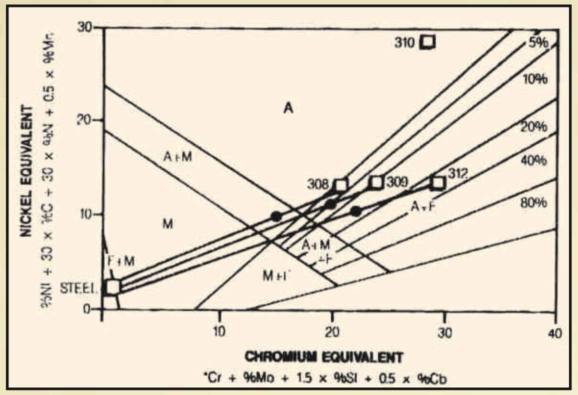

Figure 2. Effect of 25% mild steel dilution types 308, 309 and 312 weld metals. Structure of the diluted 308 is austenite and martensite while 309 and 312 is austenite and ferrite.

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.

STEEL- TO- STAINLESS STEEL WELDS (OVER 450°C)

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, tat 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.

** Information is subject to updation.*

Trough Floor under fabrication

NON- DESTRUCTIVE SURFACE INSPECTION

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 exposer 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 width similar – metal welds. For this reason, the ultrasonic testing of DMWs is seldom practicable.

CONSCLUSION

The welding of stainless steel and DMWs is not a “MAGICAL ART”. Persons involved in welding should have an appreciation for and understand the basic principles which are different from those applicable to welding plain carbon or low alloy steels.

If the basic principles are not known, and if appropriate measures are not taken, failures can will eventuate owing to welding in an indiscipline manner.

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.

ISSDA STAINLESS STEEL

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STAINLESS STEEL WELDING WITH CARBON STEELS

BASIC PRINCIPLES

ISSDA STAINLESS STEEL

Stainless Steel Dissimilar Metal Welding

Welding is without doubt, the most commonly employed method of joining stainless steel. It is accepted as the norm whereby joints of sound structural and corrosion resistant integrity may be affected, in both critical and general fabrications.

Welding technology has made create advances since 1940s and has gone hand in hand with use of stainless steel in the various industrial sectors on which the modern technological society is based.

Welding is a special process. It is a key element, specially in the building of dissimilar metals. Therefore, an awareness and understanding of the basic principles will assist in greater productivity in fabrication, operational integrity, efficiency and maintenance.

Dissimilar metal welding refers 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 there may be a conflict in that optimum control for one metal is undesirable for the other. In such cases, a compromise is needed. This is one reason the development of a DMW procedure often requires more study than a conventional, similar-metal welding procedures.

Fusion Welds and other Joining Methods

The process available for joining dissimilar metals are :

1. Fusion welds

The processes for fusion welds include shielded metal arc (smaw) , gas metal arc (GMAW), sub -merged arc (SAW), flux cored arc (FCAW), and gas tungsten arc (GTAW)with these processes, there is a well defined weld that preferably contains a substantial filler- metal addition with the GTAW process,however ,the amount of filler -metal added is controlled by the welder.the welder should be trained to make the proper filler- metaladdition used for the particular welding procedure.

2. Low-dilution welds

Low-dilution welds include eletronbeam,laser and pulsed arc;athe amount of base metal melted is relatively small and filler metals are not normally added.

3. Non-fusion joining

Typical non-fusion joinig processes are friction welding and explosion welding, diffusion bonding alomng with the briodging 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 application joining DMWs encountered in power in process industries are generally fusion welds made by commonwelding processes.

In fusionwelding, the weld metal is mixture of two metals being joined and the filler metals. In arc welds made with consumable electrode processes such as SMAW, GMAW, SAW and FCAW, and weld metal is well mixed or stirred by the arc action and the composition is quite uniform form one area to another. By sampling any place in the weld bead, the weld composition is determined, and weld properties reasonablypredicted. While the bulk of the weld is well mixed there is unmixed zone (UMZ) at the weld interface, which is a very narrow boundary layer of melted base metal that freezes before mixing with the weld metal. Fortunately, the UMZ is seldom important in normal service environments but., on rare occasions, exhibited selected corrosion attack. There is also a zone of un-melted base metal that will have been altered by the heat of we3lding. 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 predicted. Table-I lists three methods of determining the weld metal composition along with their advantages and limitations. The technique for method 1 is obvious metal is removed from the weld and analysis 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 1. Determining DMW composition

	Method	Advantages	Limitations
1.	Chemical analysis of weld	Most accurate determination	Time consuming, expensive
2.	Approximation of base metal dilution by weld cross section and composition calculated	Less expensive and usually shorter than chemical analysis	Estimating the percentage is often difficult in welds such as multi-pass welds
3.	Approximate dilution figures for common welding process and composition calculated	Quick way of estimating 'rough' composition number laboratory work involved	Welding technique can have a strong influence of dilution in some processes example GMAW, GTAW

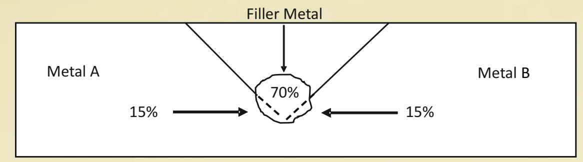

Figure 1. Weld bead with 30% dilution, 15% from Metal A and 15% from Metal B.

The figures are approximate because the welding technique has a strong influence on dilution, particularly with GTWA. Dilution in the SMWA process is most predictable, which is an advantage in making DMWs.

When the amount of dilution from the base metal is determined by either Method 2 and 3 of Table-I, the average percentage of a specific element, X, is determined by the formula,

$X_x = (X_A)(0.15) + (X_B)(0.15) + (X_F)(0.70)$,

Where X_x is the average percentage of element X in the world metal. X_A is the percentage of elements X in base metal A, X_B is the percentage of element X in base metal B, and X_F is the percentage of element X in the filler metal F.

In this example, the dilution is 15% from each base metal- A and B, while the filler metal contributes 70% of the weld volume.

Calculations are normally made for only major alloy constituents, e.g., iron, chromium, nickel, copper, and molybdenum, while elements such as carbon or manganese seldom figure. Though carbon is an important factor in the weldability of iron based alloys, it is of no more significance in a DMW than s similar-metal welding. In other words, it is assumed that both metals in DMW are basically weldable.

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% in certain cases are allowed. 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 gross mismatch 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 (more corrosion resistance than) both base metals. If the weld is anodic (less corrosion resistance), it can suffer accelerated galvanic corrosion.

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 pre-heat, 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. Electrodes can be rebaked in accordance with manufacture's recommendations to reduce moisture.
3. When a pre-heat is needed, a temperature of 150 0C is usually adequate with 200 0C pre-heat used in severe conditions. On completion, the weld should be slow cooled to allow hydrogen to diffuse from the HAZ.

Stainless Steel side

As with welding stainless steel to itself, good welding practice includes such factures as proper cleaning, good fit up and proper shielding gases. Other major consideration is post weld heat treatments to improve HAZ. This can reduce the corrosion resistance and affect the mechanical properties. Heating unstabilised stainless steel of carbon greater than 0.03% reduces intergranular corrosion resistance. If heat treatment is necessary, stabilised or low carbon stainless steel shall be used.

Filler-metal

One of the most common DMW combinations 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 eventually 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 in 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 welds are more susceptible to hot cracking or fissures than welds containing about % 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 -ductile phase prone to hydrogen- related defects, in DMWs, it is advisable to avoid martensite.