Cairo University

ROLE OF AUSTEMPERING TREATMENT IN CONTROLLING MICROSTRUCTURE, MECHANICAL, AND CORROSION PROPERTIES OF DUCTILE IRON

By

Amina Abd El-hai Dawod korany

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Metallurgical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Role of Austempering treatment in controlling microstructure, mechanical, and corrosion properties of ductile iron

Key Words:
Ductile Iron, Austempering, Two-step ADI, Dual phase ADI, Corrosion.

Summary:
In this study, corrosion behavior of ADI in water 3.5 wt. % NaCl was investigated. The effect of different austempering treatments on microstructure, mechanical properties and corrosion characteristics was studied by using different ways. Three ways to produce ADI have been studied, where austempring is carried out with conventional austempering heat treatment, two step austempering, and dual phase ADI. This research also studied corrosion behavior of ductile and grey iron. It also studied the effect of alloying element on the corrosion properties of ADI; using Copper, and Molybdenum.

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Amina Abdel Hai Dawod

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Nomenclature

α	Ferrite.
γ_0	Original austenite.
γ_{HC}	Austenite enriched carbon.
$X\gamma$	Volume fraction of austenite
$C\gamma$	Carbon content of austenite.
ADI	Austempered ductile iron.
AF	Ausferrite.
DI	Ductile iron.
EDX	Energy dispersive x-ray analysis.
GB	Grain boundry.
GCI	Grey cast iron.
IADI	Intercritical austempered ductile iron.
PF	Proeutectoid ferrite.
RA	Retained austenite.

Abstract

In this study, corrosion behavior of ADI in water 3.5 wt. % NaCl was investigated. The effect of different austempering treatments on microstructure, mechanical properties and corrosion characteristics was studied by using different ways. Three ways to produce ADI have been studied, where austempring is carried out with conventional austempering heat treatment, two step austempering, and dual phase ADI. This research also studied corrosion behavior of ductile and grey iron. It also studied the effect of alloying element on the corrosion properties of ADI; using Copper, and Molybdenum. Conventional austempering is carried out at two different temperatures (275°C and 375°C) to study effect of austempering temperature on microstructure constituents and corrosion characteristics. Lower austempering temperature has resulted in higher tensile strength than higher austempering temperature but lower ductility.

The corrosion characteristics are investigated through potentiodynamic corrosion test. The corrosion measurements revealed that the order of irons used in this study according to corrosion resistance from highest to lowest is two-step ADI, ADI austempered at 375°C, ADI austempered at 275°C, Intercritcal ADI (IADI), ductile iron (DI), grey cast iron (GI). The excellent combination of strength and corrosion resistance is obtained in condition of two step austempering ADI; this is due to the microstructure of fine ferrite with high volume fraction of austenite.

Chapter 1: Introduction

The as-cast mechanical properties of ductile iron can be significantly improved through an austempering heat treatment. This has promoted the conception of a new member of the cast iron community, the austempered ductile iron (ADI) with its unique microstructure; spheriodal graphite in an ausferritic matrix. The excellent property combination of ADI has opened new horizons for cast iron to replace steel castings and forgings in many engineering applications with considerable cost benefits.

The properties of ductile iron combine the properties of cast iron and steel. Changing microstructure of iron can be obtained by changing the treatment conditions during melting, and also by heat-treating the castings. By modifying any of the parameters, a suitable iron according to prerequisites and application can be obtained. In order to enhance the properties of ductile iron, the material can be treated with alloying elements or can be heat-treated to achieve change in the microstructure of the material.

Usually, austempering heat treatment is carried out on ductile iron; hence the name Austempered Ductile Iron or “ADI”. ADI has been used as a part of an extensive variety of segments (1) for many engineering sectors as in gears, crankshafts, transmissions, suspensions, earth-moving and construction equipment, railways etc. (2) Interest in austempered ductile irons has increased in the past few years as more successful applications are being reported.

ADI is a range of heat treated ductile cast irons with high strength, fabulous toughness, unrivaled wear characteristics, and good fatigue properties. ADI is standout among the most cost-effective materials if strength consideration was taken. It's tensile and yield strengths are at least twice that of standard ductile irons, making ADI a good decent substitution for structural steels, especially forgings, and materials that are utilized as a part of wear applications. (3.)

Austempered ductile iron (ADI) has a matrix that is a combination of acicular (bainitic) ferrite and stabilized austenite. As the matrix structure is progressively varied from ferrite to ferrite plus pearlite to pearlite to bainite and finally to martensite, in this way varition the hardness, strength, and wear resistance would be increased, but impact toughness, ductility, and machinability would be decreased. Overall, however, these structures result in an exceptional combination of strength, ductility, and wear resistance. (4)

The mechanical properties of the austempered ductile iron depend on the ausferrite microstructure. The austempered matrix offers better ratio of strength to ductility than conceivable with any other grade of ductile iron (5), (6). Various combinations of properties can be obtained from austempered ductile iron because of the ausferrite microstructure which depends on alloyed elements and heat treatment conditions.

Chapter 2: Literature Review

2.1. Ductile Cast Iron

Since ADI is originally ductile cast iron which is subjected to austempering heat treatment so we need first to define ductile cast iron. Ductile cast iron frequently referred to as nodular or spheroidal graphite iron is a relatively member of the family of cast irons. It contains spheroidal graphite in the as cast condition, through the addition of spheroidizing agents such as cerium or magnesium to the liquid iron. (7)

It derives its name from the fact that in the as-cast structure it exhibits measurable ductility. Other types of cast iron do not exhibit this much of ductility. Based on the matrix present Spheroidal Graphite iron may be classified into different types. it can be named ferritic, pearlitic, martensitic and austenitic based on cooling rate. Depending on the cooling rate the matrix may vary from a soft ductile ferritic structure through a hard and higher strength pearlitic structure to an austenitic structure. One of the most fascinating feature of ductile iron is that the tensile elongation is as high as 17% which is not comparable to other types of cast iron (6)(8).

In ductile cast iron in which the graphite is presented as tiny spheres (nodules) (see Figure 2.1), eutectic graphite separates from the liquid iron during solidification in a way like that in which eutectic graphite separates in grey cast iron. However, because of additives presented in the liquid iron before casting, the graphite grows as spheres, instead of as flakes of any of the structures normal of grey iron. Cast iron containing spheroidal graphite is much stronger and has higher elongation than gray iron or malleable iron. It might be considered as a natural composite in which the spheroidal graphite confers interesting properties to ductile iron.

Since its development in 1948, the ductile iron (DI), which possesses excellent mechanical properties and good castability, has been widely applied in many industrial fields where the material is often exposed to erosion wear of solid particles and corrosion of acidic or alkaline solutions, such as in hydraulic valves and piping.(9)

In fact, ductile cast iron provides a wide range of mechanical properties that can be obtained either by adjusting certain processing variables or through various heat treatments which introduce different and better mix of properties for application with special requirements.