JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

The influence of Austempering conditions on tensile test of Carbidic Austempered Ductile Iron for varying heat parameters

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Abstract- Austempered ductile iron (ADI) as the name indicates is a form of ductile iron. Ductile iron differs from cast iron as it has higher strength and toughness. Cast iron is said to be having lower strength towards tensile test, whereas ductile iron has better strength towards tensile loads. Austempered ductile iron got its name as it undergoes a heat treatment process called Austempering. Many research journals speak about wear resistance of CADI materials but most of it couldn't relate how Austempering temperature affect abrasion property. Wear of a material depends on many factors depending on application environment but most of it can be categorised under time load and speed. This journal gives a detailed view of, how and to what extent these variables affect wear of CADI.

Index Terms- Austempered ductile iron, Taguchi analysis, Wear test, pin on disk wear testing machine, Anova analysis.

I. Introduction

The markets for austempered ductile iron had quickly and steadily started to increase in early 1970's. Still the industry is finding difficulties in applying this material for their products. Reason behind this is lack of reliable data for production. Since the use of appropriate temperature for Austempering and bringing desirable effects were restricted to research community, an effort is made to understand relationship between wear and heat treatment temperature. It is fair to say, this production technique is low-cost manufacturing comparing to number of mechanical advantages it imparts to the material. Austempering heat treatment brings about a microstructure called ausferrite. Adequate amount of carbon enriched austenite will impart optimal properties of ADI material.

Carbidic austempered ductile iron (CADI) is a class of ADI having higher carbon composition comparatively. CADI initially developed in United States in 2011, then after it always been a area of research and development. Most of the industries are trying to adopt CADI for their applications as it said to be indicating excellent wear resistance/ Abrasion resistance, reason behind which is proved to be the free carbides present in its molecular structure. In this journal efforts are made to understand this adage.

II. HISTORY AND PRODUCTION OF ADI

It all started in 1971, when ADI is manufactured at Czechoslovakia and used for applications such as tractor shovel and diesel engines. In 1977, a multination automotive manufacturing corporation called General Motors made effort of applicating ADI in replacement to their steel material product for automobile parts. In 1983, American multinational corporation Cummins Engineering co-operation used ADI in their automobile engines. As the global warming and other environmental effects are pushing the manufacturers to switch to high mechanical strength compared to weight materials.

A. What is CADI (Carbidic Austempered Ductile Iron)?

Carbidic Austempered Ductile iron as name indicates, it's a form of ductile iron which has high amount of carbides. CADI can be produced by Austempering ductile cast iron.

B. What is Austempering?

Austempering in simple words is a heat treatment process for cast iron and its family of materials. During this heat treatment process microstructure of material changes due to which it imparts superior performance to weight ratio.

III. CHEMICAL COMPOSITION

Usually, ductile cast iron is composed of 95% of iron, 3.2 to 3.6% of carbon and other element in decimal percentages. For our experiment we casted our material with following composition.

Element	%Composition
Iron	95.90%
Carbon	3.58%
Manganese	0.31%
Chromium	0.10%
Phosphorus	0.01%
Silicon	0.02%
Copper	0.06%
Nitrogen	0.02%
Molybdenum	0.01%
Magnesium	0.03%

Table: Element composition

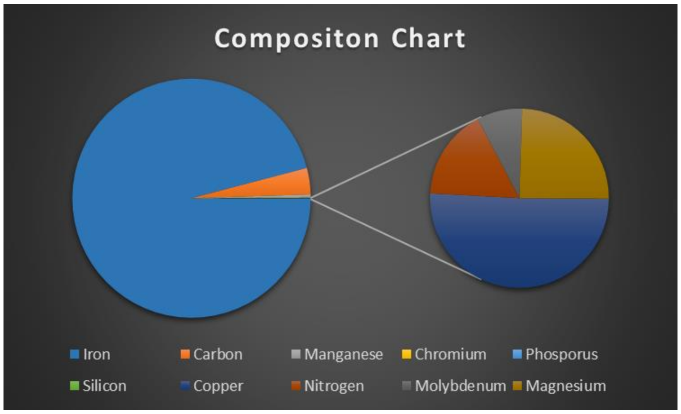
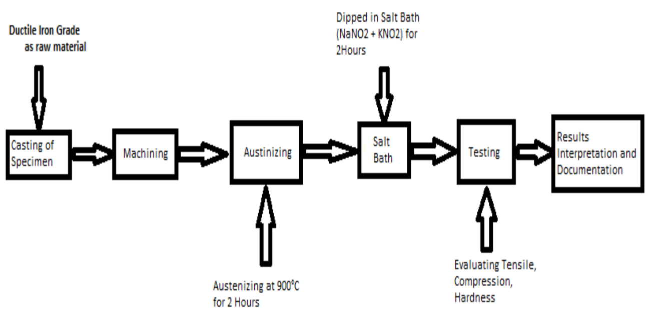


Fig: Composition Chart

Ductile iron is alloyed with Manganese which combines with sulphur to prevent brittleness. Also, Manganese allows quenching of steel in Oil rather than water, which avoids distortion and cracks. Manganese and Molybdenum. Increases the hardenability of steel. Chromium increases toughness and wear resistance. Whereas silicon increases ferrite strength.

METHODOLOGY



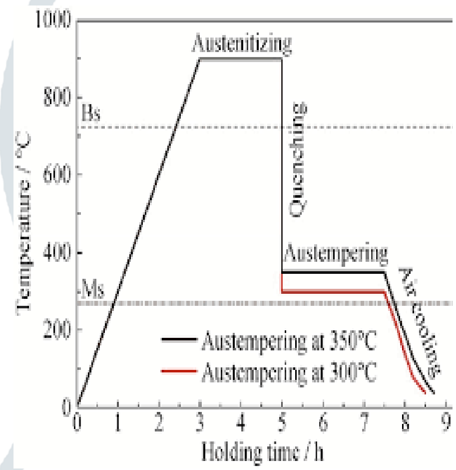
Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as casting, which is ejected or

broken out of the mold to complete the process. Casting materials are usually metals or various time setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Heavy equipment like machine tool beds, ships' propellers, etc. can be cast easily in the required size, rather than fabricating by joining several small pieces.

Machining is a process in which a material is cut to a desired final shape and size by a controlled material-removal process. The processes that have this common theme are collectively called subtractive

manufacturing in distinction from additive manufacturing, which uses controlled addition of material. Exactly what the "controlled" part of the definition implies can vary, but it usually implies the use of machine tools.

Heat treating is a group of industrial, thermal and metalworking processes used to alter the physical, and sometimes chemical, properties of a material. The most common application is metallurgical.



Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve the desired result such as hardening or softening of a material. Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering, carburizing,,normalizing and quenching.

- Austenitizing is one of the heat treatment processes of steel and other ferrous alloys where these materials are heated above their critical temperatures long enough for transformations to take place
- Austempering is a heat treating process for medium-to-high carbon ferrous metals which produces a metallurgical structure called bainite. It is used to increase strength, toughness, and reduce distortion.
- In salt bath quenching, a product is heated in a tank filled with this salt solution and then quenched in the low temperature salt solution. Because the salt solution touches the subject directly during the cooling, uneven cooling is difficult to occur

IV. RESEARCH ELABORATION

The material procured as per mentioned composition is then proceeded for heat treatment phase. To obtain austempered ductile iron, we have to follow three major steps in heat treatment. They are Austenitising, Quenching and Austempering.

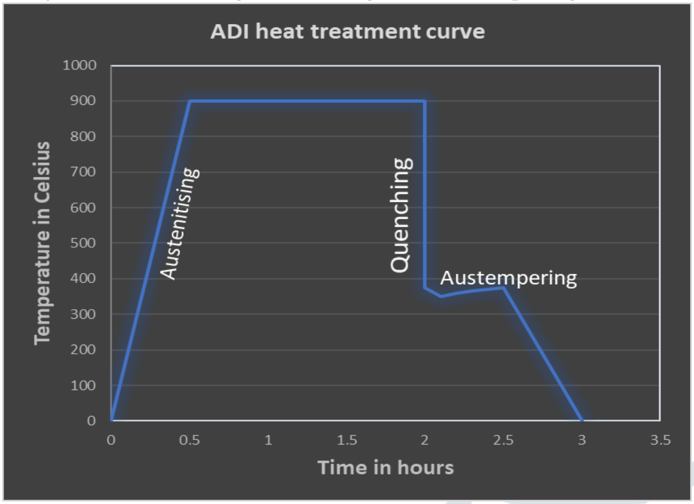


Fig: ADI heat treatment diagram

Our materials are divided into three sections. All three sections had same Austenitising temperature of 900ºC with Austenitising time of 120mins. But each section had different Austempering temperature and time as tabulated below.

Temperature no	Temperature (Celsius)	Time (minutes)
T1	375ºC	30
T2	400ºC	60
T3	425ºC	90

Table: Austempering temperature and time

For any transformation to take place, the microstructure of the metal must be austenite structure. To reach austenite microstructure temperature generally recommended is in-between 790– 915ºC, below which phase transformation is pretty much useless. So, we preferred 900ºC as austenitising temperature and by differing Austempering temperature and time, we could produce variety of microstructural scales. This research will help us understand, how mechanical performance changes with this microstructure.

A. Use of Potassium nitrate (KNO3) and Sodium nitrate (NaNO3) salt for quenching

Quenching is nothing but rapid cooling of high temperature metal by immersing it in water or oil. Through this we control mechanical properties associated with a crystalline structure or phase distribution that would be lost upon slow cooling. This process decides the crystalline structure and through Heat treatment quenching salts chosen based on their working temperature range and melting point.

After heat treatment process, specimens are ready to undergo tensiler test.

The objective of the study is to –it is used to find out how strong a material is and also how much it can be stretched before it breaks. This test method is used to determine yield strength, ultimate tensile strength, ductility, strain hardening characteristics, Young's modulus and Poisson's ratio

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Fig: Mts Servo Hydraulic Test System-250kn *Machine*

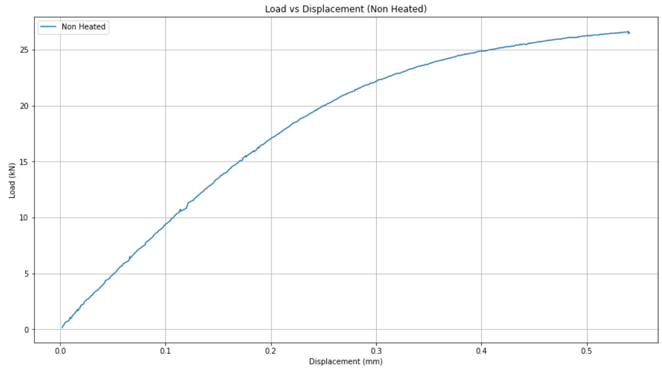
Design of experiment for tensile testing-

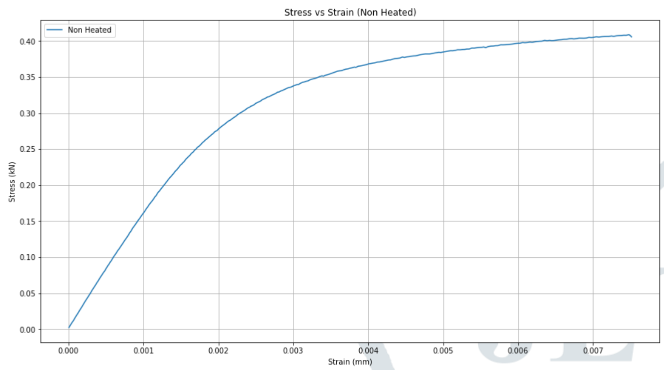
In this work, Taguchi's L09 Orthogonal array is used to study tensile performance of ADI material. ,

V. RESULTS AND DISCUSSION

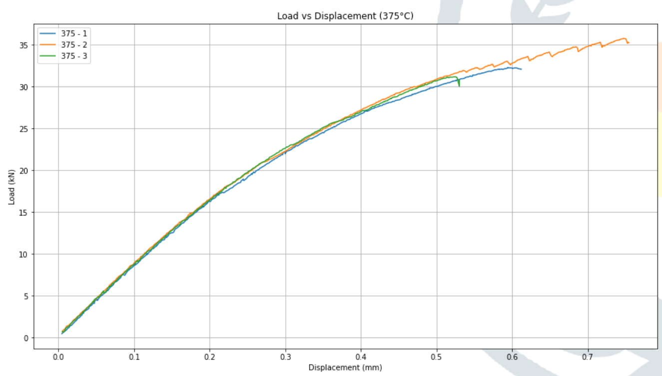
Austempered Temperature (CC)	Sample Number	Max. Axial Force (kN)	Ultimate Tensile Strength (kN/mm²)	Elastic Modulus (GPa)
Non Heat Treated	1	31.87468945	0.428067181	164.6961497
375	1	32.29711914	0.495743895	147.1978383
	2	44.74864844	0.542297391	158.1044625
	3	31.19363477	0.478805987	156.4089485
400	1	38.71414844	0.498153074	150.0754155
	2	33.13192188	0.508557681	154.8689387
	3	40.75359375	0.479052088	154.1227745
425	1	43.04601953	0.555123258	153.2837821
	2	22.05266016	0.338496805	132.1095441
	3	41.12511328	0.567002434	154.2711063

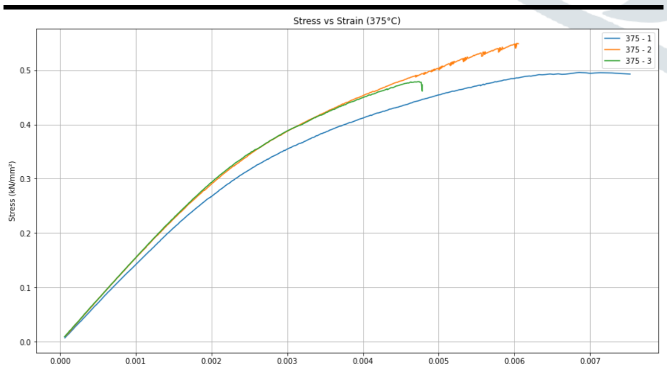
- **Non Heat Treated**



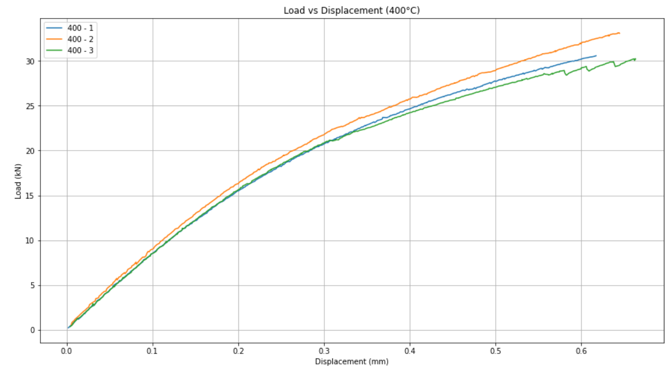


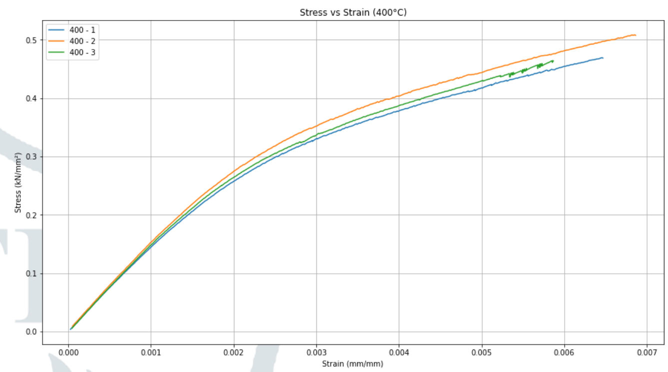
- **Iron Austempered at 375°C**



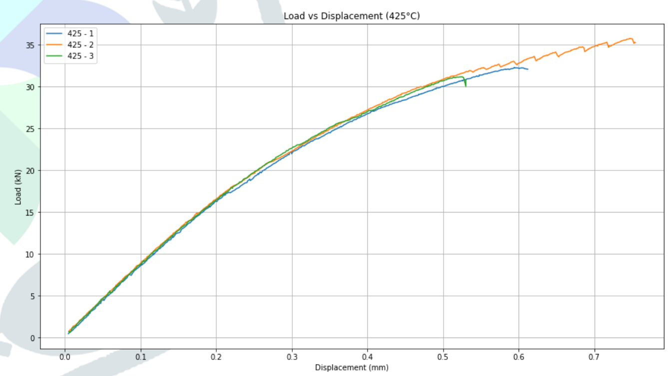


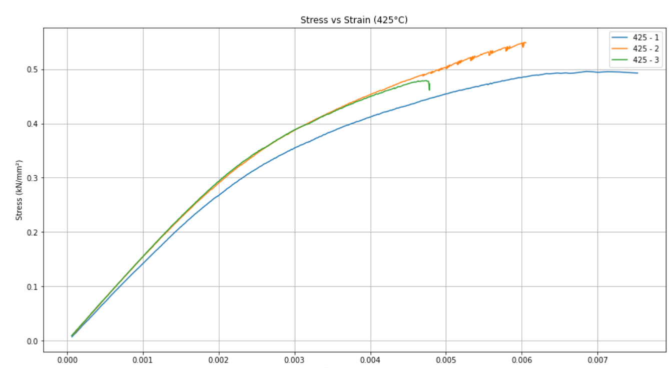
- **Iron Austempered at 400°C**





- **Iron Austempered at 425°C**





VI. CONCLUSION

- It is observed that as Austempering Temperature increases Tensile Strength and Hardness increases Lower the Austempering Temperature higher the Yield Strength.
- Tensile Strength lies around 414MPa we have obtained 505.6 MPa at 375°C, 495.2 MPa at 400°C, 486.8MPa at 425°C

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