ador WELDING

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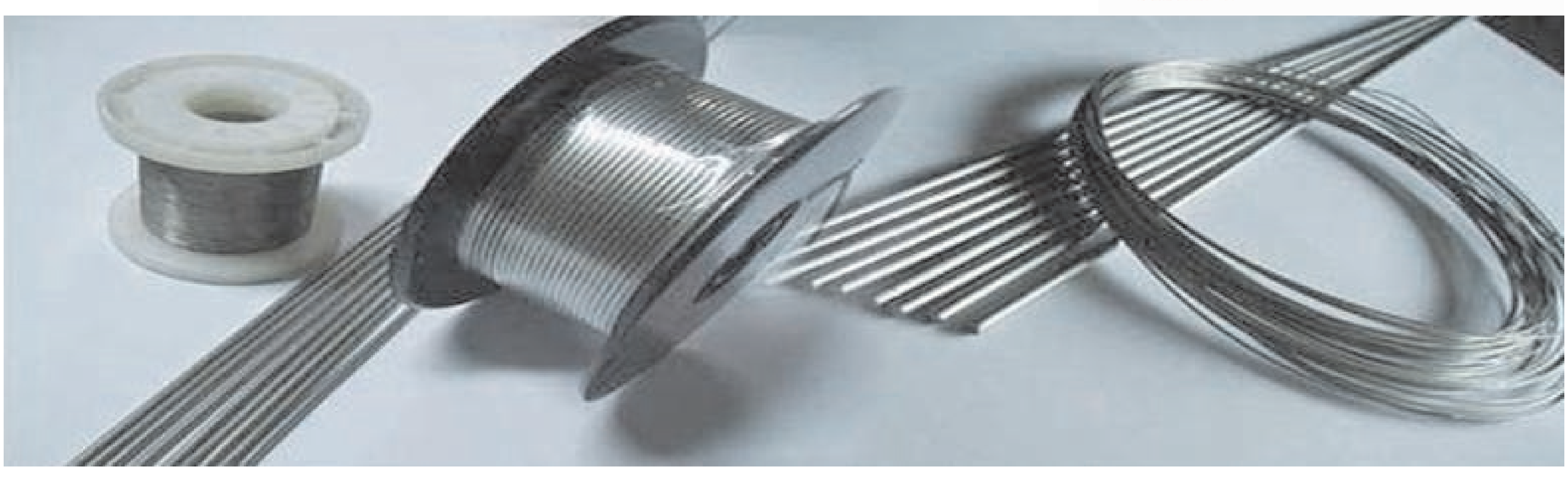
Welding with Nickel Alloys

- BASIC TYPES OF NICKEL ALLOYS
- WELDABILITY & WELDING PROCESSES.
- WELDING IMPERFECTIONS & PREVENTIVE MEASURES.
- FILLER ALLOY SELECTION.



Nickel and its alloys are chosen for:

- Corrosion resistance.
- Heat resistance and high temperature properties.
- Low temperature properties.

TYPES OF NICKEL ALLOYS:

1. Solid Solution Alloys.

Ni-Cu alloys and the simpler Fe-Ni-Cr alloys.

These alloys are readily fusion welded, normally in the annealed condition.

As the heat affected zone (HAZ) does not harden, heat treatment is not usually required after welding.

Examples: Monel ,Alloy 600,Alloy 625,Alloy 617, Alloy 800, Alloy 825

2. Precipitation Hardened Alloys.

Ni-Cu-Al-Ti, Ni-Cr-Al-Ti and Ni-Cr-Fe-Nb-Al-Ti.

Mechanical properties are developed by heat treatment (solution treatment plus ageing) to produce a fine distribution of particles in a nickel-rich matrix.

These alloys may susceptible to post-weld heat treatment cracking.

Examples: Monel K500, Alloy 700, Nimonic PE 16

Weldability

Nickel and its alloys are similar in many respects to the austenitic stainless steels & welding procedures are likewise also similar.

Nickel, however, has a coefficient of thermal expansion less than that of stainless steel so distortion and distortion control measures are similar to those of carbon steel.

Process:

Most nickel alloys can be fusion welded using gas shielded processes like TIG or MIG.

Of the flux processes, MMA is frequently used but the SAW process is restricted to solid solution alloys and is less widely used.

Solid solution alloys are normally welded in the annealed condition and precipitation hardened alloys in the solution treated condition.

Preheat:

Preheating is not necessary unless there is a risk of porosity from moisture condensation. It is recommended that material containing residual stresses be solution-treated before welding to relieve the stresses.

Post-weld heat treatment :

It is not usually needed to restore corrosion resistance may be required for precipitation hardening or stress relieving purposes to avoid stress corrosion cracking.

Surface Preparation:

The normal method of cleaning is to emote all surface oxide by machining, grinding or scratch brushing and finally degrease.

Common imperfections found in welding :

1) Porosity
2) Oxide inclusions and lack of inter-run fusion
3) Weld metal solidification cracking

Post-welding imperfections :

Post-weld heat treatment cracking

Stress corrosion cracking

1) Porosity

Porosity can be caused by oxygen and nitrogen from air entrainment and surface oxide or by hydrogen from surface contamination.

Careful cleaning of component surfaces and using a filler material containing de-oxidants (aluminium and titanium) will reduce the risk.

When using argon in TIG and MIG welding, attention must be paid to shielding efficiency of the weld pool including the use of a gas backing system. In TIG welding, argon-hydrogen (90/10) gas mixtures tend to produce cleaner welds.

As little as 0.025% nitrogen will form pores in the solidifying weld metal. Quite light draughts are capable of disrupting the gas shield and atmospheric contamination will occur resulting in porosity.

2) Oxide inclusions and lack of inter-run fusion

As the oxide on the surface of nickel alloys has a much higher melting temperature than the base metal, it may remain solid during welding.

Oxide trapped in the weld pool will form inclusions. In multi-run welds, oxide or slag on the surface of the weld bead will not be consumed in the subsequent run and may cause lack of fusion imperfections.

Before welding, surface oxide, particularly if it has been formed at a high temperature, must be removed by machining or abrasive grinding; it is not sufficient to wire brush the surface as this serve only to polish the oxide.

During multipass welding, surface oxide and slag must be removed between runs.

3) Weld metal solidification cracking

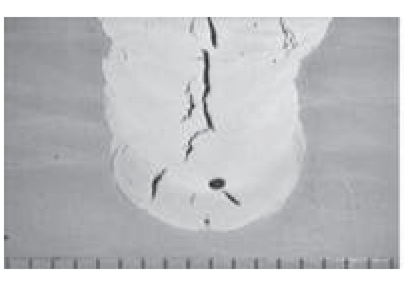
Controlling factors: Alloy, welding process and welding conditions.

e.g: solidification cracking is a factor which limits the application of submerged arc welding, both with respect to applicable alloys and welding conditions.

This type of cracking leads to restriction of weld shape, welding speed and technique.

Similar to austenitic stainless steel, nickel alloys are susceptible to formation of liquation cracks in reheated weld metal regions or parent metal HAZ.

This type of cracking is controlled by factors outside the control of the welder such as grain size or impurity content. Some alloys are more sensitive than others. For example, some cast superalloys are difficult to weld without inducing liquation cracks.



Hot Cracking :

Happens either in the weld metal or close to the fusion line in the HAZ with the latter being the more frequent.

The main source of this problem is sulphur but phosphorus, lead, bismuth and boron also contribute.

Both weld metal and HAZ cracking are generally the result of contamination by grease, oil, dirt, etc left behind following inadequate cleaning; excess sulphur in the parent or weld filler metals causing a problem is a rare event.

Machining or vigorous stainless steel wire brushing followed by thorough degreasing with a suitable solvent is necessary prior to welding, with the welding taking place within about eight hours to reduce the risk of contamination.

Any heat treatment must be carried out using sulphur-free fuel or by using electric furnaces.

Components that have been in service and require weld repair may need to be ground or machined prior to degreasing to remove any contaminants that have become embedded in the surface in or adjacent to the weld repair area.

If mechanical wire brushing is carried out AFTER the degreasing operation or during welding the compressed air from air powered tools contains both moisture and oil and the cleaned surfaces may be therefore be re-contaminated.

Post-weld heat treatment cracking:

This type of cracking is also known as strain-age or reheats cracking.

It is likely to occur during post-weld ageing of precipitation hardening alloys but can be minimised by pre-weld heat treatment.

Solution annealing is commonly used but over ageing gives the most resistant condition.

Alloy 718 alloy was specifically developed to be resistant to this type of cracking

General measures for prevention of defects:

Care must be taken to ensure that the weld area is sufficiently protected and this is particularly relevant in site welding applications.

With the gas shielded processes, gas purity and the efficiency of the gas shield must be as good as possible.

Gas hoses should be checked for damage and leaks at regular intervals and, with the TIG process, as large a ceramic shroud as possible should be used together with a gas lens.

Gas purging of the root is essential when depositing a TIG root pass.

Oxygen is also a cause of porosity in certain circumstances when it combines with carbon in the weld pool to form carbon monoxide.

Consumable manufacturers generally overcome this problem by ensuring that sufficient deoxidants (primarily manganese, aluminium and titanium) are present in the filler metal.

General measures for prevention of defects:

A difficult to remove viscous and adherent scum the surface of the weld pool is formed while welding that may result in inclusions and lack of inter-run fusion if not removed prior to depositing the next pass.

Wire brushing is frequently not sufficient to remove this layer and it then becomes necessary to grind the weld surface.

The weld start should be carried out by welding back over the arc strike position, remelting any porosity that has formed due to the poor gas shielding at the start of the weld.

Care also needs to be taken at the weld end, with the arc length reduced and travel speed increased slightly to reduce weld pool size.

The weld pool, in addition to this surface film, is also sluggish and does not flow freely as with a carbon or stainless steel.

This may result in a lumpy and very convex weld bead and a poor toe blend unless the welder manipulates the weld pool to avoid such defects. Although stringer beads may be used, a slight weave to assist the weld metal to wet the side walls of the preparation is beneficial.

Weld preparations must be sufficiently wide to enable the welder to control and direct the weld pool; an included angle of 70 to 80° is recommended for V butt welds.

General measures for prevention of defects:

Penetration of Nickel Alloys is less than with a carbon or stainless steel.

Increasing the welding current will not increase penetration. The implication of this is that the root face thickness in single sided full penetration welds should be less than with a stainless steel.

It is recommended that the thickness of the root face should not be greater than 1.5mm in a zero gap TIG butt weld.

Removable backing strips are very useful to control root bead shape. These can be made from copper, stainless steel or a nickel alloy. Carbon or low alloy steel backing strips should be avoided.

Selection of Filler alloys :

Filler composition normally matches the parent metal.

Most filler materials also contain a small amount of titanium, aluminium and/or niobium to help minimise the risk of porosity and cracking.

Filler metals for gas shielded processes are covered in BS EN 18274:2004 and in the USA by AWS A5.14.

Many of the nickel alloy filler metals have been used for making dissimilar metal joints with excellent results.

Nickel also has a coefficient of thermal expansion between that of ferritic and austenitic steels and therefore suffers less from thermal fatigue when it undergoes thermally cycling.

Alloy 625 has been a popular choice, the weld tensile strength matching or exceeding that of the parent metal and has been extensively used in welding dissimilar joints in austenitic and duplex steels.

Use of this filler metal has resulted in the formation of niobium rich precipitates adjacent to the fusion line and has been discontinued. Alloy 59 or C22 filler metals have now replaced replaced Alloy 625 as the filler of choice.

Ador Welding has many consumables for Nickel alloys for SMAW / MIG & TIG processes.

Some Nickel welding alloys from Ador Welding:

Nicalloy 1 (ENi-1) & Tigfil Ni1 (ER Ni-1)

Nicalloy Fe2 (E NiCr Fe2) & Tigfil NiCrFe2 (ER NiCrFe2)

Nicalloy Fe3 (E Ni Cr Fe3)& Tigfil NiCr Fe3(Er NiCrFe3)

Nicalloy Mo3 (E Ni Cr Mo3) & Tigfil NiCrMo3 (ERNiCrMo3)

Nicalloy Mo 4 (E Ni Cr Mo4) & Tigfil NiCrMo4 (ERNiCrMo4)

Nicalloy Mo5 (E Ni Cr Mo5) & Tigfil NiCrMo5(ERNiCrMo5)

Ador Welding also manufactures Nickel Alloys for SAW welding.