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THE EFFECT OF AUSTEMPERING HEAT TREATMENT PROCESS ON THE CORROSION RESISTANCE OF DUCTILE IRON

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ABSTRACT

Austempering heat treatment process has great effects on ductile iron which turn it to a material whose uses are increasing widely.

In the current study, austempering heat treatment process was carried out on ductile iron using different parameters and for each case of austempering, the effect of the austempering on both the resulted microstructures and the corrosion resistance of the ductile iron was investigated. This was carried out to find the effect of different austenitizing parameters on the corrosion resistance of austempered ductile iron and to determine the optimum austempering parameters to be used to increase the corrosion resistance of ductile iron.

KEYWORDS

ADI, Austempered Ductile Iron, Corrosion, Austempering, Austenitizing.

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1. INTRODUCTION AND REVIEW

The development of ***A***ustempered ***D***uctile ***I***ron (*ADI*) has provided the design engineers with a new group of cast ferrous materials which offers the exceptional combination of mechanical properties equivalent to cast and forged steels and production costs similar to those of conventional ductile cast iron. In addition ADI provides a wide range of mechanical properties therefore, it can be considered to be not a single material but a group of materials whose properties can be adjusted to suit a specific application. ADI is used in many applications such as gears and crank shafts in automotive industries; it can also be used in the manufacturing of valve bodies, compressor housings, pipes, impellers, hydraulic cylinders, and much more. The current study is concerned with the corrosion resistance of ADI which is important in some of the previously mentioned applications. The microstructure of ADI consists of ferrite sheaves, graphite nodules, and retained austenite, the ferrite sheaves and retained austenite are called ausferrite [1]. The austempering process is conducted in two stages: austenitizing and austempering (figure 1). Figure 2 shows the time – temperature – transformation diagram (T.T.T.) for ductile iron and the arrows on the diagram shows the procedures of the austempering heat treatment process.

The microstructure of ADI is affected by the austempering heat treatment process, which is conducted through two stages austenitizing and austempering. The austenitizing parameters (temperature and time) and the austempering parameters (temperature and time) have a great effect on the microstructure of ADI. Lin et al [2] noticed that the changing in austempering parameters causes change in the microstructure of the ADI. As can be seen from figure 3, the microstructure of ductile iron has been greatly changed after performing austempering heat treatment process on it.

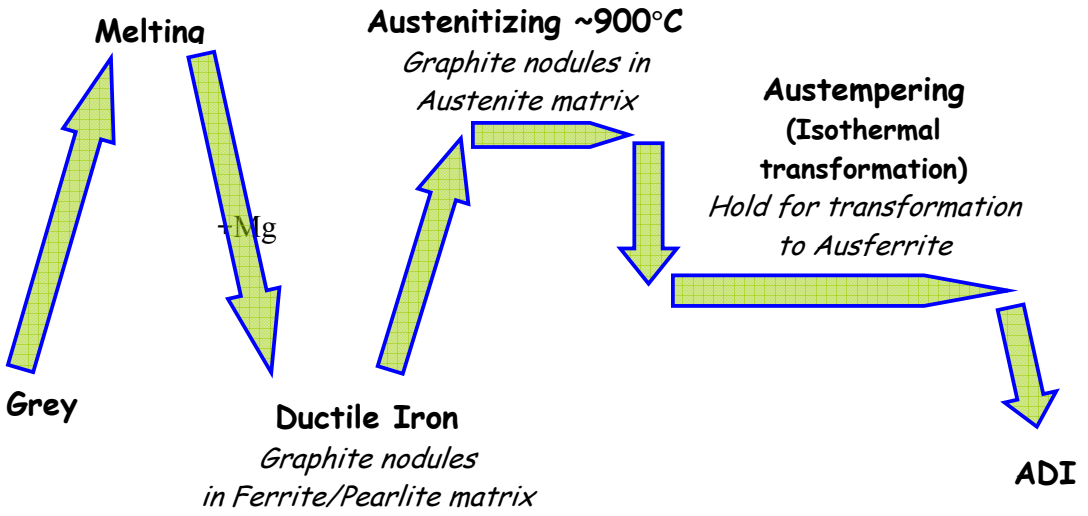


Fig. 1 Production of ADI

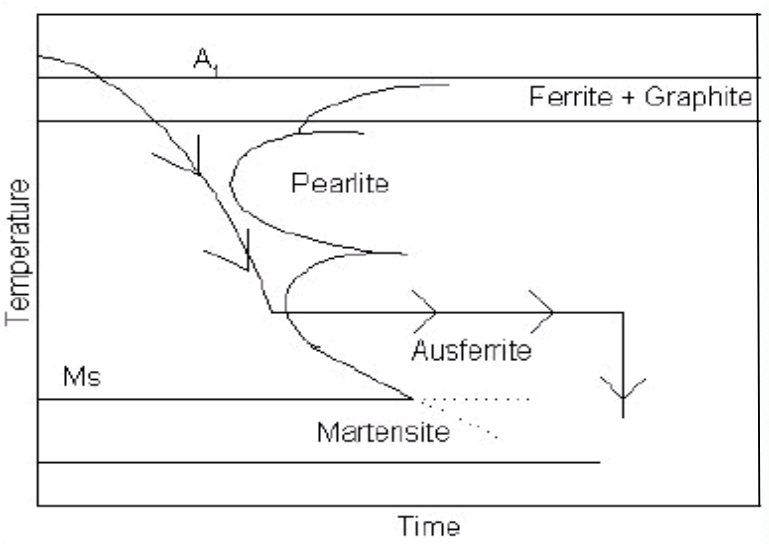
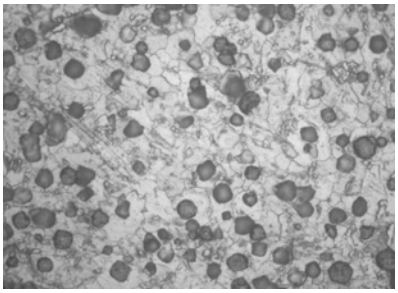
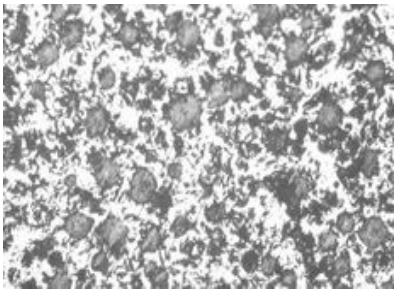


Fig. 2 T.T.T. Diagram representing Austempering process



Ductile iron without heat treatment



ADI after heat treatment

Fig. 3 Microstructres of ductile iron before and after austempering heat treatment process

2. EXPERIMENTAL WORK AND SETUP

In this research austempering process is applied to ductile iron of the chemical composition shown in table 1, the steps of the austempering process is austenitizing at 900°C for 0, 30, 60, and 90 minutes to obtain different degrees of saturation of the austenite with carbon, then austempering is carried out in lead bath at 350°C which is above the martensite transformation temperature for 2 hours which is sufficient to produce a matrix of acicular ferrite and retained stable austenite [4], (table 2).

Table 1 The chemical composition of the ductile iron used in the experiments

C %	Si %	Mg %	P %	S %	Mn %	Mo %	Ni %	Cu %
3.355	2.477	0.0258	0.0325	0.0034	0.327	0.0017	0.0025	0.0075

Table 2 The parameters of the used austempering heat treatment process

Austenetizing temperature	***Austenetizing time after the first 10 minutes to get the samples to uniform tempertaure***
900°C	0 minutes
	30 minutes
	60 minutes
	90 minutes
The heat treatment was conducted at austempering temperature of 350°C for 2 hours. Then cooled in air to room temperature	

The effect of the different austenitizing parameters on the microstructure of ADI is then investigated.

The specimens were of dimensions 20 mm x 20 mm x 50 mm. And the corrosion behaviour of the specimens is determined using acidic medium (0.1 M sulphuric acid solution) at room temperature and using spectrophotometry to measure the corrosion rate of austempered ductile iron. An indicator solution was prepared by adding 20 gm tartaric acid and 22.5 ml trioglycolic acid to 150 ml concentrated ammonia solution in 500 ml flask.

A standard stock solution was also prepared to be a reference for measurements. This solution was prepared from 100 mg $FeSO_4$ added to 1 ml Hydrochloric acid in 100 ml flask. Then the absorbency of the solution was measured at 535 nm wavelength as shown in table 3.

Table 3 Results from the standard solution

Amount of solution	**Concentration**
0.5 ml stock solution+10 ml indicator solution in 25ml flask then diluted with water	20 ppm
1 ml stock solution +10 ml indicator solution in 25ml flask then diluted with water	40 ppm
1.5 ml stock solution+10ml indicator solution in 25ml flask then diluted with water	60 ppm
2 ml stock solution+10ml indicator solution in 25ml flask then diluted with water	80 ppm
2.5 ml stock solution+10ml indicator solution in 25ml flask then diluted with water	100 ppm
3 ml stock solution+10ml indicator solution in 25ml flask then diluted with water	120 ppm
5 ml stock solution+10ml indicator solution in 25ml flask then diluted with water	200 ppm

The relationship between the concentration and the absorbency was plotted and the concentration Fe^{3+} was found from the standard curve and taken as a measure of the corrosion rate. During experiments, visible spectra were achieved using visible molecular absorption spectrophotometer. The dissolved Fe^{3+} obtained from the immersion of ADI specimens in the solution has been determined using visible spectra. This has been achieved by adding 1 ml of the solution in 20 ml flask and 1 ml indicator every 2 minutes. Reacting trioglycolic acid reagent with iron ions in alkaline medium produces a black colour. Then the determination of the amount of the dissolved iron as a function of time was performed using the spectrophotometric measurements and the previously drawn reference curve. Since the amount of dissolution of iron depends on the surface area of the immersed metal and the immersion time, the amount of corrosion is given with respect to the surface area and the immersion time (ppm/cm^2.min).

3. RESULTS AND DISCUSSION

The following figure presents the calibration (reference) curve of the used solution.

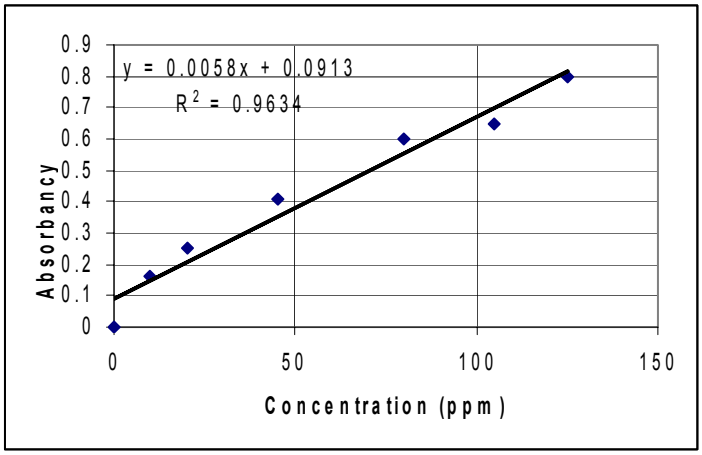


Fig. 4 The calibration (reference) curve for $FeSO_4$ solution

Figure 5 to figure 8 represent the relationship between the immersion time and the amount of Fe^{3+} ions.

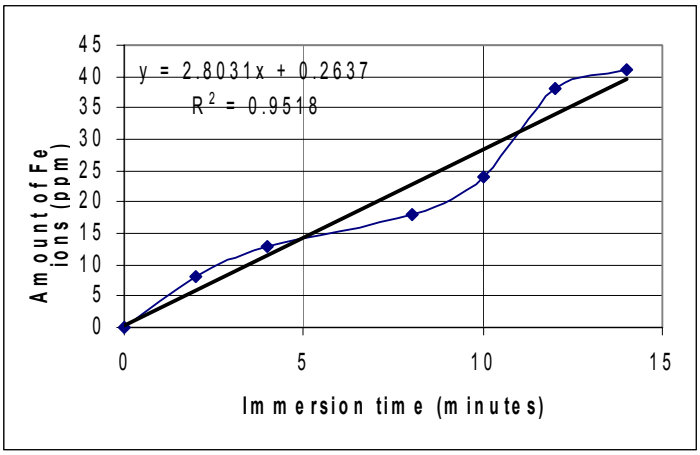


Fig. 5 The relationship between immersion time and amount of Fe3+ ions (ppm) for austenitizing temperature 900°C and austenitizing time 0 minutes

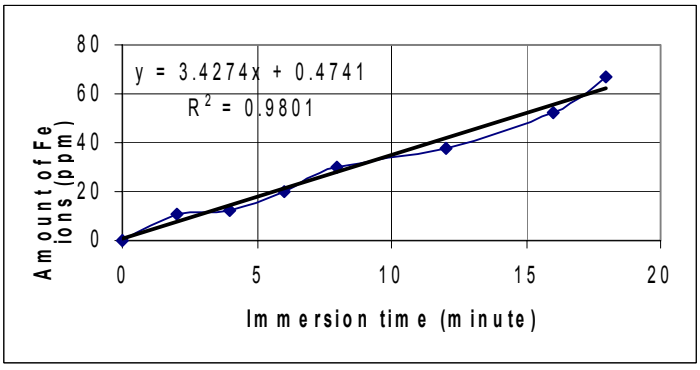


Fig. 6 The relationship between immersion time and amount of Fe3+ ions (ppm) for austenitizing temperature 900°C and austenitizing time 30 minutes

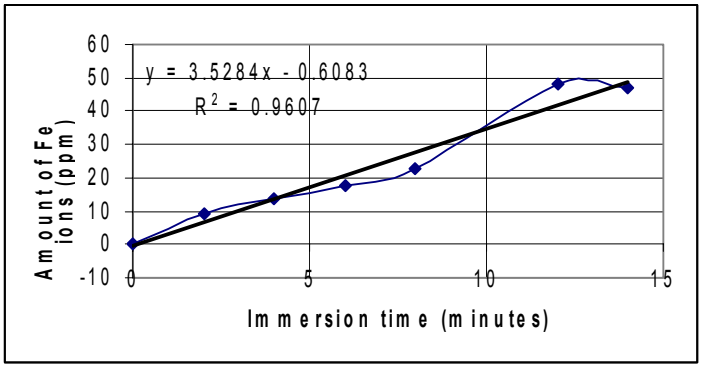


Fig. 7 The relationship between immersion time and amount of Fe3+ ions (ppm) for austenitizing temperature 900°C and austenitizing time 60 minutes

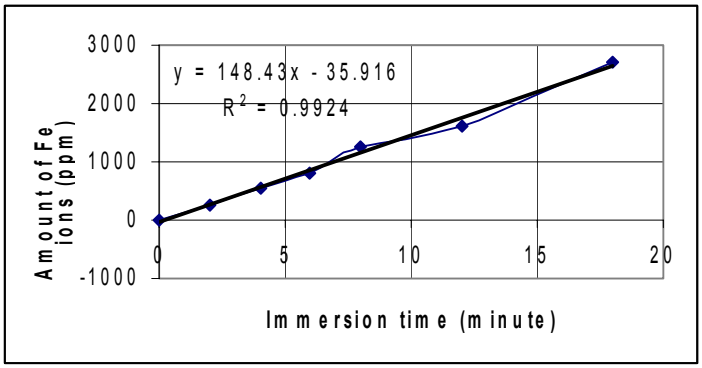


Fig. 8 The relationship between immersion time and amount of Fe3+ ions (ppm) for austenitizing temperature 900°C and austenitizing time 90 minutes

Table 4 represents the corrosion rates for the different cases of austenitizing time.

Table 4 corrosion rates for the different cases of austenitizing time.

Austenitizing time (minutes)	**Corrosion rate ($ppm/cm^2.min$)**
0	2.803
30	3.427
60	3.528
90	148.43

Fig. 9 represents the effect of the austenitizing time on the corrosion rate of **ADI.**

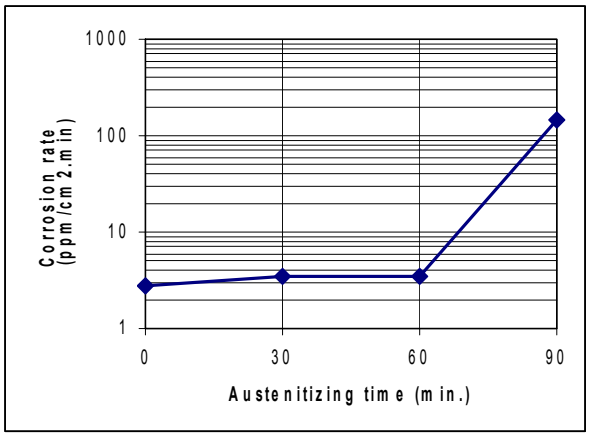


Fig. 9 the effect of the austenitizing time on the corrosion rate of ADI

From the previous results, It is obvious that as the austenitizing time increases, the corrosion rate also increases. This may be justified that as the austenitizing time increases, graphite nodules in the microstructure will get smaller in diameter and larger in count. And the austenite saturation with carbon will increase as the austenitizing time increases because the graphite will have □etallic□t time to dissolve in the austenite matrix. Therefore, for austenitizing time ranging between 0 and 60 minutes, there are few scattered large spheroidal graphite nodules. The higher resistance to corrosion in this case may be due to graphite network interfering with the reaction between the acid and the □etallic matrix. While, as the austenitizing time increases in the range from 60 to 90 minutes, the graphite nodules gets smaller in diameter and larger ing count. Therefore, the area of contact between the □etallic matrix and the corrosive media increases, and hence, the corrosion rate also increases. From that it can be concluded that as the austenitizing time dereases, the corrosion resistance increases.

4. CONCLUSIONS

Many conclusions can be deduced from the analysis of the experimental results presented in this work:

1. ADI is not a single material, but its properties can be affected greatly depending on the heat treatment parameters;
2. Corrosion rate of austempered ductile iron slightly increases as the time of austenitizing increases from 0 to 60 minutes. Then increases rapidly as the time increases from 60 to 90 minutes. Therefore, use austenitizing time of 60 minutes or less to aquire ADI of high corrosion resistance.

5. REFERENCES

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