THERMO-MAGNETIC PROCESSING OF DUCTILE CAST IRON

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Introduction
The primary objective of this investigation was to explore whether a fully ferritic microstructure can be produced in ADI (austempered ductile cast iron) by heat treating in a high magnetic field. While ADI has many attractive mechanical properties such as high strength with good ductility, good fatigue strength and fracture toughness and is used in many industrial applications, it has some limitations. The ADI microstructure is a mixture of ferrite and austenite. Austenite has higher work hardening rate than ferrite [1, 2] and this causes problems in machining of ADI [3]. Since most of the ADI components in automotive, and other manufacturing industries need to be machined, a fully ferritic ADI (austenite free) could potentially reduce machining cost of these components.

Experimental
Compact tension and cylindrical tensile samples prepared from unalloyed ductile cast iron were initially austenitized at 927°C for 2 hours and then austempered in presence of magnetic field of 20 tesla (DC magnetic field at NHFML) at 260°C. Microstructural analysis by optical metallography and XRD were carried out. In addition, the fracture toughness and tensile testings were done as per ASTM standards.

Results and Discussion
The microstructure of the samples austempered in presence of magnetic field (figure below) indicates the presence of only bainitic ferrite and some very isolated pockets of pearlite. The X-ray diffraction profile of these samples verified the presence of only BCC phase. Thus austempering in presence of a magnetic field has promoted the formation of ferrite without the presence of austenite in the matrix. The tensile properties of these materials (reported in the table below) show that the magnetically processed samples have lower yield tensile strength and hardness compared to the conventionally processed samples. However, the ductility of these magnetically processed samples was higher. This higher ductility appears to be the consequence of the absence of austenite in these samples. In conventionally processed ADI, austenite generally transforms into martensite during tensile testing by trip reaction. This results in higher strength but lower ductility. Since the magnetically treated samples did not have austenite, the strength was lower and at the same time the ductility was higher. The fracture toughness data of the conventionally processed ADI and the samples austempered in presence of a magnetic field are reported in the table below. It is interesting to note that even without the presence of austenite, magnetically treated samples had similar fracture toughness.

<table>
<thead>
<tr>
<th>Material Condition</th>
<th>UTS (MPa)</th>
<th>Yield Strength (MPa)</th>
<th>% Elongation</th>
<th>Fracture Toughness (MPa√m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventionally Processed Samples</td>
<td>1384 ± 45</td>
<td>1167 ± 37</td>
<td>2.6</td>
<td>44.5 ± 1.0</td>
</tr>
<tr>
<td>Magnetically Treated Samples</td>
<td>1065 ± 41</td>
<td>779 ± 20</td>
<td>4.0</td>
<td>44.0 ± 0.8</td>
</tr>
</tbody>
</table>

Conclusions
In this investigation, austempered ductile iron was processed in a high magnetic field of 20 Tesla at 260°C and this has resulted in mostly ferritic microstructure. Because of fully ferritic structure, such ADI will have the advantages of improved machinability and high thermal fatigue resistance.

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References