EFFECT OF HEAT TREATMENT CYCLE ON THE MECHANICAL PROPERTIES OF MACHINABLE AUSTEMPERED DUCTILE IRON

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Abstract:

ADI have been used for a wide variety of application in automotive ,rail,and heavy engineering industry because of its excellent mechanical properties such as high strength with good ductility ,good wear resistance ,and good fatigue properties. The properties of austempered ductile iron are dependent on both chemistry and heat treatment, which has lead to invention of MADI (machinable austempered ductile iron). MADI is a new class of ductile iron with superior mechanical property than regular ductile iron with the same machinability characteristic.

In this study Different cycles of austempering process (austenitization and austempering cycle) applied Due to the effect of heat treatment cycle on the metal matrix structure and tensile properties of ductile iron and effect of heat treatment cycle on the temsile properties of MADI was investigated.

Key word: MADI(Machinable Austempered Ductile Iron), ADI, Heat Treatment

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1. Introduction:

MADI is a new class of ductile iron and shouldn’t be confused with regular austempered ductile iron. Like regular austempered ductile iron, the tensile properties of MADI are superior to regular ductile iron. (fig 1)

For economic reasons or to avoid metallurgical problem, combination of alloys are often used to achieve the desirable hardenability in ADI. To avoid microsegregation and the resultant degradation of mechanical properties associated with levels of manganese and molybdenum, their levels should be carefully controlled with the desired hardenability obtained by supplementary addition of first copper (up to about 0.8%), then nickel. The properties of austempered ductile iron are dependent on both chemistry and heat treatment, which determine the size, distribution and stability of the phase present in the final microstructure. [1,2]

ADI is produced by an isothermal heat treatment known as austempering. Austempering consists of the following steps as shown in:

- Heating the casting to the austenitizing temperature in the range of 1500-1700°F (815-927°C).
- Holding the part at the austenitizing temperature for a time sufficient to get the entire part to temperature and to saturate the austenite with carbon.
- Quenching (cooling) the part rapidly enough to avoid the formation of pearlite to the austempering temperature in the range of 450-750°F (232-400°C). (This temperature is above the martensite start temperature (Ms) for the material)
- Austempering the part at the desired temperature for a time sufficient to produce a matrix of ausferrite. (That is a matrix of acicular ferrite and austenite stabilized with about 2% carbon).
- Cooling the part to room temperature

The austenitizing may be accomplished by using a high temperature salt bath, an atmosphere furnace or (in special cases) a localized method such as flame or induction heating. The austempering is most typically carried out in a nitrite/nitrate salt bath but in special cases it can be accomplished in hot oil (up to 470°F (243°C)), or molten lead or tin.

The critical characteristics in production of MADI are:[3,4]

Chemical composition

The austenitizing time and temperature

A cooling rate sufficient for the casting/alloy combination

The austempering time and temperature

Figure 1. Comparison of Mechanical Properties.
1.1. Austenitizing

The austenitizing temperature controls the carbon content of the austenite which, in turn, affects the structure and properties of the austempered casting. High austenitizing temperatures increase the carbon content of the austenite, increasing its hardenability, but making transformation during austempering more problematic and potentially reducing mechanical properties after austempering. (The higher carbon austenite requires a longer time to transform to ausferrite). Reduced austempering temperatures generally produce ADI with the best properties but this requires close control of the silicon content, which has a significant effect on the upper critical temperature of the Ductile Iron.

Austenitizing time should be the minimum required to heat the entire part to the desired austenitizing temperature and to saturate the austenite with the equilibrium level of carbon, (typically about 1.1-1.3%). In addition to the casting section size and type, the austenitizing time is affected by the chemical composition, the austenitizing temperature and the nodule count.[5,6,7]

Austempering is fully effective only when the cooling rate of the quenching apparatus is sufficient for the section size and hardenability of the component. The minimum rate of cooling is that required avoid the formation of pearlite in the part during quenching to the austempering temperature. The critical characteristics are as follows:

- Transfer time from the austenitizing environment to the austempering environment.
- The quench severity of the austempering bath
- The maximum section size and type of casting being quenched
- The hardenability of the castings
- The mass of the load relative to the quench bath.

1.2. Austempering.

The use of a correctly designed austempering system with a suitably high quench severity, and the correct loading of castings, can minimize hardenability requirements of the casting resulting in significant savings in alloy costs.

As illustrated earlier, austempering temperature is one of the major determinants of the mechanical properties of ADI castings. To produce ADI with lower strength and hardness but higher elongation and fracture toughness (good machinability characteristic), a higher austempering temperature (650-750F (350-400C)) should be selected to produce a coarse ausferrite matrix with higher amounts of carbon stabilized austenite (20-40%). Grades 125/80/10 and 150/100/07 would be typical of these conditions. To produce ADI with higher strength and greater wear resistance, but lower fracture toughness, austempering temperatures below 650F (350C) should be used.

Once the austempering temperature has been selected, the austempering time must be chosen to optimize properties through the formation of a stable structure of ausferrite.

At short austempering times, there is insufficient diffusion of carbon to the austenite to stabilize it, and martensite may form during cooling to room temperature. The resultant microstructure would have a higher hardness but lower ductility and fracture toughness (especially at low temperatures). Excessive austempering times can result in the decomposition of ausferrite into ferrite and carbide (bainite) which will exhibit lower strength, ductility and fracture toughness. At the highest austempering temperature (750F (400C)) as little as 30 minutes may be required to produce ausferrite. At 450F (230C) as much as four hours may be required to produce the optimum properties. A strength level maxima is achieved in ADI at an austempering temperature of about 475-525F (250-275C).

At temperatures below that range the hardness may increase but the strength may decrease due to the presence of martensite mixed in with the ausferritic matrix. (In other words, as the
austempering temperature is incrementally decreased below 475F (250C) the material behaves increasingly like a quenched and tempered Ductile Iron).[8,9]

2. Experimental procedure:

Y-blocks mold according to ASTM A536-84, spheroid formation and inoculation FeSi were used. Molten metal was poured into green sand mould and then left for cooling to room temperature.

The optimum composition of alloying elements according to tensile strength and hardness selected as base metal composition and effect of heat treatment cycle on the mechanical properties were deliberated.

<table>
<thead>
<tr>
<th>Sample</th>
<th>% C</th>
<th>% Si</th>
<th>% Mn</th>
<th>% Ni</th>
<th>% Cu</th>
<th>% Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.24</td>
<td>3.7</td>
<td>0.35</td>
<td>0.97</td>
<td>0.6</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Different cycle of austempering process (austenitization and austempering cycle) applied. Due to the effect of heat treatment cycle on the metal matrix structure and mechanical properties of ductile iron, as a following description:

Specimens:

A-1-1 Austenite at 750 °C for 1 hour Austempered at 350 °C for 1 hour
A-1-2 Austenite at 750 °C for 2 hour Austempered at 350 °C for 2 hour
A-1-3 Austenite at 750 °C for 3 hour Austempered at 350 °C for 3 hour
A-2-1 Austenite at 750 °C for 1 hour Austempered at 395 °C for 1 hour
A-2-2 Austenite at 750 °C for 2 hour Austempered at 395 °C for 2 hour
A-2-3 Austenite at 750 °C for 3 hour Austempered at 395 °C for 3 hour
A-3-1 Austenite at 800 °C for 1 hour Austempered at 350 °C for 1 hour
A-3-2 Austenite at 800 °C for 2 hour Austempered at 350 °C for 2 hour
A-3-3 Austenite at 800 °C for 3 hour Austempered at 350 °C for 3 hour
A-4-1 Austenite at 800 °C for 1 hour Austempered at 390 °C for 1 hour
A-4-2 Austenite at 800 °C for 2 hour Austempered at 390 °C for 2 hour
A-4-3 Austenite at 800 °C for 3 hour Austempered at 390 °C for 3 hour
A-5-1 Austenite at 850 °C for 1 hour Austempered at 350 °C for 1 hour
A-5-2 Austenite at 850 °C for 2 hour Austempered at 350 °C for 2 hour
A-5-3 Austenite at 850 °C for 3 hour Austempered at 350 °C for 3 hour
A-6-1 Austenite at 850 °C for 1 hour Austempered at 390 °C for 1 hour
A-6-2 Austenite at 850 °C for 2 hour Austempered at 390 °C for 2 hour
A-6-3 Austenite at 850 °C for 3 hour Austempered at 390 °C for 3 hour
A-7-1 Austenite at 920 °C for 1 hour Austempered at 350 °C for 1 hour
A-7-2 Austenite at 920 °C for 2 hour Austempered at 350 °C for 2 hour
A-7-3 Austenite at 920 °C for 3 hour Austempered at 350 °C for 3 hour
A-8-1 Austenite at 920 °C for 1 hour Austempered at 390 °C for 1 hour
A-8-1 Austenite at 920 °C for 2 hour Austempered at 390 °C for 2 hour
A-8-1 Austenite at 920 °C for 3 hour Austempered at 390 °C for 3 hour

Following Standards cover the requirements and works to be carried out:
1. Preparation of specimens according to ASTM E3.
3. Optical microscopic evaluation according to ASTM E883.
4. Graphite microstructure according to ASTM A 247.
5. Tensile test according to DIN EN 1563 & ASTM A370.(fig.3)

3. Result and discussion:
The heat treatment parameters austenitization temperature & time & the isothermal treatment temperature control the properties of this type of material to large extent.
The machinability of cast iron is related to its mechanical properties, microstructure, as well as the conditions of machining and machined surface. With the achieved combination of high strength and high toughness austempered ductile iron found many applications.
The propose of present paper is to show the influence of the heat treatment on the tensile properties of machinable Austempered Ductile iron.
3.1. The Microstructure of specimens austenite at 850 °C and austempered at 390 °C (A-6-1) show in figure 2.

3.2. The Yield strength & Tensile strength is illustrated in fig 3. They are continuously increasing without any minimum when the austenitic temperature is raised.
3.3. The elongation versus austenitic temperature is illustrated in fig 4. with increasing austenitization temperature up to 850 °C the elongation is increased. there is a maximum in the elongation–temperature curve at around 850 °C.

4. Conclusion:

Following conclusion could be summarized based on the results of present works:

1. Optimum macinability due to suitable tensile properties can achieved by austenitig at 850 °C & austempering at 395 °C.
2. The yield strength & tensile strength increase with increasing austenitizing temperature.
3. With increasing austenite temperature the elongation is increased up to 850 °C & minimum elongation was achieved by austenitizing at 850 °C & austempered at 390 °C.

5. References:


