If type 308 filler metal is diluted by 25% with mild steel, the weld metal is in the austenite martensite (A + M) phase area (refer Figure-2). Types 309 and 312 electrodes both have more nickel and chromium and when diluted by carbon steel are still in the austenite-ferrite (A + F) phase area and maintain good crack resistance properties.

When service temperatures are above 450°C, the ideal filler is a nickel-chromium or nickel-chromium-iron metal such as American Welding Society (AWS) A5.14 Class ENiCrFe-3 electrodes. Nickel alloy welds have a coefficient of thermal expansion (COE) between ordinary steel and austenitic stainless steel. With the higher COE type 309 and 312 welds, there is stress concentration at the steel-side fusion line, that during thermal cycling, can cause thermal fatigue failures.

Another caution in using stainless steel filler metals occurs when the weldment is heat treated between 600°C and 700°C. Welds containing higher amounts of delta ferrite, e.g., type 312 (FN more than 25) or type 309 (FN more than 10) can lose room temperature ductility and suffer reduced corrosion resistance as a result of sigma phase formation in this temperature range. A nickel alloy filler metal that is not subject to sigma formation normally avoids this situation.

**INSPECTION AND TESTING**

In qualifying welding procedure specification, DMWs are usually evaluated by tensile and bend tests like similar-metal welds. When neither of the base metals or the weld metals is significantly weaker, which is often the case, a longitudinal bend test is preferable because all elements are forced to elongate to the same extent and a better evaluation is possible. With a transverse bend test, this specimen may move in the bend dye, causing all of the elongation to take place in the weaker member and often results in fracture.

Magnetic particle testing is not possible if one or more parts of the joints are non-ferro magnetic. Even when the entire material is ferro-magnetic, the degree of ferro-magnetism can vary because of composition differences, and the magnetic differences can give false indications at the fusion line. Due to this, liquid penetrate inspection is most frequently used for surface inspection.

**NON-DESTRUCTIVE RADIOGRAPHIC INSPECTION**

DMWs can be inspected using the same procedures and inspection standards employed in similar metal joints. The exposure should be selected for the material and thickness of greatest interest. Due to differences in the radiographic density, interpretation of radiographs can be somewhat different than welds similar – metal welds. For this reason, the ultrasonic testing of DMWs is seldom practicable.

Stainless steels by their very nature are employed in aggressive situations as critical components, where the consequences of failures can be significant. Therefore, those who utilise welding in fabrication and maintenance should:

- Acquire the required knowledge, experience and ability
- Observe basic precautions of Dos and Don’ts
- Practice self-discipline in work.

For further details, please contact the product development centre of the plant.

**Indian Stainless Steel Development Association**
L-22/4, Ground Floor, DLF Phase-II, Gurgaon - 122 002, Ph : 0124 - 43755-02,03,
Email: nissda@gmail.com
Welding is without doubt, the most commonly employed method of joining stainless steel. It is accepted as the norm for nearly all points of sound structural strength. However, welding is not the only way to form metal or to bond dissimilar materials together. Many different welding processes are available for both similar and dissimilar metals.

**Fusion Welds and other Joining Methods**

There are several joining methods available for joining dissimilar metals, some of which are more commonly used than others. The processes for fusion welds include shielded metal arc welding (SMAW), gas metal arc (GMAW) submerged arc (SAW), flux cored arc (FCAW), and gas tungsten arc (GTAW) welding. Each of these processes has its own advantages and disadvantages, and the choice of process depends on the specific requirements of the application.

Dissimilar metal welds refer to the joining of two different alloy systems. Actually all fusion welds are dissimilar-metal welds (DMWs) because the metals being joined have a wrought structure and the welds have a cast structure. Frequently the matching-composition filler metal is deliberately altered from that of base alloys, to meet metal forming and working environments.

**Metallurgical Factors**

In dissimilar-metal welding (DMW), the properties of the three metals must be considered; the two metals being joined and the filler metal used to join them. For example, if one of the metals being joined is welded using pre-heat when welding to itself, pre-heat should be used in making a DMW. Another variable might be heat input control. On certain occasions, exhibited selected corrosion attack. There is also a zone of un-melted base metal that will have been altered by the heat of welding. This heat-affected zone (HAZ) can influence service life.

**Determining Weld Composition**

It is necessary to know the approximate weld metal composition before the service performance can be accurately predicted. Table I lists the weld metal composition along with their advantages and limitations. The technique for method 1 is obvious metal is removed from the weld bead and transition analyses performed. Method 2 approximated weld dilution by area measurement as shown in figure 1. Method 3 uses the following base metal dilution percentage for some of the common welding processes:

- SMAW (covered electrode): 20 to 25% dilution
- GMAW (spray arc): 20 to 40% dilution
- GTAW: 20 to 50% dilution
- SAW (Submerged arc): 20 to 50% dilution

<table>
<thead>
<tr>
<th>Table 1: Determining DMW composition</th>
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<tr>
<td><strong>Method</strong></td>
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<tr>
<td>1. Chemical analysis of weld</td>
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<td>2. Approximation of base metal dilution by weld cross section and composition calculated</td>
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<tr>
<td>3. Approximate dilution figures for common welding processes and composition calculated</td>
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</table>

**Service Condition Effects**

A properly engineered DMW matches weld properties to the service conditions. Some of the more important factors to be considered are mechanical and physical properties and weld corrosion/oxidation resistance.

**Mechanical Properties**

The weld metal shall be equal to or stronger than the weaker material being joined, although a weld strength of 95% is a minimum for all cases. Ductility comparable to the metals being joined is desirable.

**Physical Properties**

Weld metal physical properties similar to the base metals are desirable. In joints that are heat cycled, a good match in the coefficient of thermal expansion can lead to an early thermal fatigue failure.

**Weld corrosion / Oxidation resistance**

The weld will have corrosion and oxidation resistance equal to the least resistance base metal being joined. When a DMW is in an environment where the liquid can be an electrolyte, the weld metal should be cathodic to the less resistant material and have sufficient weld metal to form a galvanic couple.

**STEEL TO STAINLESS STEEL WELDS (BELOW 450 OC)**

These are probably the most frequently encountered DMWs in the industry. In developing a DMW procedure, it is important to note the welding parameters normally used for each of the metals being joined. So that those that are appropriate are included in the welding procedure.

**Carbon and Low-Alloy Side**

A simple guide in making DMWs is to use the same parameters such as pre-heat, interpass temperature, heat input, post-weld heat treatment, etc. that are used in welding the alloys to themselves. Salient points in this regard are:

1. Carbon steels with less than 0.20% carbon can normally be welded with austenitic fillers without preheat, but when the carbon is greater than 0.30%, temperature control is necessary. As alloy content increases, like in low-alloy steels, pre-heat is usually resorted to.

2. Austenitic covered electrodes or flux-cored wires shall have low moisture content to prevent hydrogen-associated defects in the low-alloy HAZ.

3. When a post-weld heat treatment is necessary, a temperature of 150°C is usually adequate with 200°C preheat used in severe conditions. On completion, the weld shall be air cooled to allow hydrogen to diffuse from the HAZ.

**Stainless Steel side**

As with welding stainless steel to itself, good welding practice includes such factors as proper cleaning, good fit up and proper shielding gases. Other major considerations are post weld heat treatment and any associated defects in the low-alloy HAZ. This can reduce the corrosion resistance and affect the mechanical properties. Heating unstabilized stainless steel to a temperature of 400°C is enough to increase corrosion resistance. If heat treatment is necessary, stabilised or low carbon stainless steel shall be used.

**Filler-metal**

One of the most common DMWs is type 304 stainless steel to a low-carbon or mild-steel. Type 308, the standard filler metal for welding type 304 to itself, should not be used to make this weld. Some type 308 welds may be satisfactory, but there can be quality problems because of iron dilution. A higher alloy filler metal such as type 309 with a ferrite number (FN) over 10 or type 312 with an FN over 25 should be used. The effect of dilution on an austenitic stainless-steel weld can be illustrated using the diagram. Figure 2. The structure of a stainless-steel weld may be fully austenitic, such as type 310, or contain varying amounts of delta ferrite, as with type 308, 309 or 312. The amount of ferrite is determined by the composition and weld cooling rates; the faster the cooling, the higher the ferrite content. Fully austenitic stainless steels are more susceptible to hot cracking or fissures than welds containing about 5% or more ferrite. Figure 2 also shows that martensite (M) may be formed as the nickel and chromium equivalents are reduced. Martensite being a hard, low-ductility phase prone to hydrogen-related defects, in DMWs, it is advisable to avoid martensite.