Mechanical properties of AA5083 in different tempers at low temperatures

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Background

The Al-Mg alloy 5083 (AA5083) takes advantage of exceptional combination of economy of fabrication, weldability, and corrosion resistance, which is suitable for utilization at room temperature. Moreover, the AA5083 in annealed treatment (temper O) demonstrates extremely high fracture toughness both at room and cryogenic temperatures. Research results have shown that the tensile strength, elastic moduli, and fatigue properties of the AA5083-O at cryogenic temperature were as high as, or even higher than those at room temperature. This makes it suitable for arctic and cryogenic applications, for instance, storage and transport for liquid natural gas (LNG).

The strain hardening treatment is also widely used for AA5083, mainly including the strain hardened only (temper H11), and strain hardened and following stabilized (temper H31). In the present work, the tensile, bend, Charpy impact, and fatigue crack propagation behavior of the AA5083 in different temper, i.e., O, H112, and H32 were investigated at room and cryogenic temperatures.

Sample preparation

The AA5083 plates with a thickness of 50 mm in temper O, H112, and H32 conditions were used as received.

The dumbbell shape tensile specimen has a gauge length, width and thickness of 50 mm, 10 mm and 2 mm respectively, which complies with requirements by standard ISO 898-3.

The specimen geometry for three-point bend test complies with requirements by standard ISO 748. ISO 748.

The V-notch specimen for Charpy impact testing complies with requirements by standard ISO 148-1.

The compact tension specimen for test of fatigue crack growth rate complies for standard ISO and ASTM E647 and ISO 12108 and the specimen has an initial crack length/thickness ratio of 0.35.

Experimental Procedures

The tensile and bend tests were conducted with a model MTS SANS CNS5105S test machine with a load capacity of 100 kN at 77 K under a displacement-controlled mode. The local deformation was monitored with an Epalon extensometer with a GL of 25 mm. The 77 K environment was obtained through immersing the test jigs and the whole specimens into liquid nitrogen in the cryostat.

The Charpy impact test was conducted with an model MTS SANS SJX-300A Charpy impact test machine with an alternative hammer of 150 J energy. The test at 77 K was conducted with specimens immersed in liquid nitrogen for more than 15 min and then transferred to the tested machine within 5 s to keep the temperature.

The fatigue crack propagation behaviour was investigated with an Instron 8801 axial/torsion fatigue machine (axial load capacity: ±120 kN). The CMOD was recorded with a Epalon clip-on extensometer. The test was conducted with a constant-load controlled mode and with a load ratio (R) of 0.1, i.e., a stress intensity factor (K) increasing method.

Conclusion

The tensile properties including 0.2% proof stress, ultimate tensile stress and elongation at failure depended slightly on the temper at 77 K.

The temper H32 resulted in a highest bend strength whereas the temper H112 resulted in the lowest bend strength at 77 K.

The AA5083-O exhibited same Charpy impact energy value as the AA5083-H112 and both are slightly lower than that of the AA5083-H32 at 150 K. The Charpy impact energy of the AA5083-O, AA5083-H112, and AA5083-H32 were close at 77 K and all were lower than those at 150 K.

At 77 K, the fatigue crack growth rates of the AA5083-H32 were higher than those of the AA5083-O, whereas the AA5083-H112 demonstrated the lowest value.

Table 1. The tensile properties AA5083-O, AA5083-H112, and AA5083-H32 at 77K

<table>
<thead>
<tr>
<th>No.</th>
<th>Rm (MPa)</th>
<th>Rp0.2 (MPa)</th>
<th>A (%)</th>
<th>E (%)</th>
</tr>
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<tbody>
<tr>
<td>AA5083-O</td>
<td>177 ± 0.18</td>
<td>420 ± 0.24</td>
<td>82.6 ± 0.58</td>
<td>46.4 ± 1.52</td>
</tr>
<tr>
<td>AA5083-H112</td>
<td>177 ± 0.17</td>
<td>417 ± 0.24</td>
<td>82.6 ± 0.58</td>
<td>46.4 ± 1.52</td>
</tr>
<tr>
<td>AA5083-H32</td>
<td>175 ± 0.20</td>
<td>419 ± 0.45</td>
<td>81.8 ± 2.39</td>
<td>44 ± 2.09</td>
</tr>
</tbody>
</table>

As shown in Figure 3, the fatigue crack growth of AA5083 in all interest temper occurs more slowly at low temperature than that at room temperature if small to moderate aK values (8.23 MPa.m1/2) are applicable, whereas faster crack growth was observed for larger aK values with Kc close to plane stress fracture toughness Kc.

The fatigue crack growth rates of the AA5083-H32 are higher than those of AA5083-O, whereas the AA5083-H112 seems to demonstrate the lowest value at 77 K.