AN OVERVIEW ON GAS METAL ARC WELDING (GMAW) OF STAINLESS STEEL (SS)

Scope

This document provides information on welding and related operations of stainless steel which are fabricated in accordance with the terms specified in the latest edition of the following Code:

- AWS D1.6/D1.6M-Structural Welding Code, Stainless Steel

Welding Procedure

The welding shall be done Semi-automatically using the Gas Metal Arc Welding (GMAW) process (Note: Fully Automatic application can also be used).

Please note that as per AWS D1.6 Code, GMAW process is named for both solid wire and also metal cored wires.

GMAW-Metal Cored Wire designed primarily for welding of thin gauge materials. It has higher deposition rate and less penetration than a solid wire and so this wire are best for small butt, fillet and lap type welds on gauge material at increased travel speeds compare to solid wire. Some of the applications for this process are catalytic converters, manifolds, mufflers, exhaust system and cladding.

Semi-automatic welding: Welding with equipment that supplies continuous wire feed with or without means for mechanical travel. Manual manipulation by the welder of one or more of the variables of speed of travel, guidance, and direction of wire is involved during the welding operation.

Joints shall be made by single or multiple pass welding, from one or both sides as specified on WPS.

Fact on Stainless Steels

Stainless steels are commonly divided into the following general groups:

(1) Martensitic (4XX Series)

(2) Ferritic (4XX Series)

(3) Austenitic (include 2XX Series, Cr-Ni-Mn and 3XX Series, Cr-Ni)

(4) Precipitation-hardening (which grades are assigned designations based on their Cr and Ni contents; including austenitic, semi-austenitic and martensitic)

(5) Duplex

Austenitic stainless steels have excellent weldability; have better ductility and toughness than carbon steels or low alloy steels because of the Face-Centered cubic Crystal (FCC) structure.

Base Metals

The base metals used shall conform to ASTM austenitic stainless steel specifications as noted on the WPS.

Other grades of stainless steel may be welded provided accepted WPS are available.

Note: For the purpose of this document, Table 5.2 of Prequalified Austenitic Stainless Steels, base metal Groups A, B, C, D and E of the AWS D1.6 code can be used. However Alloy Designation like 304L, 304, 316L and 316 of group A or B are the most popular ones used in industry.

Base Metal Thicknesses

Base metal from 1.5 mm (1/16 in) or 16 gauge to unlimited thickness as per AWS D1.6 Code.

Filler Metals

Filler metal as per specifications for Stainless Steel Electrodes for Gas Metal Arc Welding under AWS A5.9 for solid wires and AWS A5.22 for metal cored wires.

Following are guides for choosing filler metal match for austenitic stainless steels:

-Joining of similar metal joints; use filler metal of matching composition (e.g. weld 304L material with 308L electrode).

-Dissimilar joining; use the lower alloyed of the two base metals (e.g. use 308 electrode to weld 304 to 316 materials).

-If both metals are low carbon (3XXL), then use low carbon (3XXL) filler metal as well.

Note1: For low or high temperature, corrosive or any critical applications always confirm wire choice with wire manufacturer.

Note 2: For the purpose of this document, Table 5.3 of Prequalified Filler Metal Classifications, lists filler metal groups, based upon strength, which are prequalified for the corresponding prequalified Base Metal Group of Table 5.2 of AWS D1.6 Code. For welding of two different base metal groups in Table 5.2, use filler metal of Table 5.3, corresponding to the lower strength of the two base metal groups.

Storage and Conditioning of Wires

Wires shall be dry and free from surface rust and foreign material. Wires shall be delivered in sealed containers that do not show evidence of damage.

All Wires shall be stored in warm and dry conditions and kept free from oil, grease and other deleterious matter once they have bee removed from their containers.

Shielding Gas

The shielding gas shall be a welding grade having a dew point of -40 °C (-40 °F) or lower.

Shielding gas shall not be done in a draught or wind unless the weld is protected by a shelter.

The shielding gas/ wire combination shall be as shown on the accepted WPS.

Shielding Gas for GMAW-Solid Wire:

Normally shielding gases like Ar+1-2% O2, Ar+1-2% CO2 and Ar+18-33% He+1-2% CO2 are good choices for spray transfer mode of solid wire. However 90% He+7.5% Ar+2.5% CO2 (the most popular one), Ar+2% O2 and Ar+25% CO2 are used in short circuiting transfer mode.

Note 1: Prequalified gases for GMAW are argon and/or helium-based and limited to those containing 0.5% Min. to 6% Max., by volume, of O2 or CO2, including no more than 3% CO2.

Note 2: For the purpose of prequalification, short circuiting transfer mode limited to helium base shielding gas mixes of at least 85% He by volume (like 90% He+7.5% Ar+2.5% CO2).

Shielding Gas for GMAW-Metal Cored Wire:

Shielding gases like Ar+1-2% O2 and Ar+1-2% CO2 are good choices for spray transfer mode of Metal Cored Wire.

Position(s) of Welding

The welding shall be done preferably in the flat position, but other positions such as horizontal, vertical and overhead are permissible when specified on the proper WPS.

Electrical Characteristics

The welding current shall be direct current (reverse polarity) using a constant voltage type power supply. The range of parameters, as per wire manufacturer's instructions, will show on the WPS.

Note on GMAW-Solid Wire:

Note: In short circuiting transfer mode, when using Ar+2% O2 and/ or Ar+25% CO2, voltage shall be reduced about 5 to 6 volts compare with 90% He+7.5% Ar+2.5% CO2 gas mixture.

Preheat and Interpass Temperature

Preheat does not normally apply to the welding of austenitic stainless steel, but if required, details will be shown on the specific WPS. The minimum preheat shall be sufficient to remove moisture from the work. The maximum interpass temperature shall not exceed 350 °F (175 °C) according to AWS D1.6 Code.

Heat Treatment and Stress Relieving

This will not be applicable to structures welded under this document, unless a specific WPS showing all the parameters and acceptance is obtained by an authorized person.

Types of WPS:

There are two types of WPS, Prequalified or non Prequalified. Prequalified WPS uses prequalified joint as specified in a governing code or standard that does not require validation of welding parameters through the performance of a procedure qualification test.

Prequalified joints and requirements for Prequalified WPS are outlined in Section 5 of AWS D1.6

Note 1: All prequalified WPS to be used shall be prepared, approved, and controlled by the manufacturer or Contractor as written prequalified WPS, and shall be available to those who need to use or review them.

Note 2: The use of a Prequalified joint shall not exempt the Engineer from using engineering judgment in determining the suitability of application of these joints to a welded assembly or connection.

General Requirements for Prequalified WPS:

Definition: Groove welds without steel backing, welded from one side, and groove welds welded from both sides, but without back gouging, are considered Partial Joint Penetration (PJP) groove welds for purposes of prequalification. In other hand Complete Joint Penetration (CJP) groove welds made without the use of backing shall have the root back gouged to sound metal before welding is started from the second side.

-Prequalification covers weldments in thickness of 2 mm (1/16 in) or 16 gage and greater, designed for supporting mechanical loads under normal atmospheric corrosion conditions. It applies only to nominally austenitic stainless steel base metals and filler metals whose as-welded fusion zones normally contain a small amount of delta ferrite.

-In addition to the requirement of Table 5.1 and Table 5.4, the following requirements shall apply to all PWPS's (See Clause 5.7 of AWS D1.6 for more detail):

-The classification and size of electrode, voltage, amperage, travel speed, and gas flow rate shall be suited to thickness of material, type of groove and welding position.

-Base Metal Prequalification: Austenitic stainless steels whose filler metals normally produce a small amount of ferrite (as per Table 5.2 of AWS D1.6 for prequalified limits) shall be considered prequalified, provided they are welded with filler metals in accordance with Table 5.3 and the WPS used conform to all the applicable requirements of this code. All other stainless steels or combinations, and WPS which are not prequalified, shall be qualified in conformance to this Code.

-Steel for backing shall be of the same base metal group (Table 5.2 of AWS D1.6) as the base metal, unless otherwise approved.

-Neither the depth nor the maximum width in the cross-section of weld metal deposited in each weld pass shall exceed the width at the surface of the weld pass; see Figure 5.6 of AWS D1.6 Code.

-For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained..

-Prequalified shielding gases are argon and/or helium-based and limited to those containing minimum 0.5% to maximum 6%, by volume, of O2 or CO2, including no more than 3% CO2.

-For the purpose of prequalification, in GMAW-Solid Wire, short circuiting transfer mode limited to helium base shielding gas mixes of at least 85% He by volume (like 90% He+7.5% Ar+2.5% CO2). It also limited to 5 mm (3/16 in) thickness for all position.

-Prequalification for spray mode of transfer is limited to welds in flat position and fillet welds in the flat/ horizontal positions.

Essential Variables

Essential variables should be, as per Table 6.1 of the AWS D1.6 Code. Changes to any of the essential variables require requalification of WPS. **(Note: For Supplementary Essential variables for CVN Testing, See Table 6.2 of AWS D1.6)**

AWS D1.6 Table 6.1: PQR Essential Variable Changes Requiring WPS Requalification

Highlights for Essential Variables of Table 6.1:

Following are general changes requiring a requalification for GMAW process based on Table 6.1 of AWS D1.6, however for full detail list of essential variables, Table 6.1 of AWS D1.6 applies:

(a) a change in base metal thickness qualified per Table 6.3 of AWS D1.6

(b) a change in F-Number (Table 6.5) and/ or A-Number (Table 6.6) of filler metal qualified

(c) a change in the type of welding current (AC or DC) or polarity

(d) a change in base metal M-Number or Clause 6.5 or in base metal type if unlisted

(e) a change in deposited weld metal thickness, exceeding the maximum per Table 6.3

(f) a change from a single gas to any other single shielding gases, or to a mixture of shielding gases, or a change in specified percentage composition of shielding gas mixture, or omission of shielding gas

Preparation of Base Material

The edges or surfaces of parts to be joined by welding shall be prepared by machining, grinding, chipping, plasma or air carbon arc gauging (provided that oxidized surfaces are removed). The process(es) used for removal shall be controlled in such a matter that the adjacent weld metal or base metal is not nicked or gouged and without substantial removal of the base metal. Oxyfuel gas gouging is not permitted. Where hand cutting is involved the edge will be ground to a smooth surface. All surfaces and edges shall be free from fins, tears, cracks or any other defects which would adversely affect the quality of the weld.

All moisture, grease or other foreign material that would prevent proper welding or produce objectionable fumes, shall be removed. Contact with lead, zinc, or lead or zinc compound shall be avoided due to the potential for hot cracking. Chemical cleaning only allowed under supervision of the Engineer for safety, corrosion and weldability effects (**Clause 7.21**).

All surfaces to be welded shall be wire brushed prior to welding. In multi-pass welds the weld bead shall be wire brushed between passes. The brushes shall be of stainless steel and be kept exclusively for use on stainless steel and be kept clean and free of contaminants.

All other equipment such as grinding discs shall be kept exclusively for use on stainless steels.

Back gouging of welds shall produce a groove having a profile and a depth adequate to ensure fusion with the adjacent base metal and penetration into the root of the previously deposited weld metals.

Welds Quality

Cracks or blowholes that appear on the surface of any pass shall be removed before depositing the next covering pass. All welds shall be free of cracks and overlap.

The procedure and technique shall be such that undercutting of base metal or adjacent passes is minimized.

Fillet and groove welds shall meet the desirable or acceptable weld profiles specified in Clause 7.15.2, Figure 7.2, Clause 8.9, and Table 8.1 of AWS D1.6 Code.

The reinforcement in groove welds shall not exceed 3 mm (1/8 in) and shall have a gradual transition to the plane of the base metal surface. Undercut shall be limited to that described in Clauses 6.9 and 7.15.2 of AWS D1.6 Code.

In general, the weld quality will be such as to meet the requirements of Clause 8.7 of AWS D1.6 Code for both statically loaded structures and cyclically loaded structure.

Weld Metal Cleaning

Slag remaining after a pass, if any, shall be removed before applying the next covering pass. After the final pass all slag and weld spatter shall be removed. Arc strikes shall be removed by grinding or other suitable means (by using only stainless steel chipping tool, brush). Cracks or blemishes caused by arc strike shall be ground to a smooth contour and examined visually to assure complete removal.

Welding Technique

Refer to the WPS for the precise variables to be used in welding a particular thickness and joint configuration, position and parameters, i.e. stick-out, gas flow rate, travel speed, passes and layers, etc.

The selection of the torch angle depends on joint type, material thickness, edge preparation, in addition to the degree of skill and experience of the operator.

Generally, the forehand technique provides better visibility of the weld joint and a flatter weld puddle. The backhand technique yields better penetration. Forehand (pushing) technique usually used for butt welds while backhand (drag) technique is usually easier on fillet welds and will result in a neater weld. Torch angle is usually maintained with 10 to 20 degrees on either side of vertical.

The size of any single-pass weld or the size of the first pass of a multiple-pass weld size shall be such as to minimize the possibility of cracking.

Prior to depositing weld metal on the underside of a welding groove, the root shall be gouged, or chipped to sound metal, unless otherwise specified on the applicable WPS.

Keep stainless steel materials clean and dry and keep them in separate place in warehouse.

Special ventilation and/or exhaust are required when welding high chromium alloys such as stainless steels.