Welding Job Knowledge

Nickel and nickel alloys

Weldability of materials

Job Knowledge

Nickel and nickel alloys are chosen because of their:

- corrosion resistance
- heat resistance and high temperature properties
- low temperature properties

Types of nickel alloys are identified and guidance is given on welding processes and techniques which can be used in fabricating nickel alloy components without impairing their corrosion or mechanical properties or introducing flaws into the weld.

Material types

The alloys can be grouped according to the principal alloying elements. Although there are National and International designations for the alloys, tradenames such as Inconel and Hastelloy, are more commonly used.

In terms of their weldability, these alloys can be classified according to the means by which the alloying elements develop the mechanical properties, namely *solid solution alloys* and *precipitation hardened alloys*. A distinguishing feature of precipitation hardened alloys is that mechanical properties are developed by heat treatment (solution treatment plus ageing) to produce a fine distribution of particles in a nickel-rich matrix.

Solid solution alloys

Solid solution alloys are pure nickel, 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.

Precipitation hardening alloys

Precipitation hardening alloys include Ni-Cu-Al-Ti, Ni-Cr-Al-Ti and Ni-Cr-Fe-Nb-Al-Ti. These alloys may susceptible to post-weld heat treatment cracking.

Weldability

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

Filler alloys

Filler composition normally matches the parent metal. However, most fillers contain a small mount 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. Recommended fillers for selected alloys are given in the table.

Table 1: Filler selection for nickel alloys		
Parent Alle		**Comments**
Alloy		
kel		
00		ıg filler metal normally contains 3%Ti
opper		
0		ıg filler metal contains additions of Mn, Ti and Al
hromium		
ıy S		ıd Ni-Cr-Fe filler metals may be used
75		
hromium-		
0		welded with Ni-Cr-X alloys, but more nearly matching consumables are available which c and also Nb
0		ıg filler metal contains Nb addition
8		ıg filler metal is normally used but Alloy 625 is an alternative consumable , if postweld he ınt is not applied
hromium- enum		
5		etal is also used widely for cladding and dissimilar welds

y C-22	
Molybdenu	
y B-2	on resistant alloys require matching fillers

Imperfections and degradation

Nickel and its alloys are readily welded but it is essential that the surface is cleaned immediately before welding. The normal method of cleaning is to degrease the surface, remove all surface oxide by machining, grinding or scratch brushing and finally degrease.

Common imperfections found on welding are:

- porosity
- oxide inclusions and lack of inter-run fusion
- weld metal solidification cracking
- microfissuring

Additionally, precautions should be taken against post-welding imperfections such as:

- post-weld heat treatment cracking
- stress corrosion cracking

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 deoxidants (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 gas mixtures tend to produce cleaner welds.

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.

Weld metal solidification cracking

Factors which control solidification cracking include alloy, welding process and welding conditions. For example, solidification cracking is a factor which limits the application of submerged arc welding, both with respect to applicable alloys and welding conditions. More generally, this type of cracking leads to restriction of weld shape, welding speed and technique.

Microfissuring

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.

Post-weld heat treatment cracking

This is also known as strain-age or reheat 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 overageing gives the most resistant condition. Alloy 718 alloy was specifically developed to be resistant to this type of cracking.

Stress corrosion cracking

Welding does not normally make most nickel alloys susceptible to weld metal or HAZ corrosion. However, when Alloy 400 will be in contact with caustic soda, fluosilicates or HF acid, stress corrosion cracking is possible. For such service, thermal stress relief is applied after welding.

Stress corrosion can also occur in Ni-Cr alloys in high temperature water. High chromium filler metal has been developed for welds and overlays in this environment.