Analysis of Mechanical Behaviour of Dissimilar Metal Welding for Monel and Inconel

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Abstract

Welding process can be performed on similar or dissimilar metals. Welding of dissimilar metals involves different types of metals with distinct chemical composition. The two dissimilar metals involve in welding process have different mechanical properties and microstructures which in turn may affect welding parameters like weld current, hold time, weld force etc. In our project we investigate about dissimilar metal welding of Monel and Inconel in various parameters and to evaluate the Mechanical (hardness, Tensile, Toughness) properties in welded materials.

Introduction

The modern age demands fast production of structures. Welding is an efficient process where two materials whether of same or different composition are join together permanently. The cryogenic requirements for the pharmaceutical and biotechnology industries are relatively high and the materials of construction for processing vessels and piping systems must demonstrate outstanding corrosion resistance and clean ability to ensure the purity and integrity of the drug product.

The project starts with chemical analysis of materials and preparation of Welding Procedure Specification (WPS) based on thermal and mechanical properties and compared with American Welding Society. In welding by controlling the parameters of thermal property mechanical deviations are reduced and so weld with fewer defects could be obtained and also the service life of material will be increased.

Methods of Welding

There are different methods of welding that are used to join dissimilar metals such as explosive welding, cold welding, ultrasonic welding, diffusion welding, friction welding, electron beam welding, arc welding and resistance spot welding.

Dissimilar Metal Welding

In modern steel constructions it is extremely important to perform a durable dissimilar metal weld between carbon steel and stainless steel. When welding such dissimilar metal welds the choice of filler metal plays a vital role and usually has a composition differing from both of the parent metals.

Welding dissimilar metal welds faces many characteristic problems caused by structural changes and several constitutional changes can occur during welding. Changes in the dilution ratio of the parent metals are possible and affected by the welding conditions. During welding a stable manufacturing and good crack resistance is important. If the dilution between the filler metal and parent metals increases, the ferrite content will decrease in the case of welding carbon steel to stainless steel. If the amount of stainless steel diluted to the weld metal increases the structure can be fully austenitic and the risk of hot cracking increases significantly.

Selection of Materials

Monel

Monel is a group of nickel alloys, primarily composed of nickel (up to 67%) and copper, with small amounts of iron, manganese, carbon, and silicon. Stronger than pure nickel, Monel alloys are resistant to corrosion. They can be fabricated readily by hot- and cold-working, machining, and welding.

Fig 1. Monel

Monel Chemical Composition

Elements	% Level
Carbon (**c**)	0.3
Manganese (**Mn**)	2.0
Silicon (**Si**)	0.5
Nickel (**Ni**)	63.0
Sulphur (**s**)	0.024
Copper (**cu**)	28.0-34.0
Iron (**Fe**)	2.5

Table 1.Monel chemical composition

Monel properties

Monel is a solid-solution binary alloy. As nickel and copper are mutually soluble in all proportions, it is a single phase alloy. Compared to steel, Monel is very difficult to machine as it work-hardens very quickly. It needs to be turned and worked at slow speeds and low feed rates. It is resistant to corrosion and acids, and some alloys can withstand a fire in pure oxygen. It is commonly used in applications with highly corrosive conditions

Uses of Monal

- Aerospace applications
- Oil production and refining
- Marine applications

Inconel

Inconel is a non-magnetic, corrosion and oxidation resistant, nickel based alloy. This alloy has high fatigue strength, exhibits excellent resistance to stress corrosion cracking. Nickel and Chromium provide stabilizing effect from oxidizing environments. The nickel based alloys like Inconel also resist problems caused due to carbon migration.

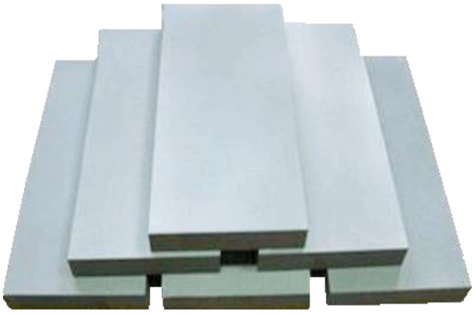

Fig 2. Inconel

Inconel Chemical Composition

Elements	% Level
Carbon (C)	0.05 max
Manganese (Mn)	0.50 max.
Silicon (Si)	0.50 max.
Copper (Cu)	0.50 max.
Sulphur (S)	0.015 max
Chromium (Cr)	27.0 – 31.0
Nickel (Ni)	58.0 min
Iron (Fe)	7.0 – 11.0

Table 2. Inconel chemical composition

Mechanical properties

For service at 1200°F and below- Hot finished, cold-finished, and annealed conditions (depending on requirements involved) are recommended.

For service above 1200°F- Either annealed or solution-treated material will give best service. The solution-treated condition is recommended for components that require optimum resistance to creep or rupture.

Inconel Application

- Marine Industries
- Chemical processing Industries
- Oil and gas industries.

Welding process

Welding is a fabrication process that joins materials by causing coalescence in which heat is supplied either electrically or by mean of a gas torch, This is often done by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

Tungsten inert-gas arc welding

Tungsten inert-gas arc welding (TIG) is a fusion welding method that was developed in the late 1930's. The TIG-method is characterized by its high quality weld metal deposits, great precision, superior surfaces and excellent strength. . In the TIG-method a non-consumable electrode of tungsten or tungsten alloy is used, in comparison to other common welding methods where the filler metal also is the electrode.

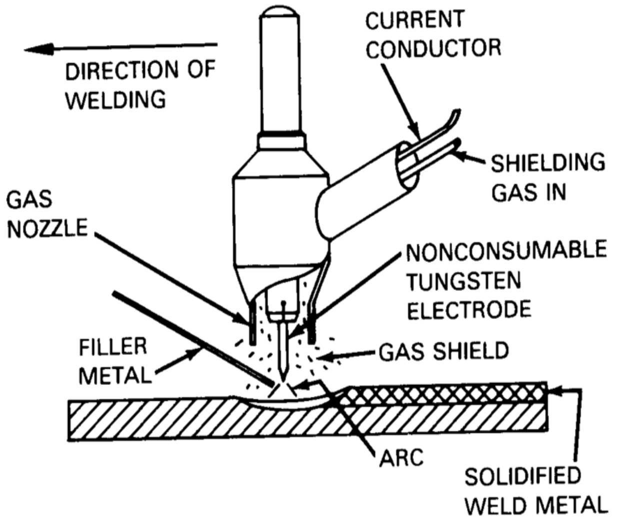

Fig 3. Tungsten Arc Welding

Advantages

- Produces a high quality and a low-distortion weld
- Free of splatter that is associated with other methods
- Can be used with or without filler metal

Filler rod

E 304	Corrosion resistant
E 316 , 330	High and low temperature strength
E 410, 420	Abrasion resistant

E304-16 electrodes are used to weld stainless steel.

Welding procedure specifications

Gas : ARGON
Rod : ER304L (Filler Rod)
Flow Rate : 4-6L/min
Current : 60-110A
Speed : LOW SPEED
Class Diameter Range :1.6mm
Voltage : 10-12V
Polarity : DCEN-Direct Current Electrode Negative
Bead : Weaving Bead
Heat Input :Medium Heat Input

Mechanical Property Test

Tensile Test

Tensile test is used to determine the tensile strength of the specimen, % elongation of length and % reduction of area. Tensile test is usually carried out in universal testing machine Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen

Hardness Test

A simple and economical way to characterize the mechanical properties and microstructure is by performing hardness measurements. By performing hardness measurements the highest and lowest levels of hardness can be determined. In dissimilar metal welds the hardness level of parent metals and weld metal are determined. The most interesting part is where the transition from parent metal to weld metal takes place and in the root bead of the weld.

Toughness Test

It is well understood that ductile and brittle are relative, and thus interchange between these two modes of fracture is achievable with ease. The term Ductile-to-Brittle transition (DBT) is used in relation to the temperature dependence of the measured impact energy absorption.

Advantages and Applications:

1. Non-ferrous metals with high strength and toughness
2. Higher creep stress and rupture properties when compared with 304
3. Ideal for high temperature services
4. Overcomes sensitization and inter granular corrosion concerns
5. Can be used in elevated temperature applications for boiler and pressure vessel application

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6. Corrosion resistance, wear resistance
7. Aerospace aircraft gas turbines

Tensile Test:

ID	Yield load (KN)	Yield strength (N/mm^2)	Tensile load (KN)	Tensile strength (N/mm^2)	%E
1	65.92	293.01	72.55	401.68	4.32

Table 3. Tensile Test

Thickness = 6mm

Width = 30mm

Cross Sectional Area (CSA) = $180mm^2$

Initial Gauge Length (IGL) = 100mm

Final Gauge Length (FGL) = 104.32mm

% Elongation= ((FGL-IGL)/IGL) ×100

Hardness Test:

ID	Impression (Hardness Value in HRB)
1	123, 126

Table 4. Hardness Test

Impact Test (Charpy Test):

ID	Impact Values in Joules
1	74

Table 5. Impact Test

Conclusion

In raw materials before welding the Strength calculated and also Micro and chemical test is made to get the exact values of material composition. During Welding Strength will be decreased as because due to the change of properties and behaviour of materials. After Welding Heat treatment is to be carried out to maintain the strength of material. Finally Tensile, Toughness and Hardness test are tested.

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