STUDY OF MECHANICAL PROPERTIES IN A WELD BEAD OF DISSIMILAR METALS

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Abstract:
The dissimilarity of the metals may arise due to the difference in chemical composition. The chemical composition of the steel affects weldability and the mechanical properties of the welded joint. During the reclamation and repair work of structural and machine components the difference in chemical composition of the material to be welded is very much pronounced. These differences in chemical composition arise due to age hardening, oxidation and many other factors. In this paper an attempt has been made to study the mechanical properties of the welded joint formed between dissimilar metals and the affect of process parameters on it.

Introduction
Joining of dissimilar metals is carried out since ancient times. Nowadays, joining dissimilar metals has become indispensable in the field of manufacturing and construction of equipment, machinery and products. Different kinds of metals feature different chemical, physical, and metallurgical properties. Joining dissimilar metals is, therefore, to compose different properties of metals in order to maximize the performance with minimum cost.

When welding two dissimilar materials, there are a number of aspects that need to be addressed, in addition to those associated with welding similar materials. The different methods of welding dissimilar metals include fusion welding, solid state welding, high energy density beam welding, brazing, and soldering. Dissimilar metal joints can usually be made by any of these methods but low dilution and non-fusion joining processes are more often used for high production & special applications. The joining of dissimilar metals by arc welding requires careful consideration of aspects like selection of filler wire to optimize dilution & alloying, melting temperature ranges of the metals, their thermal conductivities, co-efficient of thermal expansion, weld metal-base metal interaction and joint design.

The dissimilarity of the metals may arise due to the difference in chemical composition. The chemical composition of the steel affects weldability and other mechanical properties. Several elements are purposefully added in the production of structural steel, but other undesirable elements may be present in the scrap materials used to make the steel. Carbon and other elements that increase harden ability increase the risk of “cold” cracking, and therefore higher preheat and inter pass temperatures, better hydrogen control, and sometimes post heat are necessary to avoid cold cracking. The alloying elements and their general affects are given hereunder:

Carbon (C) is the most common element for increasing the strength of steel, but high levels of carbon reduce weldability. Carbon increases the harden ability of the steel, increasing the formation of undesirable martensite with rapid HAZ cooling. Higher preheats and higher heat input welding procedures may be needed when welding a steel with relatively high carbon contents. Typical steel specifications limit carbon below 0.27%, but some steel specifications have much lower limits.

Manganese (Mn) is an alloying element that increases strength and hardenability, but to a lesser extent than carbon. One of the principal benefits of manganese is that it combines with undesirable sulphur to form manganese sulfide (MnS), reducing the detrimental effects of sulfur. With high levels of sulfur, however, numerous large MnS inclusions may be present, flattened by the rolling operation, increasing the risk
of lamellar tearing when high through-thickness weld shrinkage strains are created. Manganese limits are typically in the order of 1.40% or lower. A steel such as A36 does not place limits on Mn content for shapes up to 634 kg/m (426 lb./ft.), or for plates and bars up to 20 mm.

Phosphorous (P) is an alloying element that increases the strength and brittleness of steel.

Larger quantities of phosphorous reduce ductility and toughness. Phosphorous tends to segregate in steel, therefore creating weaker areas. Phosphorous is typically limited to 0.04% to minimize the risk of weld and HAZ cracking.

Sulfur (S) reduces ductility, particularly in the transverse direction, thereby increasing the risk of lamellar tearing, and also reduces toughness and weldability. Higher sulfur levels will form iron sulfide (FeS) along the grain boundaries, increasing the risk of hot cracking. Manganese is used to form MnS to reduce this tendency. A minimum Mn:S ratio of 5:1 to 10:1 is recommended. Typical steel specifications limit sulfur to 0.05%.

Silicon (Si) is a deoxidizer used to improve the soundness of the steel, and is commonly used to “kill” steel. It increases both strength and hardness. Silicon of up to 0.40% is considered acceptable for most steels.

Nickel (Ni) is an alloying element used to improve toughness and ductility, while still increasing strength and hardenability. It has relatively little detrimental effect upon weldability. Where nickel is reported as a part of steel composition, it is generally limited to a maximum value between 0.25% and 0.50%.

For the present study the material selected, its compositions and physical properties are described in Table:1

<table>
<thead>
<tr>
<th>S/N</th>
<th>Name of Material</th>
<th>Composition in % of Weight</th>
<th>Thermal Conductivity W/m-k</th>
<th>Density Kg/m³</th>
<th>Melting Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mild Steel IS-2602</td>
<td>C 0.2, Mn 0.25, Si 0.05, Cr 0.05, S 0.05, P 0.57, Mg 53</td>
<td>53</td>
<td>7850</td>
<td>1540</td>
</tr>
<tr>
<td>2</td>
<td>EN-8 or IS-45 C8</td>
<td>C 0.4, Mn 0.8, Si 0.2, Cr 0.06, S 0.06, P 0.06, Mg 46</td>
<td>46</td>
<td>7850</td>
<td>1540</td>
</tr>
<tr>
<td>3</td>
<td>EN-9 or IS-C55</td>
<td>C 0.55, Mn 0.15, Si 0.65, Cr 0.06, S 0.06, P 0.06, Mg 46</td>
<td>46</td>
<td>7850</td>
<td>1540</td>
</tr>
<tr>
<td>4</td>
<td>EN-31 IS-103 Cr1</td>
<td>C 1.5, Mn 0.52, Si 0.22, Cr 1.3, S 0.05, P 0.05, Mg 46.6</td>
<td>46.6</td>
<td>7810</td>
<td>1540</td>
</tr>
</tbody>
</table>

Table:1
The mechanical properties of the material are tested by taking 10 samples from each material. The mechanical properties are tabulated in Table: 2

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of Material</th>
<th>Hardness of material (N/mm²)</th>
<th>Rupture Energy (U) J</th>
<th>Modulus of Rupture (U₁) J/mm²</th>
<th>Notch Impact strength (L₁) J/mm²</th>
<th>Breaking Strength N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mild Steel IS-2602</td>
<td>1451.630</td>
<td>31.0</td>
<td>0.0088</td>
<td>0.4950</td>
<td>616.466</td>
</tr>
<tr>
<td>2</td>
<td>EN-8 or IS-45 C8</td>
<td>1866.758</td>
<td>18.0</td>
<td>0.0051</td>
<td>0.2830</td>
<td>737.236</td>
</tr>
<tr>
<td>3</td>
<td>EN-9 or IS-C55</td>
<td>1711.260</td>
<td>38.0</td>
<td>0.0123</td>
<td>0.6759</td>
<td>891.479</td>
</tr>
<tr>
<td>4</td>
<td>EN-31 or IS-103 Cr1</td>
<td>3210.048</td>
<td>9.0</td>
<td>0.0025</td>
<td>0.1410</td>
<td>1102.457</td>
</tr>
</tbody>
</table>

Table: 2

As it can be compared from table:1 and table: 2 that although the physical properties of all four metal specimen selected have similar value but there is a remarkable difference in their mechanical properties. As the mechanical properties of the parent material are different, so the effect of it on the welded joint is required to be verified. Also the affect of process parameters on the welded joint is required to be studied while joining materials posing such type of dissimilarity.

**Experimental Details:**

For doing the experiments the size of parent metal was taken as (250 x 75 x 8) mm. The edge preparation is done to do welding as single V groove joint. In three steps the experiment was conducted.

In the first step the dissimilar metals with the prepared edges are taken for forming the welded joint. The material pairs selected for forming the welded joints are shown in the table:

<table>
<thead>
<tr>
<th>Material Pair Selected for welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS 2602 &amp; IS 45 C8</td>
</tr>
<tr>
<td>IS 2602 &amp; IS 103 Cr1</td>
</tr>
<tr>
<td>IS C 55 &amp; IS 103 Cr1</td>
</tr>
</tbody>
</table>

As the second step of this experiment the welded joint was formed for defined and different input process parameters. This step is undertaken to study the affect of process parameters on the mechanical properties of welded joint. The process parameters selected were wire feed rate, current and voltage. The weld specimen were prepared for different predefined set of current, voltage and wire feed rates.

As the third step the mechanical properties like hardness, toughness and the ultimate strength of the welded joint was tested. Some non destructive tests like liquid penetration test, X-ray radiographic test and ultrasonic test were conducted to study the acceptability of welded joint.

**Result & Analysis:**

The mechanical properties of the parent material and the welded bead is compared. It can be observed from graph-1 that the hardness of parent material and the weld bead is dependent on the type of parent materials used.
Still while joining IS-2602 & IS-103Cr1 it can be observed that the hardness resembles closely to the parent material IS-2602. This can be attributed to the electrode material used during the welding.

The graph-2, 3 & 4 shows the affect of heat input on the hardness of weld bead while joining dissimilar metals. It can be seen that as the heat input increases the hardness of the weld bead increases. But if the heat input is increased to a very higher value then the hardness decreases, it may be due to the decrease in heat density. The same trend is observed in the graphs -2, 3 & 4.
Further from the graph- 5,6 & 7 it can be seen due to increase in power input as the hardness of the material is increased but there is no substantial change in the breaking strength of the weld bead.

The table-3 indicates the mechanical properties of weld bead joining IS 2602 & IS 45 C8 for increasing current and wire feed rate. It can be noted from the table that for increasing current and wire feed rate the mechanical properties like rupture energy, notch impact strength and modulus of rupture increases where as the breaking strength of the weld bead decreases.

Similar results as in table-3 are obtained by joining other dissimilar metals. In all the weld beads the breaking strength shows a decreasing trend for increasing welding current and feed rate.
Conclusion:

From the experimental results it can be concluded that due to slight variation of alloying elements the physical properties of material like IS2602 may not change drastically but considerable change occurs in mechanical properties. When the materials with considerable difference in mechanical properties are joined by arc welding method then the mechanical properties of the weld bead depends a great extent on the type of filler material used, the heat input applied, the preheating and post heating conditions of the weld bead.

References: