Joining Stainless Steel by Soldering, Brazing and Resistance Welding

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Reprinted from
Stainless Steel Industry
January 1975

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by L. D. Connell (Johnson Matthey Metals Ltd)

Stainless steel is a general term covering a group of materials which have different corrosion and heat resistant properties dependent upon their composition and heat treatment. Most users appreciate this difference but there are still instances where drawings will merely state ‘stainless steel’. All stainless steels can be classified into groups and this article relates specifically to those which are collectively known as martensitic and austenitic steels.

Martensitic Stainless Steels

These steels are heat treated and consequently the effects of temperature can influence the mechanical and corrosion resistant properties. It is sometimes necessary to localize the heat affected zone or heat treat the assembly after joining. Martensitic steels are magnetic.

Applications The stainless irons can be fabricated and present few problems in welding although they can give difficulties in brazing. Common applications are turbine blades and household cutlery.

High chromium stainless steels are more affected by temperature and consequently care must be taken to ensure that the correct heat treatment is employed, either before or after joining. Common applications are valve holders and seatings, and surgical instruments where sharp edges are required.

The third group of materials have better corrosive resistant properties coupled with good mechanical properties. They are used for the more specialized components in the turbine, chemical and aircraft applications.

Austenitic Stainless Steels

The austenitic steels are based on the 18% chromium 8% nickel composition although the chromium addition can vary from 15—22% and the nickel from 6—11%. These steels cannot be hardened by heat treatment and must rely for their mechanical properties on mechanical working. This means that any thermal joining treatment will reduce the mechanical properties in the heat affected zone.

The austenitic steels if heated between 550^{0}C and 750^{0}C will precipitate a complex chromium carbide. This will render the material susceptible to corrosion at a rapid rate. The degree of this precipitation will be a function of the carbon content but it is obvious that most thermal joining processes will be a potential hazard. The steels can be stabilized by the addition of either niobium or titanium and all austenitic steels that are to be brazed or welded should either be in this condition or have a low carbon content. Most austenitic stainless steels have low proof stress values and are therefore not used for structural applications unless heavily cold worked. The main applications are in domestic fittings, hotel and general catering utensils and pressed or sheet metal assemblies.

Joining Processes

Soldering Stainless steel can be soldered using the conventional lead—tin solders but the bond strength is often poor as is the colour match. Better results are often obtained by using the silver-bearing soft solders. The silver—tin alloys with approximately 5% silver are particularly useful especially with the stainless steel holloware.

When soft soldering stainless steel it must be remembered that the surface will be protected by a thin oxide film which will have to be removed before satisfactory results can be achieved. The use of resin-based, non-corrosive fluxes will not be satisfactory and an acid-based flux will have to be used especially on the higher melting point silver-bearing alloys. In this case care must be taken to wash off the flux residues. As with most soft solder joints the bond strength of these alloys on stainless steel is low. It is therefore important to design the joint to give the maximum strength on the assembly.

This type of soldering is employed for application where high temperatures, such as would be required for brazing, can cause distortion or where a joint is held mechanically and a seal is required. A typical example is the joining of spouts and bases onto kettle bodies.

The alloys used are as follows:

		Melting range ^{0}C
JMM Plumbsol	25% Ag-Sn	221—225
JMM P5	5% Ag-Sn	221—235
JMM LM10A	10% Ag-Sn-Cu	214—275

Low Temperature Silver Brazing

Stainless steel is used for many applications where it is subjected to stress and it is also frequently subjected to a corrosive environment. For these applications the relatively low strength of the solders makes them unsuitable and the high strength silver brazing alloys are preferred.

Strong ductile joints can be easily made on stainless steel but care must be taken in the choice of brazing alloy and grade of stainless steel to ensure that the joint will be satisfactory in service. Brazing will involve heating the steel to a temperature where carbide precipitation would take place. It is therefore essential that the steel must be stabilized or a low carbon content steel is used.

Particular care must be taken in the selection of brazing alloys for stainless steel when the resultant joints are to be exposed to water or humidity in service. In these conditions failure of the joint can result from corrosion, often referred to as ‘crevice corrosion’, at the brazing alloy stainless steel interface. The mechanism of this failure is complex but the basic mechanism is that a galvanic cell will be set up between the brazing alloy and stainless steel which causes the interface to be removed. Joints that have failed from crevice corrosion usually appear bright and unpitted as though the joint had not been brazed correctly. Failure due to crevice corrosion is rare in joints made in austenitic stainless steel but is more common in the low nickel or nickel-free chromium steels of the ferritic or martensitic type.

Special brazing alloys have been developed to overcome this problem. The most suitable silver brazing alloy for service with any stainless steel where crevice corrosion is a problem is a silver—copper-indium—nickel alloy known as JMM Argo-braze 56. Other alloys which are less resistant to crevice corrosion are also available.

Table 1 Brazing Alloys for Stainless Steels

Name	Composition	BS ref 1845	Resistance to crevice corrosion
JMM Easy-Flo	50% Ag-Cu-Cd-Zn	AG1	No
JMM Easy-Flo No. 2	42% Ag-Cu-Cd-Zn	AG2	No
1845 AG4	61% Ag-Cu-Zn	AG4	No
JMM Easy-Flo No. 3	50% Ag-Cu-Cd-Zn-Ni	—	In some cases
JMM Argo-braze 56	56% Ag-Cu-In-Ni	—	Yes

Table 2 Typical Settings for Spot Welding Stainless Steel

Sheet thicknesses			Electrode tip diameter		Electrode force		Weld time	Weld current
in.	mm*		in.	mm*	lb	kg	cycles	amps
0.022	0.56	24	5/32	4.00	400	180	4	4,000
0.028	0.71	22	3/16	4.75	650	295	5	6,000
0.036	0.92	20	3/16	4.80	750	340	6	7,000
0.048	1.22	18	7/32	5.50	1200	545	8	9,500
0.064	1.63	16	1/4	6.35	1500	680	10	11,000
0.080	2.03	14	5/16	7.95	1900	860	14	14,000
0.104	2.64	12	5/16	7.95	2400	1090	16	16,000

*Approximate metric conversion.

Table 3 Typical Settings for Seam Welding Stainless Steel

Sheet thicknesses			Tread width		Electrode force		Machine setting cycles	
in.	mm*	swg	in.	mm*	lb	kg	on	off
0.012	0.31	30	1/8	3.175	900	405	1	2
0.022	0.56	24	5/32	4.00	1100	495	2	2
0.036	0.92	20	3/16	4.75	1300	590	2	3
0.048	1.22	18	7/32	5.55	1500	680	3	3
0.064	1.63	16	1/4	6.35	1800	815	3	4
0.080	2.03	14	9/32	7.15	2000	905	4	4
0.104	2.64	12	5/16	7.95	2200	995	5	5
0.128	3.25	10	11/32	8.75	2400	1090	5	5

P Approximate metric conversion.

The use of a flux is essential when brazing stainless steel in air. With components where the joint area can be easily heated up to brazing temperature, the JMM Easy-Flo flux stainless steel grade can be used. However, should prolonged heating be necessary, a flux metal reaction will take place when this flux is used. This reaction will form a film on the surface of the stainless steel so that it cannot be wetted by the brazing alloy and the addition of fresh flux will not remove this film. In these instances it is necessary to use a flux known as JMM Tenacity Flux No 5. This has improved high temperature properties and does not react with stainless steel. The only problem is that the residues are not water soluble and have to be removed with caustic soda.

Another aspect associated with the brazing of stainless steel is that of stress cracking. Alloys such as stainless steel have high stress relieving temperatures. This means that stresses can be present in the material when the brazing alloy is molten which can result in the brazing alloy penetrating the grain boundaries to cause cracking. This problem can be overcome by annealing the components before brazing or by slow even heating. Uneven heating can in itself induce stress in the steel and cause cracking on annealed material.

Noble Metal Brazing Alloys Where stainless steel is used in highly corrosive environments or at elevated temperatures likely to cause oxidation, then the choice of brazing alloy and technique is important.

The selection of alloy will depend upon the degree of resistance required. The 5% Pd—Ag—Cu alloy, JMM Pallabraze 810, is the lowest palladium content alloy. These alloys have oxidation resistance up to 500ºC and their corrosion resistance is a function of the palladium content.

Where maximum oxidation resistance coupled with high strength at elevated temperatures is required, the gold—nickel series of alloys should be used. These alloys have excellent flow properties and resultant joints are neat and smooth. The Pallabraze alloys are resistant to crevice corrosion whilst the gold—nickel alloys give maximum protection from crevice corrosion and chemical attack. These alloys are therefore particularly suitable for stainless steel chemical plant.

Whilst joints with the noble metal alloys can be made using a flux and torch heating, most applications require a furnace and vacuum brazing is often employed. It should be noted that where a reducing atmosphere is used then the dew point of the furnace gas must be controlled to at least —40ºC.

Where furnace brazing is the preferred technique and crevice corrosion is a problem with less emphasis on oxidation and corrosion resistance, the maximum economy can be achieved by the use of copper-base alloys. These include a Cu—Ni—B alloy known as JMM 'B' Bronze. This alloy can be used with a flux but is designed for furnace brazing under a reducing atmosphere. Although it is free-flowing and capable of producing neat smooth joints it can also be used for filling gaps—an advantage which in some cases can eliminate costly close tolerance machining.

Resistance Welding

Brazing produces neat leak-proof joints but for some applications appearance is not important and localized heat affected areas are preferred. In these cases resistance welding may be specified.

Spot and Seam Welding Stainless steel can be satisfactorily spot welded provided that the correct procedure is used. It is important to recognize that stainless steel has a high strength at elevated temperatures. This means that a high forging temperature is necessary to ensure that sound welds are produced. Electrode Forces for stainless steel should be approximately 50% greater than those used for mild steel. The effect of this high electrode force will be deformation of the electrode and consequently the necessity for frequent redressing of the electrode. Due to the fact that stainless steel has high electrical resistance it is possible to employ electrodes with a higher resistance than the chromium copper types used on mild steel. The preferred electrode material for stainless steel is a copper—cobalt—beryllium material known as Mallory 100. This alloy has a tensile strength of 69 h bar and an electrical conductivity of 45% IACS. It is also the preferred alloy for seam welding wheels.

Projection Welding Projection welding of stainless steel, although a practical proposition, is not widely used. The strength of the projection and the high pressure involved usually mean that electrodes inserted with copper tungsten Elkonite 20W3 have to be used. Where projection welding is in the form of cross wire welding the Mallory 100 alloy is usually satisfactory.

Typical resistance welding settings for use on stainless steel are given in Tables 2 and 3.

Printed by Adlard & Son Ltd., Bartholomew Press, Dorking