Interfacial Corrosion in Stainless Steel Brazed Joints

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Interfacial corrosion or crevice corrosion can occur in stainless steel brazed joints if certain adverse conditions exist. This article summarizes the available literature and also relates to Johnson Matthey Metals' own experience in this field. The visual appearance of a joint that has failed due to interfacial corrosion is described and the requirements necessary to produce failure and means of preventing such failures occurring are discussed. There is also a brief mention of the failure mechanism.

Visual Appearance of Failure

When a failure of this type occurs the initial reaction is usually to blame the operator, since the joint does not appear to have been brazed properly in the first place. Although, if the joint is tested after brazing, it will be found to have adequate strength. Typically the brazing metal has become detached or can be peeled away easily from the joint surfaces of the parent materials. In those areas where the brazing alloy has been removed the surface of the stainless steel beneath is a dull slate grey in colour, suggesting that the alloy has failed to bond and wet successfully. It is also typical that the extreme outer edge of the brazing alloy still remains firmly attached to the parent materials giving a halo effect in certain circumstances.

It is sometimes possible to see the first signs of interfacial corrosion attack within 30min to 2 hr. Initially a brown tinge can be observed around the periphery of the braze metal which transforms readily to spots of rust-like appearance. However, this is not conclusive evidence that the joint will be attacked to the point at which failure occurs, since research has shown that the attack can be arrested.

Requirements to Produce Failure

To produce a joint failure by interfacial corrosion three requirements need to be satisfied.

1 One member of the joint must be made from a stainless steel.

2 The brazing alloy must be susceptible to this form of attack.

3 The finished joint must be exposed to damp or wet environments.

The Parent Materials

All types of stainless steel and certain iron-chromium alloys outside of the stainless steel classification are susceptible to attack by interfacial corrosion. The available research information and the experience of Johnson Matthey Metals indicate that the nickel-free or low nickel ferritic and martensitic type stainless steels are more susceptible to attack and suffer a more rapid rate of corrosion than the austenitic grades. Failures with ferritic stainless steels have been reported within as little as 48 hr, while the austenitic steels under the same conditions have resisted attack for periods in excess of 30 days.

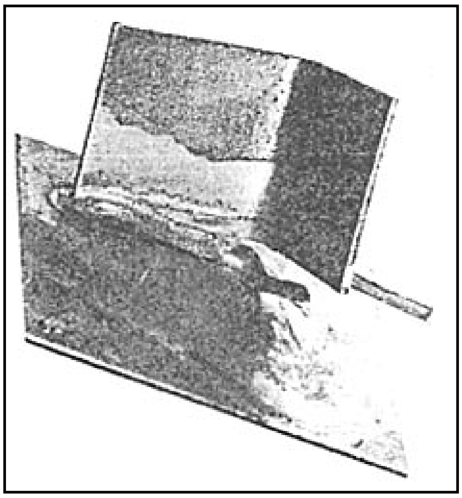
Susceptible Brazing Alloys

This is probably the most confused area within the whole subject of interfacial corrosion. It is apparent from research and from the company's experience that the degree of susceptibility or immunity is dependent not only on the type of brazing alloy employed, but also on the type of steel being brazed, the service environment of the joint and to some extent even on the brazing technique. It has also been found that such operations as polishing on the finished joint affect the likelihood of attack.

Unfortunately the most common brazing techniques, i.e. where a flux and silver-containing brazing alloys are employed, represent those joints which are the most susceptible to failure. As already indicated the question of susceptibility is complex. In some cases a positive conclusion can be reached, but there are still instances where it is difficult to give precise reasons for the failure. Table 1 is a summary of the available information related to the susceptibility of various alloys and base metal combinations.

Service Environment

Research into interfacial corrosion has been conducted using tap water, aqueous solutions of acids, aqueous solutions containing sodium chloride and other alkaline cations and alkaline earths. All of these solutions produced failure on those joints brazed with susceptible alloys. Experience at Johnson



1 Example of a joint that failed.

Matthey Metals suggests that most aqueous solutions will produce failure on susceptible joints to a greater or lesser degree. Such solutions as tap water, beer, orange juice and coffee have all produced failure on susceptible joints at some time. Joints exposed to the atmosphere have also failed, but only after three or four years in service. The only environment tested that did not produce failure was a 5% sodium hydroxide solution.

Table 1 Brazing Alloys

	Susceptibility of steel type	
Brazing alloy type*	Ferritic	Austenitic
Ag—Cu—Zn—Cd (Easy-flo)	C	D
Ag—Cu—Zn (Silver-flow 45)	C	D
Ag—Cu—Zn—Cd—Ni (Easy-flo No 3)	D	B
Ag—Cu—Zn—Ni (Argo-braze 40)	D	B
Ag—Cu—Zn—Ni—Mn (Argo-braze 49)	D	B
Ag—Cu—Zn—Sn (Silver-flo 55)	D	B
Ag—Cu—In—Ni (Argo-braze 56)	A	A
Ag—Cu—Sn—Ni	A	A
Ag—Cu Silver copper eutectic	C	C
Ag—Mn 15% Manganese silver	C	C
Palladium containing alloys (Pallabraze 810)	A	A
Gold-containing alloys (Orobraze)	A	A
Nickel-based alloys	A	A
High copper alloy (JMM 'B' bronze)	A	A

A Should be resistant under most conditions.
B May offer limited or complete protection dependent on conditions.
C Rapid joint failure can be expected in very short period.
D Joint failure likely to occur after some time (less rapid than above).
* JMM trade names are given in brackets below each alloy.

Failure can also be produced, even on resistant brazing alloys and base metal combinations, if certain types of fluxes are used in making the joint. Such fluxes are fairly readily identifiable since they are dark brown in colour. JM fluxes of this type are Tenacity No. 5A and Tenacity No. 6.

Prevention

The easy way of preventing failures due to interfacial corrosion is to use those brazing alloys which offer a high degree of protection. This is not always a convenient route since the brazing characteristics of some of the suitable alloys tend not to be particularly good. Such a change may also result in changing the joint design, joint clearance, brazing technique, type of flux employed, etc. It can also be important with some of the specialized alloys that they are applied in a certain manner as incorrect application can result in joints which are susceptible to attack. Table 1 lists alloys that offer protection.

Protection can also be provided by the application of a coating which will prevent the service environment coming in contact with the brazing alloy. Plating may be considered but care is necessary since joints may be produced that are partially corroded as a result of attack by the plating solution. An application of soft solder over the brazing alloy is one method which has also been adopted. In addition, it has been suggested that resistant joints may be made as a result of brazing onto a plated surface of either nickel, gold or palladium.

The Failure Mechanism

The physical reasons why joints fail in this particular mode have been investigated by various research workers who have evolved a fairly complex theory of the mechanism about which there is general agreement. For those wishing to understand more about the phenomena, references are included at the end of this article but the summary below based on personal investigations should be of assistance to those engaged in the fabrication and brazing of stainless steel.

Interfacial corrosion in simple terms appears to be a two stage process. It involves initially a corrosive attack on the brazing alloy itself. Although the attack will occur all over the surface of the braze metal exposed to the corrosive environment, it is only at a point slightly in from the edge of the brazing alloy where it is critical. At this point a selective form of corrosive attack similar to dezincification takes place at an accelerated rate, due to the cathodic nature of the stainless steel surface in the near vicinity. This attack results in the formation of channels which extend from the surface of the braze to the interface region; this in turn allows the corrosive environment to affect this interface region. Once this initial stage has occurred (it has been suggested that this can occur within 30 min) the dissolution of the interface layer then takes place in an electrolytic cell manner. The secondary stage of the dissolution of the interface layer would seem to have a very complex nature, with corrosion products contributing to the reaction and also the chromium-depleted surface beneath the brazing alloy.

The resistance of certain alloys has been attributed to the type of interface layer which is of course dependent on the brazing alloy composition. Nickel has been found to be a beneficial addition to silver brazing alloys, as this is a major constituent of the interface layer when such alloys are employed. Gold and palladium are also considered beneficial in this respect but are expensive. The following elements have been found to be detrimental and are listed in decreasing order of merit, with respect to the effects of such additions on interface corrosion: cadmium, tin, manganese, zinc.

Summary

The subject of interfacial corrosion is a very complex one indeed. There is still a great deal to learn about the phenomena and no one can yet provide a positive guarantee that any particular joint will not fail. Experience has shown that susceptible alloys can be used without failures being reported while reputedly resistant alloys have not always proved satisfactory. Wherever interfacial corrosion is likely to be a service hazard and the application is of a critical nature tests should be conducted. If the application is not critical, one of the recommended alloys, which appears to offer resistance under most conditions, should be used.

References

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