardness measurement. Rockwell Hardness test was performed at room temperature to measure the hardness of the ADI specimens in **A** scale. The load was applied through the square shaped diamond cone indenter for few seconds during testing of all the alloyed and unalloyed samples. Four measurements for each sample were taken covering the whole surface of the specimen and averaged to get final hardness results. A load of 60 kg was applied to the specimen for 30 seconds. Then the depth of indentation was automatically recorded on a dial gauge in terms of arbitrary hardness numbers. Microstructures of the mirror polished samples were observed using Nikon Optical microscope. The samples were etched with 2% Nital solution for 45 seconds each. X-Ray diffraction (XRD) analysis was performed for few selected samples. This technique was used to estimate the volume fractions of retained austenite and ferrite in the material after treatment. XRD was performed 30 KV and 20 mA using a Cu-Kα target diffractometer. Scanning was done in angular range 2θ from 40° to 48° and 70° to 92° at a scanning speed of 1°/min.

RESULTS AND DISCUSSION

Hardness Measurement

The hardness values in Rockwell A scale (R_A) of the Copper alloyed and unalloyed samples for various austempering time and temperature are summarized in Table 2.

Fig 1, 2 & 3 show the variation of hardness with respect to the austempering time at temperature 250^{o}C, 300^{o}C &350^{o}C respectively for two grades (one with copper and another without copper). From these graphs it is observed that hardness is increasing from 30 min to 60 min but it is decreasing form 60 min to 90 min and for 90 min to 120 min hardness is almost same i.e. not showing significance difference for both the grades. Austempered ductile iron alloyed with cooper is showing little bit higher hardness than the unalloyed austempered ductile iron.

Fig 4, 5, 6 & 7 show the variation of hardness with respect to the austempering temperature for 30 min, 60 min, 90 min and 120 min respectively for both the grades (one with copper and another without copper). It is observed that hardness is decreasing with respect to the austempering temperature. i.e with increasing austmpering temperature hardness is decresing in both grades.

X-ray diffraction analysis

The XRD pattern of austempered ductile iron (with and without copper) austempered at different temperatures and different times are shown in fig 8 to 11.

In the XRD pattern it is observed that the austenite (111) peaks and ferrite (110) peaks are identified nearly in all cases. The maximum intensity of the austenite (111) peak is increasing with increasing temperature but ferrite (110) peak is increasing with increasing austempering time and decreasing with increasing temperature.

Microstructure

The microstructures of unalloyed and alloyed ductile iron samples were observed under the optical microscope and are shown in fig 12. In the microstructure it is observed that in all the samples Graphite is in spheroidal shape. Hence it is called spheroidal graphite iron (Ductile Iron). The samples which are autempered at higher temperatures having upper bainitic structure and the samples which are austempered at lower temperatures are having lower bainitic structure. It is because when the austempering temperature increasing the morphology of bainite changing from acicular to plate like. There is no significance difference between copper alloyed ductile iron and ductile iron without copper.

CONCLUSIONS

Hardness and microstructure of alloyed and unalloyed ADI were studied by means of Rockwell Hardness test, optical microscopy and X-ray diffraction analysis. From the study, it is concluded that:

- As the austempering temperature is increasing hardness is decreasing for both the alloyed and unalloyed ductile iron.
- As the austempering time is increasing hardness is increasing for both the grades.
- The ductile iron alloyed with copper is showing little bit higher hardness compared with unalloyed ductile iron.
- In microstructure austenite is increasing with increasing austempering temperature and ferrite is increasing with increasing austempering time in both the grades.

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Table 1 Chemical compositions of alloyed/unalloyed ductile iron

Specimen	C %	Si %	Mn %	Cr %	Ni %	Mg %	Cu %	S %	P %
Copper Alloyed	3.55	2.1	0.18	0.03	0.22	0.038	0.49	0.009	0.024
Unalloyed	3.57	2.22	0.23	0.03	0.23	0.045	0.001	0.011	0.026

Table 2 Hardness values of Unalloyed and Copper alloyed ADI in Rockwell A scale.

Austempering Temperature (^{o}C)	Time (min)	Hardness	
		Unalloyed ADI (R_A)	Copper alloyed ADI (R_A)
250	30	75	76
	60	80	82
	90	79	80
	120	78	79
300	30	69	71
	60	73	74
	90	71	72
	120	72	73
350	30	65	68
	60	69	72
	90	68	70
	120	67	69

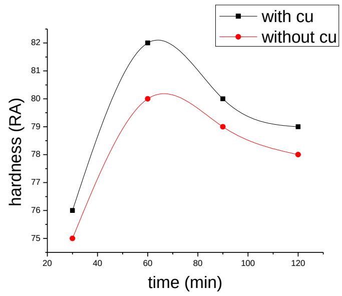

Figure 1. Variation of hardness with respect to the austempering time at temperature 250°C

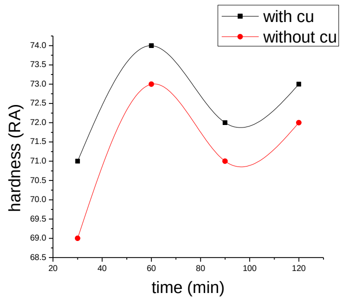

Figure 2. Variation of hardness with respect to the austempering time at temperature 300°C

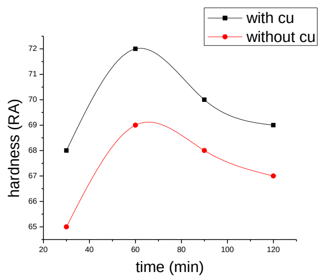

Figure 3. Variation of hardness with respect to the austempering time at temperature 350°C

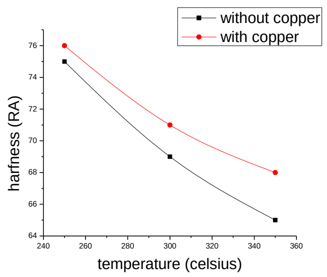

Figure 4. Variation of hardness with respect to the austempering temperature for 30 min

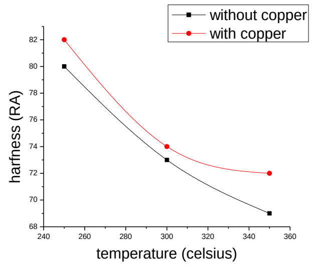

Figure 5. Variation of hardness with respect to the austempering temperature for 60 min.

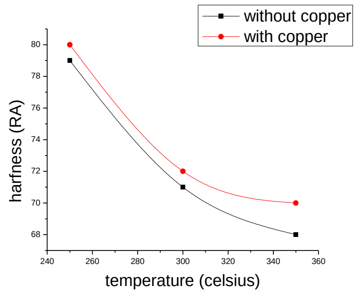

Figure 6. Variation of hardness with respect to the austempering temperature for 90 min

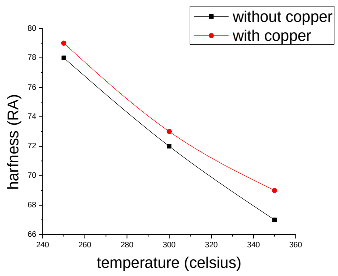

Figure 7. Variation of hardness with respect to the austempering temperature for 120 min.

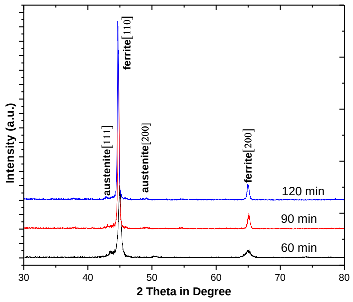

Figure 8. XRD pattern of unalloyed ductile iron austempered at 250°C.

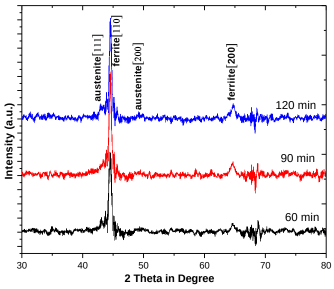

Figure 9. XRD pattern of Cu alloyed ductile iron austempered at 250°C.

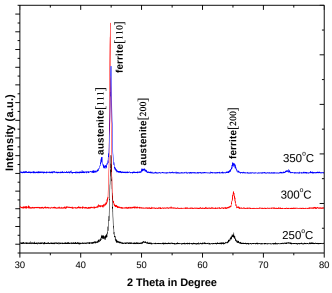

Figure 10. XRD pattern of unalloyed ductile iron austempered for 60 min.

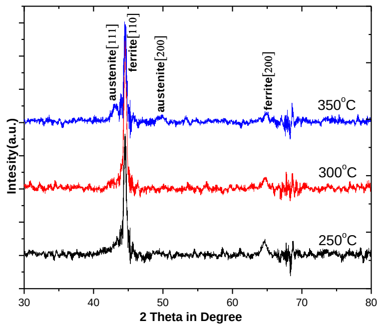

Figure 11. XRD pattern of Cu alloyed ductile iron austempered for 60 min.

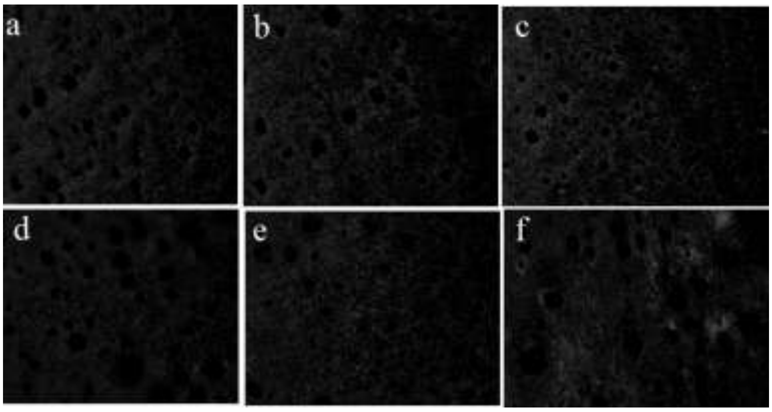

Figure 12. Microstructure of the autsmpered ductile iron (without copper) austempered for 60 min at (a) 250°C (b) 300°C (c) 350°C & autsmpered ductile iron (with copper) austempered for 60 min at (d) 250°C (b) 300°C (c) 350°C.