IMME17

Development of copper coating technology on high strength low alloy steel filler wire for aerospace applications

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Abstract

0.3C-CrMoV(ESR) grade steel is considered as a potential candidate for realizing solid booster cases in aerospace applications due to its high strength coupled with toughness. To obtain the maximum weld efficiency, these steels are welded using filler wires of the same chemical composition. However, due to inherent corrosive nature, bare filler wires could not be stored for long time. To overcome this problem, a suitable coating technology using copper as coating material has been developed which provides uniform, adherent and thin coating on the wire and do not impair the required mechanical properties of weldment. In order to alleviate the gas pick-up issues associated with electro-plating technique and considering the product configuration, immersion coating technique was adopted. Process optimization to obtain a uniform and adherent coating on wire spools was carried out. Wires were also analysed for coating thickness, adhesion and gases (O, H, N). Coating has been observed to be adherent and gas content were found within the aerospace specification. Further, weldment realized using coated filler wire shows similar quality of weldments and properties as obtained through uncoated filler wire, confirming this process and coating can be adaptable for storage of filler wire.

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Selection and/or Peer-review under responsibility of International Conference on Emerging Trends in Materials and Manufacturing Engineering (IMME17).

Keywords: 0.3C-CrMoV(ESR), copper, coating, filler wire

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1. Introduction

Aerospace grade materials are unique in nature mainly because of the high specific strength associated with superior cleanliness. Majority of the areas warrant not only high strength but superior fracture toughness also. One such application is the booster motor case which demands materials having excellent strength with toughness. High strength alloy steels viz. D6AC, maraging steels etc. are widely used for booster motor cases. R&D efforts are also in progress to find a potential alternative of these materials so that cost and fabricability issues can be addressed. 0.3C-CrMoV(ESR) steel is being discussed as an alternate to maraging steels for launch vehicles, attributing to lower cost, good combination of strength and fracture toughness [1, 2]. 0.3C-CrMoV(ESR) steel is basically a modified version of 15CDV6 steel where carbon content has been doubled along with minor addition of Nb and re-melted using Electro Slag Re-melting (ESR) technology. Typical chemical composition of the steel is given in Table 1 and mechanical properties (in heat treated condition) are presented in Table 2. The alloy is used in heat treated condition (925°C/ 1 hr water quenching followed by tempering at 505°C/ 2 hr air cooling) and the same has been followed.

### Table 1: Chemical composition of 0.3C-CrMoV(ESR) steel

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>Mn</th>
<th>V</th>
<th>Nb</th>
<th>Si</th>
<th>S</th>
<th>P</th>
<th>H2</th>
<th>N2</th>
<th>O2</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>1.3-</td>
<td>0.8-</td>
<td>0.8-1.0</td>
<td>0.2-</td>
<td>0.08-</td>
<td>0.25</td>
<td>0.015</td>
<td>max</td>
<td>0.02</td>
<td>2ppm</td>
<td>125</td>
<td>50 ppm</td>
<td>balance</td>
</tr>
<tr>
<td>1.5</td>
<td>1.0</td>
<td>0.12</td>
<td>0.3</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>ppm</td>
<td>max</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: Mechanical properties of 0.3C-CrMoV(ESR) steel in heat treated condition

<table>
<thead>
<tr>
<th>Property</th>
<th>Specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Tensile Strength</td>
<td>1400MPa(min)</td>
</tr>
<tr>
<td>0.2% Proof Stress</td>
<td>1275MPa(min)</td>
</tr>
<tr>
<td>% Elongation</td>
<td>10 (min)</td>
</tr>
<tr>
<td>Fracture toughness</td>
<td>80MPa√m(min)</td>
</tr>
</tbody>
</table>

Welding of this steel is done using Gas Tungsten Arc Welding (GTAW) technique and a filler wire having the matching chemical composition to that of the parent metal is used to achieve 100% weld efficiency. Filler wires of dia 1.6mm and 2.5mm is used for welding the alloy. Due to higher carbon and lower chromium content, the wire is severely prone to rusting which in turn leads to various weld defects when used in welding. To avoid this issue, coating of the wire using a suitable material is of paramount importance, which can protect the wire from corrosion without impairing the properties of the weldment. As a widely accepted coating material for majority of high strength low alloy steel wires, copper was considered as a candidate coating material [3-4].

Electro-plating technique has been selected for copper coating of filler wire. Further, to alleviate the gas pick-up issues associated with electro-plating technique and considering the product configuration, immersion coating route was selected [5-6]. Immersion coating process involves the deposition of a metallic coating on the base metal from a solution containing the coating material. One metal is displaced by a metal ion that has a lower oxidation potential than the displaced metal ion. Process differs from electroless plating because in this process, reducing agents are not required to reduce the metal ions as the base metal itself acts as a reducing agent. It follows the basic principle of coating where the steel component is immersed in a copper sulphate solution and following reaction occurs:

\[
\text{Fe} + \text{Cu}^{+2} \rightarrow \text{Cu} + \text{Fe}^{+2}
\]

Iron displaces the copper from its solution and the copper coats the steel part. Deposition stops when the exposed substrate is coated with copper and due to this reason the thickness obtained using immersion coating process is
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