The influence of Austempering conditions on machining of austempered ductile iron using wire EDM method 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

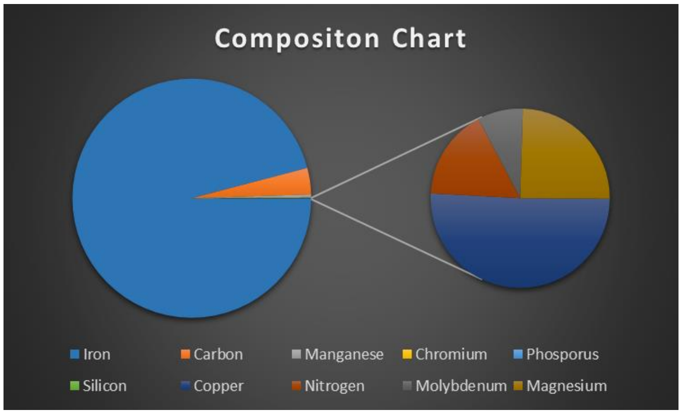


Fig: Composition Chart

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.

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.

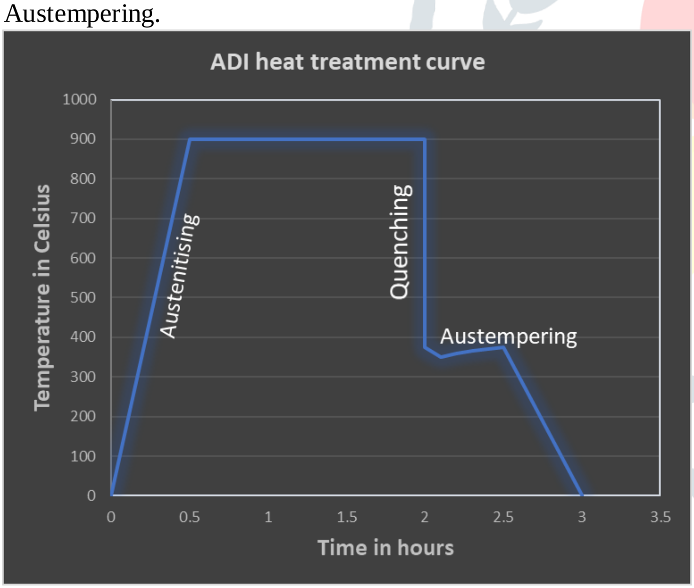


Fig: ADI heat treatment diagram

Our materials are divided into six sections. All six 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	300ºC	30
T2	325ºC	60
T3	350ºC	90
T4	375ºC	30
T5	400ºC	60
T6	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,

V. RESULTS AND DISCUSSION

Wire electronic discharge machine[WEDM]

WEDM is used for electrically conductive materials only and is most suited for difficult to machine material like superalloys, titanium, hardened steel. Unlike conventional machining, cutting does not take place during the WEDM process. Instead, their occurs melting or even vaporizing of the workpiece material that leaves nearly no debris along with a highly accurate cut

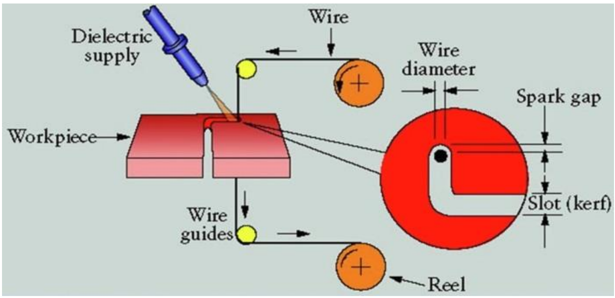
[1]Wire-cut electric discharge machining (WEDM) usage is proliferating in tool rooms and die shops floors of modern industrial facilities to impart solution to machine difficult to machine materials. WEDM is not only capable of machining extremely hard materials but, is also suitable for exceptionally delicate materials as the machining is done without any direct contact between workpiece and tool. Besides these advantages, the complexity of the process with a large number of process control parameters makes it difficult for even a skilled operator to avoid wire rupture or achieve the opti- mal performance

[2]. Selection of control parameters during WEDM to provide optimal performance has been a hefty

challenge for researches and developers of this non-conventional machining process

What is Wire EDM?

Also known as spark eroding or spark machining, Wire EDM is a machining process where an electrically charged single strand wire is constantly fed within a dielectric fluid (usually deionized water) the resulting discharge when presented by the CNC in close proximity to the grounded workpiece is used to cut a conductive material. The wire is moved closer to the part being worked on to produce electric sparks that cut, or rather erode, through the metal. They are flushed and usually immersed in deionized water to get rid of the particles, cool the wire from breakage and control the sparks.

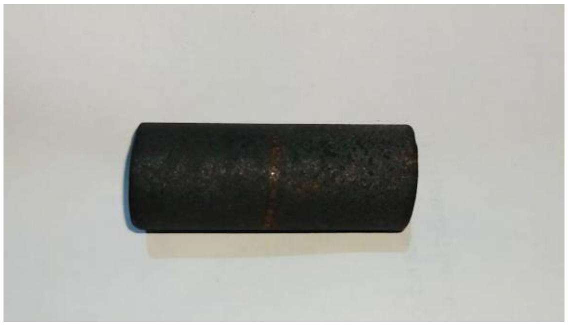


How the Wire EDM Process Works

starts with the thin piece of electrically charged wire made of brass of any other material being held in position by the upper and lower guide. An electric discharge between the wire and the conductive material produces some sparks, which are precisely guided to cut through the material to achieve the desired cuts. When a piece is being worked on, it is submerged in deionized water to cool and flush out the debris produced.

When the wire is brought closer to the conductive metal rapid electrical discharges are produced. The discharges erode the metal on the focused areas, leaving no blemishes or deformations. The CNC controls the path the wire follows producing a contoured path bound only by the size of the wire itself (usually 0.,010” in diameter).

RESULTS:

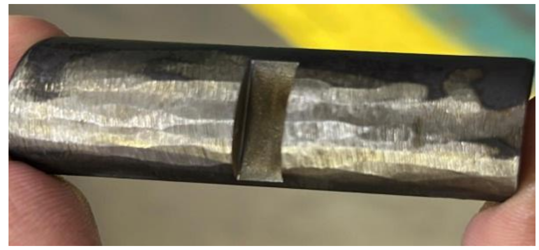


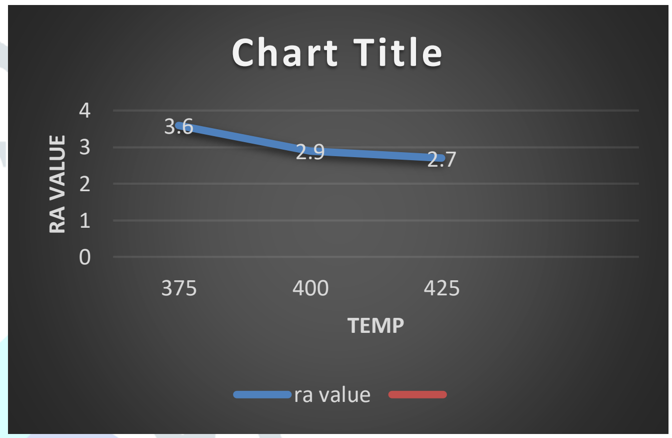
(a) before machining and; (b)after Wire EDM machining.

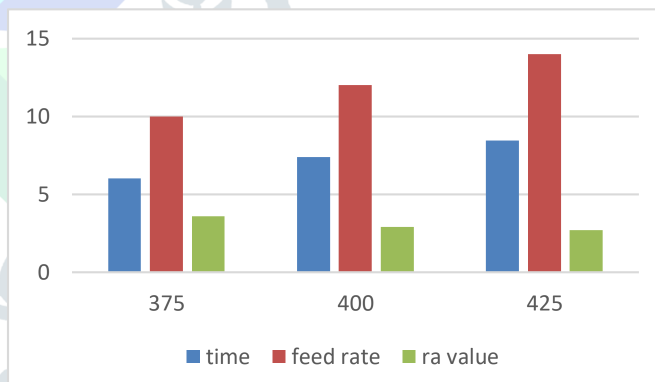
WEDM setup used for machining.

SL.No.	Parameters	Range
1	Frequency	0-200KHz
2	Pulse width	1–10 ms
3	Gap percentage of voltage	60–100%
4	Gain	0–100
5	Pulse peak current	40A
6	Output voltage	60–250 V
7	Dwell time	0.205
8	Polarity	+/-
9	Hole diameter	0.05–1 mm

WEDM machining process







The increase of discharge current and voltage causes the pulse energy to increase and as a result, the material removal rate and tool wear increase

The average surface roughness of the temperature 375o C 400o C 425o C are 3.06

After comparing the above reading we concluded that the Wire EDM is good for 425o C having low RA value shows that it has good surface roughness

CONCLUSIONS

The increase of discharge current and voltage causes the pulse energy to increase and as a result, the material removal rate and tool wear increase.

This work deals with the investigations on material removal rate and surface roughness while machining ADI in WEDM. Through Boxbehnken design of DOE the experiments were done and mathematical models were developed in second order to establish the relationship between input parameters (peak current, pulse on time and pulse off time) and the response The following conclusions have been derived.

The increase in peak current increases the material removal rate significantly.

The increase in pulse on time increases the material removal rate whereas there is no much impact when pulse off time is increased.

The surface roughness values in µm increases when there is increase in peak current.So the peak current must be kept optimum for minimum Ra value.

When the pulse on time increases the roughness average values also increases.So for better surface finish,the pulse on time must be optimum.

There is no change in Ra value when the pulse off time is increased.

The increase of pulse on time from 35 to 50µs causes the tool wear rate to increase. With a further increase of pulse on time from 50 to 100µs, the tool wear rate diminishes, but the material removal rate goes up.

The increase of pulse off time causes both the material removal rate and tool wear to decrease. with the increase of voltage, relative electrode wear increases and consequently, material removal rate diminishes. With the increase of discharge current and pulse on time, relative electrode wear decreases and as a result, material removal goes up.

Surface roughness increased with increasing pulsed current and pulse time

Increasing wear on electrode surface is unavoidable during EDM process. Therefore, work piece surface roughness will be increasing due to wear rate on electrode.

Wear on electrode surface is unavoidable during EDM process. Surface roughness of machined work piece would increase when surface quality of electrode decreases due to pulsed current density.

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