WELDWELL Spectrum

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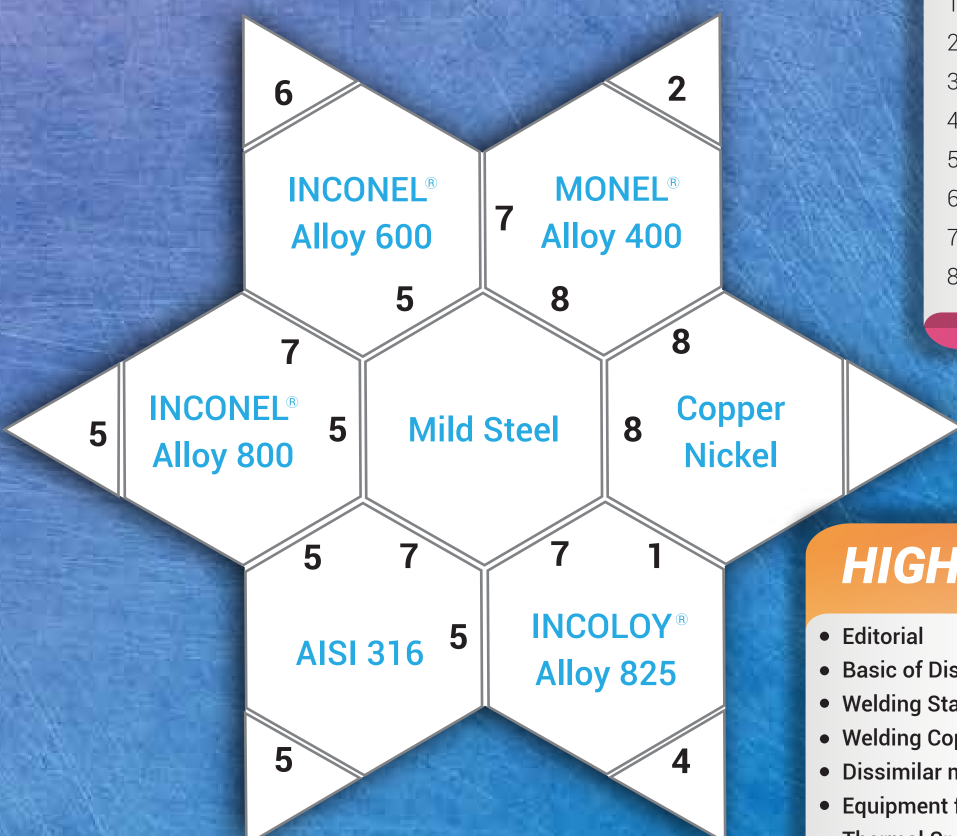
Dissimilar Metal Welding



Consumable Key

1. Inconel® Filler Metal 625
2. Monel® Welding Electrode 190
3. Monel® Welding Electrode 187
4. Inconel® Welding Electrode 112
5. Inco-Weld® A Welding Electrode
6. Inconel® Welding Electrode 182
7. Inconel® Filler Metal 82
8. Monel® Filler Metal 60

HIGHLIGHTS

- Editorial
- Basic of Dissimilar Metal Welding
- Welding Stainless Steel of other Metals
- Welding Copper to Various Metals
- Dissimilar metal Welding of other metals
- Equipment for Dissimilar Metal Welding
- Thermal Spray Applications Get A Boost In India
- Dissimilar Welding of Ni and Ni base alloys
- Matrix of Nickel-based Welding Consumables for Welding of Dissimilar Metals
- NEWS from Industrty

WELDWELL®

IN SERVICE TO THE WELDING COMMUNITY

EDITORIAL

Dear Reader,

Wishing one and all a very happy, educative and prosperous year 2020.

After highlighting, the proud achievements of the Indian Space and Nuclear Industries, the new issue of Weldwell Spectrum focusses on the importance of Dissimilar Welding. There are numerous products being designed using different metal and alloy combinations to optimize specific properties of finished products. This leads to many dissimilar metal welding applications across all industries. It allows each section of the product subjected to different environments to be optimized. The welding of steels of different strengths are also considered as dissimilar welding.

The considerations of a successful dissimilar joint and the fundamental factors affecting dissimilar welding are spelled out in "Basics of Dissimilar Welding".

Stainless Steel is one of the most common metals involved in joining of different metals. The factors influencing and selection of consumables through prediction charts are discussed in "Welding Stainless Steel to other Steels".

Copper surfacing and overlaying for corrosion resistance is one of the most important applications, especially in the maritime sector plays an important role. The characteristics are covered in "Welding of Copper to various Metals". Joining applications with its own alloys and the welding consumables used also forms an important part of this article.

For application metals resistant to corrosion and at high temperature Nickel & Nickel-based alloys are preferred. "Dissimilar welding of Nickel and Nickel base Alloys" describes the typical requirements of welding.

"Dissimilar Metal Welding of other Metals" discusses various miscellaneous common combinations of dissimilar joints for specific applications.

A case study of dissimilar metal welding indicates the special parameters required. The details of the welding machine used is described in "Equipment for Dissimilar Metal Welding".

"Thermal Spray Applications Get a Boost in India" indicates the expansion of our product profile in this important segment of the industry.

We once again appeal to our esteemed readers to offer their valuable comments and feedback to make the 'Spectrum' more interesting.

Ashok Rai
Editor

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Basics of Dissimilar Metal Welding

Introduction

Design engineers are increasingly faced with the need to join dissimilar materials as they are seeking creative new structures or parts with tailor-engineered properties. Sometimes a part needs high-temperature resistance in one area, good corrosion resistance in another. Structures may need toughness or wear resistance in one area combined with high strength in another location. Improving the ability to join dissimilar materials with engineered properties are enabling new approaches to light-weighting automotive structures, improving methods for energy production, creating next generation medical products and consumer devices, and many other manufacturing and industrial uses. Dissimilar materials joining can be described as combining materials or material combinations that are often more difficult to join than similar two pieces of material or alloys. However, many dissimilar materials can be joined successfully with the appropriate joining process or welding consumables. It is known that all metals have different properties, and even two metals with the same name, such as austenitic steel, can have different properties too. Dissimilar metals are welded together in order to maximise on the benefits that each metal produces, while minimising the drawbacks. Dissimilar metal welding being used in common power plant, chemical plant and food processing applications as it can join ferritic low alloy steel with austenitic stainless steel, a metal that is commonly used in these industries. Aluminium and steel are a popular combination. Steel is a strong, cheap and easy-to-work with metal, so is often the go-to choice for many industries such as the automotive sector. Aluminium, on the other hand, isn't as cheap or as strong, and is more complicated to work with, but is much lighter than steel. Another popular combination is welding stainless steel and copper due to the high level of electrical conductivity that is provided. Alongside this, it is resistant to corrosion and rust. So, a combination of these two metals is a great way to maximise on these benefits.

Factors Influencing Dissimilar Metal Welding

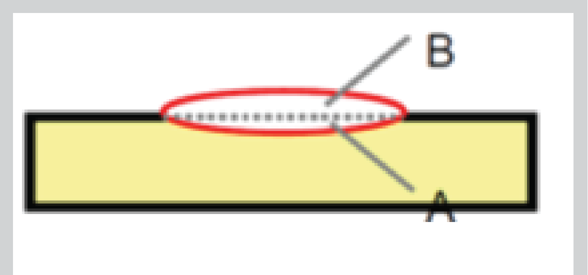
It is important to consider various factors, as mentioned below, before attempting to join two different metals, as this will determine not only how successful the welding will be, but also how long the newly joined components are likely to last.

Solubility

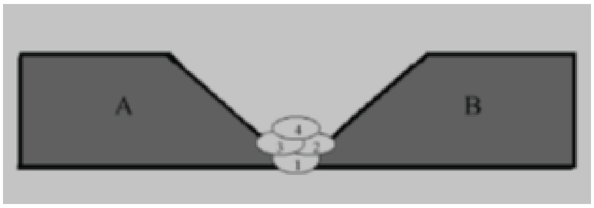
Firstly, the solubility that is the chemical property of a substance which determines its ability to dissolve in a solvent, of the two dissimilar metals must be mutual. If the metals cannot be dissolved together, then the welding process will fail.

Weld metal dilution

The weld deposit is a mixture of base metals (usually 15%) and filler composition. A simple way to understand weld metal dilution is illustrated and care needed that base metal fusion, heat affected zone and weld metal should have desirable characteristics. It is important to note that for overlays higher alloys are to be deposited over low alloys.



Dilution % = A/A+B x 100



Multiple-pass dissimilar weld

Bead 1 is diluted by the 2 base metals

Bead 2 is diluted by 1 & base metal B

Bead 3 is diluted by bead 1 & base metal A

Bead 4 is diluted by beads 2 & 3

Fig. 1 Dilution during welding

Intermetallic compounds formation

Sufficient consideration must be given to the intermetallic compounds that will form within the transition zone between the two metals, investigating crack sensitivity, susceptibility to corrosion and their ductility. This explains why it can be useful to have a "buttering layer" that is easily soluble with both the two dissimilar metals.

Weldability

The level of weldability, incorporating the solubility and intermetallic compounds, refers to the ability of the two metals in question to be successfully welded without resulting in cracks or any kind of defect. This will vary from metal to metal.Part of the calculating process is done by determining the carbon equivalency (CE) of the dissimilar metals, and can be done using the following formula:

CE = C + (Mn + Si) / 6 + (Cr + Mo + V) / 5 + (N i+ Cu) / 15

Knowing the CE will allow one to determine the temperatures to use before, during and after the welding process, as well as how susceptible the new welded metals will be to cracking. welded metals will be cracking. Knowing this will also allow one to select appropriately, pre-heat and interpass temperatures or selection of low hydrogen filler metals.

One needs to know the chemical make-up of the dis-similar metals used as well.

Thermal expansion

One must also consider the coefficient of thermal expansion of the two metals involved, which relates to how the metals will change shape in response to a change in temperature. If TE is significantly different for the metals, then the internal residual stresses of the two metals will greatly reduce the operating life of the new welded joint.

Melting rates

Just as the two dissimilar metals may have different coefficient of thermal expansion, they may also have different melting points, which will cause an immediate problem between the two metals. If this is the case, then high input process is used. Both metals melt and weld quickly enough and eliminates the problem.

Corrosion

Corrosion can occur in the transition of the two dissimilar metals. If the two metals are on widely different sections of the electrochemical scale, then this suggests a high level of susceptibility to corrosion, which is, of course, a damaging problem to the new weld. (Fig.2)

Fig. 2 Corrosion within a plumbing pipe where two dissimilar metals have been welded together

End-service conditions

Finally, it is important to consider the end-service conditions that the dissimilar joints will be subject to.

Some industries, such as the construction industry, typically protect their heavy equipment using welded-on abrasive- resistant plates to their machinery. However, this same process cannot always be used with metals of a lower tensile – strength, as this increases the chances of cracking and shorter fatigue life. Using a small fillet weld can help to solve this problem by reducing the heat input and residual stress levels on the abrasive-resistant plate.

Appropriately considering the heat and abrasiveness that the dissimilar metal welds will be subject to in their end-service will allow one to select the right filler metals and joint designs to prolong the life of the new weld.

Dissimilar Metal Welding Process

Once it has been thoroughly investigated considering the above factors, one can begin the dissimilar metal welding (DMW). DMW is, for the most part, extremely similar to the welding of two similar metals. This is done by physically melting the two metals together until they form one strong, connected joint. The complication with DMW is that often, two very distinct, very different metals may be getting welded together, which means it is not always as easy as simply melting the two parts together to form a bond. The problems arise in the transition zone between the two metals, where the intermetallic compounds are formed.

A buttering layer, as mentioned earlier, is often used in between the two parent metals and the weld metal to make the joining process smoother and help to provide an easy transition, solving many of the factors that need to be considered above. The success of the buttering layer depends on which metal coating is used, how thick the coating is, and how successfully the buttering layer has bonded with the metal that it is coated on. The following example demonstrates the use of a buttering layer within a DMW, the differing qualities of the metals used, and the order in which they are aligned:

Component	Material	Yield Strength (Megapascal) at 300°C	Tensile Strength (Megapascal) at 300°C
Stainless Steel	316L	213	453
Weld Metal	308L	333	441
Buttering Layer	309L/ 308L	333	441
Carbon or Low Alloy Steel	A508	463	640

For a successful dissimilar metal weld to have taken place, the dissimilar joint needs to be as strong as themetal with the weaker tensile strength, so that you know the joint will be able to withstand any stresses that it faces; in the example shown above this is the stainless steel. Copper and steel are two other metals which are often welded together, but both possess very different properties and are not mutually soluble. However, nickel is soluble with both and so can be used as the buttering layer, either as a whole piece of nickel or as smaller nickel deposits on the steel surface.

Residual Stresses In A Dissimilar Metal Weld

Residual stresses in a Dissimilar Metal Weld is caused by the thermal contraction of the weld metal and the heated metal that is opposite, meaning that the residual stress distribution is extremely similar between the two different types of metal welding processes.

Fig. 3 Cracking due to residual stress

Residual stress levels can be both good and bad, as it can either positively or negatively affect fatigue strength, fatigue life, crack propagation, and resistance to environmental factors such as corrosion(Fig. 3). Whether it is good or bad depends on the levels of residual stress, and it is recommended to measure what the resulting stress levels will be in the dissimilar metal weld, either by physically testing it or calculating it on a computational welding system.

Some dissimilar welds undergo post-weld heat treatment to ensure that the strength of the two joined dissimilar metals is maintained. However, this can cause a new set of residual stresses to be formed, as you will be heating up the two metals again with potentially different thermal expansion levels.

Welding Metals with Dissimilar Strength Levels

It is possible that residual stress could be also caused by dissimilar strength levels of the metals being welded. Although the two metals by nature are dissimilar, one must do the best to appropriately match them closely. This is done by making sure the tensile strength of the filler metal and the metal with the lower level of strength are as similar as possible. One will not be able to find exact match, but by keeping the difference between those two values as close as possible, one will be reducing the chances of the weld cracking.

As an example, if one is attempting to weld A514 low-alloy steel, with a minimum tensile strength of 110-KSI with A36 steel that has a minimum tensile strength of 58-KSI then one should choose a filler metal that has similar KSI levels to the A36 steel , such as a metal with a 70-KSI. On occasion, the filler metal can have a lower tensile strength than both the higher and lower strength of metals. For example, two metals with strengths of 100-KSI and 130-KSI could be theoretically welded with a 70-KSI filler metal. However, each metal is different, and one would need to check the welding specifications. One should avoid overmatching the filler metal, as this can result in a high level of stress, thereby reducing the usage life of the weld.

Conclusion

DMW is a boon to engineering industry if one is looking for contrasting properties for any specific application as is presently often demanded. Dissimilar metals welding gives opportunity to maximise on the benefits that each metal produces, while minimising the drawbacks. Welding process for dissimilar or similar metal welding is no different but much more considerations need to be given to factors mentioned in this article while welding dissimilar metal welding.

Welding Stainless Steel to other Steels

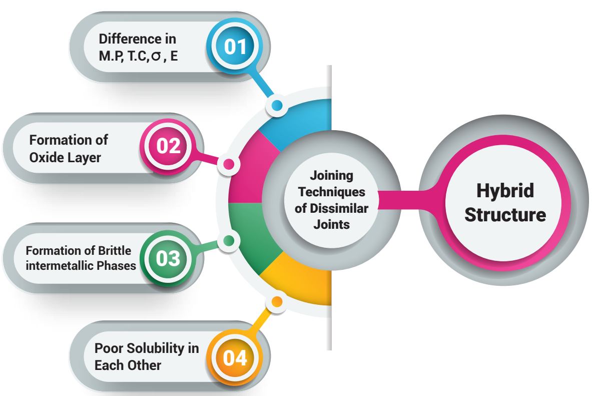
Introduction

Stainless steel is one of the metals which is subjected most to dissimilar welding since even a change in the chemical composition (grade) in stainless steel is also considered as dissimilar metal. These changes in the chemical composition makes significant impact on properties and consequently their applications. Stainless steels are welded to metals such as low-alloy steels, carbon steels, nickel besides other stainless-steel grades. This section will primarily cover areas of welding of stainless steels with nickel and its alloys, low-alloy steels, carbon steels and other stainless steels grades.

Factors Influencing Dissimilar Metal Welding

Dissimilar welding of stainless steels is also subjected to the influence of all the factors mentioned in the lead article on basics of dissimilar welding.

Some of the major factors are presented below:



(M.P - Melting point, T.C - Thermal conductivity, σ - Coefficient of thermal expansion, E - Strength)
Fig. 1 Various factors influencing DMW of Stainless steel

Welding process

Welding austenitic stainless steels to carbon and low alloy steels are common in the process and construction industries. Dissimilar metal welds involving stainless steels can be done using most full fusion weld methods, including GTAW and GMAW. Weld procedures using filler (consumable) enable better control of joint corrosion resistance and mechanical properties. In selecting the weld filler, the joint is considered as being stainless, rather than the carbon steel. Over-alloyed fillers are used to avoid dilution of the alloying elements in the fusion zone of the parent stainless steel.

Carbon and alloy steels containing less than 0.20%C do not normally need any preheat when being welded to austenitic stainless steels. Carbon and alloy steels with carbon levels over 0.20% may require preheat. High restraint joints, where material thickness is over 30mm, should also be preheated. Temperatures of 150 C are usually adequate. Carbon steels may be more prone to hydrogen associated defects than austenitic stainless steels and so careful drying of welding consumables is advisable. When welding stainless steels to galvanised steel, the zinc coating around the area to be joined should be removed before welding. Molten zinc if present in the weld fusion zone can result in embrittlement or reduced corrosion resistance of the finished weld.

Challenges

Stainless steel has a high coefficient of thermal expansion, a measure that refers to the rate at which a material expands with changes in temperature. In short, stainless steel expands and contracts more with temperature changes in comparison to carbon steel.

Stainless steel also has about half the thermal conductivity of carbon steel. Because of that lack of thermal conductivity, a piece of hot stainless steel will remain hot for much longer because it doesn't conduct heat away from the source as quickly. Since carbon steel has more thermal conductivity, heat conducts along that piece relatively quickly, drawing heat away from the weld zone. Carbon steel must not be welded directly to austenitic stainless steels as solidified weld metal will form martensite, which has low ductility and which, as it contracts, is likely to crack. Therefore, it is recommended to select a higher alloy filler, which will dilute to give the correct austenitic microstructure with enough ferrite to avoid shrinkage cracks. Using Schaeffler diagram or WRC -1992 diagram also, 309L welding consumable for CS to SS 304 and 309LMo for welding CS to SS 316 is recommended.

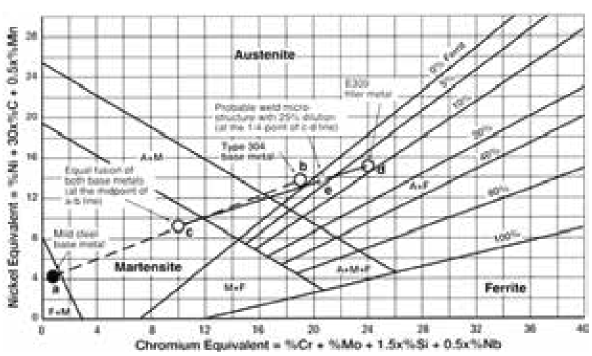


Fig.1- A Schaeffler diagram and the procedure (a-b-c-d-e) of estimating the microstructure of E309 type diluted weld metal in welding type 304 to mild steel WRC 1992 diagram

Selection Of Welding Consumables (Filler)

Selection of welding filler for dissimilar joints are decided with the help of WRC 1992 diagram to avoid hot cracking and other undesirable metallurgical changes. Hot cracking can be prevented by adjusting the composition of the base material and filler material to obtain a microstructure with a small amount of ferrite in the austenite matrix. The ferrite provides ferrite-austenite grain boundaries which are able to control the sulfur and phosphorous compounds, so they do not permit hot cracking. This problem could be avoided by reducing the S and P to very low amounts, but this would increase significantly the cost of making the steel. Selection of filler metal for a successful dissimilar welding of stainless-steel uses WRC 1992 diagram extensively. The diagram is reproduced below with an example of joining AISI 304 to ASTM A36

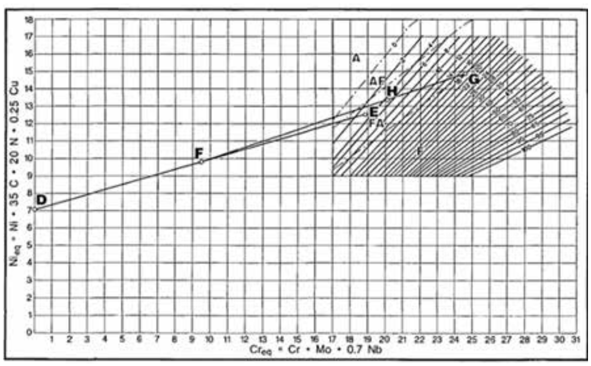


Fig.2-Illustration of Welding SS304 to AST A36 with E 309L-16 electrode Point D (A36), Point E(304) & Point G (309-16) - assuming 30% base metal dilution in the root pass shown as Point H

WRC diagram and its use in welding

Duplex stainless steels can be welded to other duplex stainless steels, to austenitic stainless steels and to carbon and low alloy steels. Duplex stainless steel filler metals with increased nickel content relative to the base metal are most frequently used to weld duplex stainless steels to other duplex grades. The higher nickel content of the filer metal ensures that an adequate level of austenite is formed in the weld metal during cooling. When welding to austenitic grades, the austenitic filler metals with low carbon and a molybdenum content intermediate between the two steels are typically used. AWS E309LMo/ER309LMo is frequently used for these joints.

AWS E309L/ER309L is commonly used to join duplex stainless steels to carbon and low alloy steels. If nickel-base filler metals are used, they should be free of Niobium (Columbium). Because austenitic stainless steels have lower strength than duplex grades, welded parts made with austenitic filler metals will not be as strong as the duplex base metal.

Essentially, such welding consumables should be used that satisfy the mechanical properties of at least one of the base metals of the joint

- For welding dissimilar metals, such a welding process that features a big dilution ratio, as submerged arc welding is not recommended.
- When the GMAW & GTAW processes are used for dissimilar metals, penetration into the carbon steel should be kept as small as possible
- In welding of carbon steel with austenitic stainless steel, 309–type welding consumables with higher Cr and Ni are ordinarily used. This is because, with 308–type welding consumables, Cr and Ni get diluted by the carbon steel base metal and thus martensitic structure (brittle structure) can be formed in the weld metal.
- For welding dissimilar metals by a welding process that features a big dilution ratio as submerged arc welding process is not recommendable.
- The normal GTAW & GMAW welding processes are most suitable, and these can be carried out without preheating.
- For high carbon steel (>0.2%) or a thickness >30mm, a pre-heat of 150*C is adequate
- When the GMAW and GTAW welding processes are used for welding dissimilar metals, penetration into the carbon steel should be kept as small as possible

Conclusions

Stainless steel is one of the metals which is most commonly subjected to dissimilar metal welding. The advantage of high temperature and better corrosion resistant properties of stainless steel are exploited by DMW with less expensive metals for best economic considerations. In DMW of stainless steel any change of chemical composition is also considered as DMW. Though stainless steel can be welded with most of the other common engineering metals, high thermal coefficient of expansion and low thermal conductivity do pose some challenge. Selection of most suitable filler metal is key to successful DMW of stainless steels. A guideline has been provided for suitable selection of welding consumables by way of tables.

Welding Copper to Various Metals

Introduction

Copper and its alloys have some unique properties, which in combination with other metals, provide a wide array of applications where contrasting requirements are specified. To meet this demand DMW of copper and its alloys is a possible solution. High thermal conductivity and its metallurgical impact on other metals, though, calls for higher degree of precautions while doing DMW. Welding of copper and alloys with other metals have been presented below.

Copper to Steel

Copper and copper-based alloys can be successfully welded to the low-alloy and mild-alloy steels and stainless steels. This can be done using a high-copper-alloy filler for areas where the metal is thinner, and for thicker sections, the steel should have a buttering layer of the high-copper-alloy filler, and then welded to the copper.

The copper must be pre-heated, as it has a melting point of approximately 1,085°C. It must also be noted that the steel metal should not be excessively penetrated in to, as any iron pickup within the copper will create a brittle insert that is more susceptible to cracking.

Another approach is to cover the copper with a nickel-based electrode, and if the metal is particularly thick, then a second layer is usually recommended. To complete this process for thicker coppers, it should be pre-heated to 540°C.

Copper to Copper-Nickel

It is rarely that copper requires direct welding to pure nickel, but joints between copper and the copper nickels are quite common in many heat-exchanger and chemical plant applications. In dissimilar metal joints with copper, it is common practice to use the copper nickel rather than the other copper-base filler metals to minimise the risk of porosity, and to give weld metal strength compatible with the copper nickel side of the joint. There are no special metallurgical difficulties in producing such a joint by direct weld runs on a conventional weld preparation. The difference in thermal conductivity will, however, mean close attention to preheating the copper side of the joint to ensure that full fusion of the copper is attained. For this reason, it may be helpful to direct the welding arc towards the copper. There will be dilution of the copper nickel weld metal by copper, and this must be considered when selecting the composition of the filler alloy in terms of maintaining matching corrosion resistance.

Welding copper nickel alloys to each other presents no undue problems.

Copper to Aluminium Bronze

Welded joints of this nature are mainly encountered where branches, pump housings, etc ,utilising aluminium bronzes for their excellent corrosion resistance to severe turbulence or sea water are joined to the main shell of, say, a copper heat exchanger.

In these instances, the aluminium bronze will often be in cast form. Direct welding is suitable and both aluminium bronze filler metal compositions (C13 and C20) have excellent welding characteristics for the purpose, provided that the castings are sound.

Aluminium Bronze to Copper Nickel

The increasing use of copper nickel alloys, both 90/10 and 70/30 compositions for heat exchanger shells can mean welds between the copper nickel and aluminium bronze castings for branches and end plates. Such joints are satisfactorily made directly using an aluminium bronze filler of matching composition.

Often a very useful step in making Cu-Ni dissimilar metal welds is to overlay or butter the other metal with nickel, nickel-copper or any other appropriate filler. In applying Cu-Ni overlays on steel, the usual practice is to apply a first layer with ERNi-1 or ERNiCu-7 and then ERCuNi for subsequent layers. Although a high alloy barrier layer is standard, it is possible to apply ERCuNi by GMAW directly on carbon steel with carefully controlled welding procedures designed to achieve relatively low iron dilution on the first layer.

Welding to aluminium

To weld the dissimilar metals of aluminium and copper together, one should use a copper-aluminium transition insert piece.

The aluminium bronzes are a family of copper-based alloys offering a combination of mechanical and chemical properties unmatched by any other alloy series for many demanding applications such as marine and hydroelectric projects.

Picture: A typical Aluminium bronze elbow joint to flanges

Filler Metals for Dissimilar Metal Welds (2014 Rev.)
Source: Copper Development Association (CDA)

Metal to be joined to Cu-Ni	SMAW (AWS)	GMAW and GTAW (AWS)	Comments
Copper	AWS A5.6 ECuNi or ECuAl-A2	AWS 5.7 ERCuNI or ERCuAl-A2/ S Cu 7158 or S Cu 6180	Preheat to 1000°F (540°C)
Phosphor bronzes	AWS A5.6 ECuSn-A	AWS 5.7 ERCuSn-A/ S Cu 5180A	—
Aluminium bronzes	AWS A5.6 ECuAl-A2	AWS 5.7 ERCuAl-A2/ S Cu 6180	—
Carbon steel	AWS A5.11 ENiCu-7/ E Ni4060	AWS A5.14 ERNiCu-7/ S Ni4060	Steel side to be overlaid first with ERNi-1 or ERNiCu-7
Austenitic Stainless Steels	AWS A5.11 ENi-1 or ENiCrFe-2 E Ni2061 or E Ni6092	AWS A5.14 ERNi-1 or ERNiCr-3 / E Ni2061 or S Ni6082	Stainless side to be overlaid first with ERNi-1

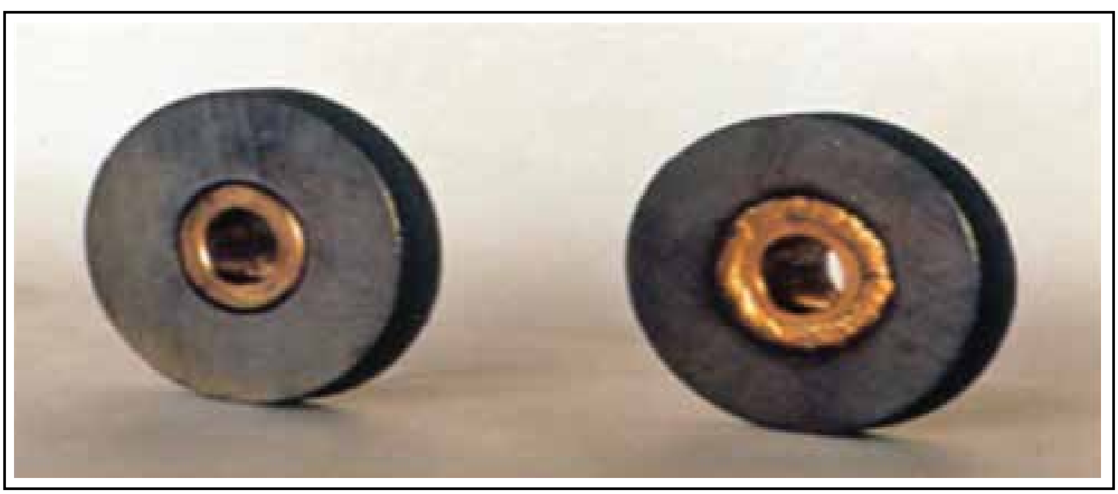
Suggested welding filler and preheat temperatures

Copper because of its high conductivity requires preheating that increases with thickness and for over 15mm will require 540°C on the copper side for proper wetting. Also is to be noted that alloys that contain low melting elements such as Zinc and Tin will require lower preheating levels. The following tables recommends the maximum preheat temperatures for GTAW dissimilar welds with copper and suitable welding consumables:

Some of the popular welding filler metals are described below:

- COPR-TRODE is used primarily to fabricate deoxidized copper and repair weld copper castings. It may also be used to weld galvanized steel and deoxidized copper to mild steel
- Where high strength joints are not required. It is also used to overlay surfaces to resist corrosion.
- SIL-TRODE is used for inert gas welding of silicon bronze welding alloy (UNS C65600), for the inert gas welding of copper-silicon, copper zinc, copper to copper-silicon, copper to themselves and also to mild steel.
- AMPCO-TRODE 10 is used to weld and join many ferrous and nonferrous metals and combinations of dissimilar metals. These metals include the more weldable grades of cast iron, high and low carbon steels, copper, bronzes and copper-nickel alloys.
- AMPCO-TRODE 46 is used for welding of cast and wrought nickel-aluminum bronze. AMPCO-TRODE 46 is a recommended for weld repairing NiBral boat propellers, power plant valves, propeller gear housings, ship fittings, marine propulsion systems and others.
- AMPCO-TRODE 40 is used for welding of cast ship propellers conforming to MIL-B-21230, Alloy 2 for high resistance to corrosion, erosion and cavitation. AMPCO-TRODE 40 also exhibits good ability to join dissimilar metals.

<table>
<tr><th rowspan="2">Base metal</th><th colspan="5">METAL B</th></tr>
<tr><th>Copper</th><th>Phosphor bronzes</th><th>Aluminium bronzes</th><th>Silicon bronzes</th><th>Cupro-nickels</th></tr>
<tr><td>Low zinc brasses, eg C23000</td><td>PHOS-TRODE -C
ERCuSn-C
540 °C Max</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Phosphor bronzes eg C51000</td><td>PHOS-TRODE -C
ERCuSn-C
540 °C Max</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Aluminium bronzes, eg C61400</td><td>AMPCO-TRODE 10
ERCuAl-A2
540 °C Max</td><td>AMPCO-TRODE 10
ERCuAl-A2 200 °C</td><td></td><td></td><td></td></tr>
<tr><td>Silicon bronzes, eg C65500</td><td>PHOS-TRODE -C
ERCuSn-C
540 °C Max</td><td>ERCuSi-A 65°C max</td><td>AMPCO-TRODE 10
ERCuAl-A2
65°C max</td><td></td><td></td></tr>
<tr><td>Cupro-nickels, eg C70600</td><td>AMPCO-TRODE 10
ERCuAl-A2
540 °C Max</td><td>PHOS-TRODE -C
ERCuSn-C
65°Cmax</td><td>AMPCO-TRODE 10
ERCuAl-A2
65°Cmax</td><td>AMPCO-TRODE 10
ERCuAl-A2
65°Cmax</td><td></td></tr>
<tr><td>Nickel, eg N02200 and Nickel-copper alloys, eg N04400</td><td>NICKEL 61
MONEL 60
ER Ni or
ERCuNi-7
540 °C Max</td><td colspan="3" rowspan="2">These combinations are not usually welded</td><td>NICKEL 61
MONEL 60
ER Ni or
ERCuNi-7
65°C max</td></tr>
<tr><td>High nickel alloys, eg N08800, N06600</td><td>INCONEL 82
ERNiCr-3
540 °C Max</td><td>INCONEL 82
ERNiCr-3
65 °C Max</td></tr>
<tr><td>Low carbon steels</td><td>AMPCO-TRODE 10
ERCuAl-A2
540 °C Max</td><td>PHOS-TRODE -C
ERCuSn-C
200°C Max</td><td>AMPCO-TRODE 10
ERCuAl-A2
150°C Max</td><td>AMPCO-TRODE 10
ERCuAl-A2
65°C max</td><td>AMPCO-TRODE 10
ERCuAl-A2
65°C max</td></tr>
<tr><td>Low alloy steels</td><td>AMPCO-TRODE 10
ERCuAl-A2 540°C</td><td>PHOS-TRODE -C
ERCuSn-C 260°C</td><td>ERCuAl-A2
260°C Max</td><td>ERCuAl-A2
200°C Max</td><td>ERCuAl-A2
65°C max</td></tr>
<tr><td>Stainless steels, eg S30400</td><td>AMPCO-TRODE 10
ERCuAl-A2 540°C</td><td>PHOS-TRODE -C
ERCuSn-C 200°C</td><td>ERCuAl-A2
65°C Max</td><td>ERCuAl-A2
65°C Max</td><td>ERCuAl-A2
65°C max</td></tr>
</table>



Dissimilar metal welding of other metals

There are many more metals which are subjected to DMW in addition to the one already discussed in some details. In this article some of the other commonly dissimilar welded metal are covered.

Low Alloys – Cr Mo Steels

These steels are extensively used for high temperature applications. The structural components of a power generation boiler use several types of steels; therefore, joining dissimilar steels is unavoidable at the interface of different service condition areas. When joining carbon steels and Cr-Mo steels, or when joining dissimilar Cr-Mo steels, a filler metal with a composition similar to the lower-alloy steel or to an intermediate composition is commonly used for butt joints. This is because the weld metal need not be stronger or more resistant to creep or corrosion than the lower alloy base metal in normal applications.

For instance, carbon steel can readily be joined to 2.25Cr-1Mo steel by using either a carbon steel or 1.25Cr-0.5Mo steel filler metal. However, carbon steel filler metals are usually selected except where carbon migration (the diffusion of carbon from lower-Cr metal to higher-Cr metal during PWHT and service at high temperatures) must be decreased. Likewise, 2.25Cr-1Mo steel can be joined to 9Cr-1Mo-V-Nb steel by using a 2.25Cr-1Mo filler metal. In contrast, Cr-Mo steel and austenitic stainless steel are joined with a high Cr-Ni stainless (e.g., E309) but where carbon migration and thermal stress are important factors, nickel alloy (e.g., ENiCrFe-1) filler metal are used. A quick guide to recommended consumable for joining dissimilar metals is tabulated below.

A quick guide to select filler metals for welding dissimilar metal butt joints for general applications

Base metal	Mild steel	0.5Mo	1.25Cr-0.5Mo	2.25Cr-1Mo	5Cr-0.5Mo
Type 304 Stainless steel	NC-39 (E309), NC-39L (E309L), TGS-309 (ER309). TGS-309L (ER309L) NIC-703D (ENiCrFe-3), NIC-70A (ENiCrFe-1), TGS-70NCb (ERNiCr-3)				
9Cr-1Mo-V 9Cr-1Mo-V-Nb	LB-52 (E7016) TGS-50 (ER70S-G)	CMA-76 (E7016-A1) TGS-M (ER80S-G)	CMA-96 (E8016-B2) TGS-1CM (ER80S-G)	CMA-106 (E9016-B3) TGS-2CM (ER90S-G)	CM-5 (E8016-B6) TGS-5CM (ER80S-B6)
5Cr-0.5Mo	LB-52 (E7016) TGS-50 (ER70S-G)	CMA-76 (E7016-A1) TGS-M (ER80S-G)	CMA-96 (E8016-B2) TGS-1CM (ER80S-G)	CMA-106 (E9016-B3) TGS-2CM (ER90S-G)	
2.25Cr-1Mo	LB-52 (E7016) TGS-50 (ER70S-G)	CMA-76 (E7016-A1) TGS-M (ER80S-G)	CMA-96 (E8016-B2) TGS-1CM (ER80S-G)		
1.25Cr-0.5Mo	LB-52 (E7016) TGS-50 (ER70S-G)	CMA-76 (E7016-A1) TGS-M (ER80S-G)			
0.5Mo	LB-52 (E7016) TGS-50 (ER70S-G)				

Note: (1) This table guides to recommended filler metals matching the lower-alloy steels in various dissimilar metal joints, excepting for Type 304 steel. Other types of filler metals may be needed where a specific requirement is imposed.

Note: (2) Preheating and post-weld heat treatment for dissimilar Cr-Mo steels should be sufficient to the higher-alloy steel: however, the PWHT temperature should be lower to avoid damage to the Base metal

Aluminium Alloys

Aluminium alloys are an extremely popular and useful metal for engineering applications. An aluminium alloy is typically 85% aluminium, and then the remaining percentage is comprised of a metal such as copper, silicon, tin, magnesium or zinc.

The metal itself offers a range of advantages such as its ductile and corrosion resistant nature, as well as a high level of electrical conductivity. But it is alloyed with other metals in order to provide it with a higher strength too. The properties that aluminium alloys can offer to has been of great interest in joining the alloy with metals such as steel, titanium, magnesium and copper.

Low melting temperature and high reactivity of Aluminium and its alloys makes welding of these with other metals difficult and is not very popular. However, it is commonly used in high-volume industries like the automotive industry or the aircraft industry, where two different parts are often welded together and needs to handle incredible pressures to provide a high level of safety and security. For example, it is used to weld together two separate parts of an airplane fuselage, which demands high levels of strength at such high altitudes. Dissimilar metal welding is commonly used in the automotive industry as well.

Conclusion

DMW of most of the metals are extensively used in industry though aluminium poses some restrictions for such welding. Selection of right welding filler metal and preheat temperature play significant role.

Equipment for Dissimilar Metal Welding

Dissimilar Metal Welding joints are extensively used in all segments of the industry. One of the most common applications, is that between low-alloy steel and stainless steel. Pressure vessels made of low-alloy steel and connected to SS piping systems is a prime example of dissimilar welding requirement in the power industry. In the welding of these joints, there are several challenges such as, elemental migration, formation of secondary and complex phases, partially mixed zones and vulnerability of the weld metals to liquation and hot cracking. These problems mainly arise due to the differences in chemical composition, thermal expansion coefficients of the metals employed.

Attempts have been carried out on the common welding techniques such as GTAW, GMAW and SMAW for solving the drawbacks as mentioned above. There are some solutions adopted by the industries such as the use of the pulsed current technique, proper selection of process parameters and filler metal.

Pulsed current, a modified form of conventional GTW method, enjoys several benefits regarding metallurgical and mechanical properties including lower heat input, reduced bead width and heat affected zone, grain refinement and lower distortion. In addition to that, the cooling rates are faster compared to the conventional GTAW technique. Several research and experimental studies have confirmed use of Pulsed GTW is one of the optimum solutions to overcome these disadvantages.

The chemical composition study showed that where Pulsed Current Gas Tungsten Arc (PCGTA) welding technique was used to weld dissimilar metals using Kemppi Master TIG MLS 4000 provided best mechanical and metallurgical results.

Dissimilar laser welding can be conducted in a variety of different ways. Modern laser welding machines are designed to be maintenance free with 'fit and forget technology', making them a reliable, efficient and effective solution to many other technologies.

Regardless of the thickness, or how different the chemical and mechanical properties of two dissimilar metals are, successful welding can be achieved using laser welding process. Lasers can work with all of the key metals including aluminium, brass, copper, and various types of steel. A continuous wave range of laser offering strengths of 200W to 1kW, can weld everything from thin steel to thick carbon steel and stainless steel.

This makes them the perfect solution for dissimilar metal welding whether this is for medical devices, fine wires, or other larger industrial solutions found in the automotive or aerospace industries. The use of Pulsed Lasers represents another direction for dissimilar welding, offering both commercial and technical benefits

For details of features and availability of Kemppi Master TIG MLS 4000 please contact
Nivek Agencies, sales@weldwel.com

Brief Note on Kemppi Master TIG MLS 4000

Kemppi Master TIG MLS 4000 belongs to the MLS DC range, which has become an industry standard for many users offering precise welding performance and lightweight, portable design. The MLS 4000 has a 400 A power source with 30% duty cycle at maximum output current

IMPORTANT FEATURES

- Precise and Reliable HF Ignition - Even at low currents and with long torches or cable sets Modular Adaptability
- Four different control panel containing basic and specialist functions required for quality TIG and MMA welding
- Ignition pulse, MMA arc dynamics, pulse and synergic pulse, TIG spot timer, 4T log and memory channel function
- Compact size and lightweight means simple site movement

Optional features include :
pre-gas and post-gas control, torch switch latching 2T/4T, remote control and set up options, welding current upslope and downslope timer,

For details of features and availability of Kemppi Master TIG MLS 4000 please contact
Nivek Agencies, sales@weldwel.com

Thermal Spray Applications Get a Boost In India

Thermal Spray is becoming one of the fasted growing surfacing technologies when it comes to meet the need for prolonging the working life of a critical component or enhancing the mean life before failure for better economics, competitiveness and lower environmental impact in comparison to many other conventional processes.

It provides a shield to the machine components to resist both primary and secondary industrial wear and achieves this with deposition of just a few microns which not only makes the entire process very economical but also saves the machine components from the adverse effects of heat affected zone.

This technology is fast becoming the most potent process to drive cost economics and extensively used in industries as sophisticated as aviation and additive manufacturing and conventional brick and mortar industries like steel, power, glass, oil & gas, engineering and so many others.

The success of thermal spray processes to a great extent determined by the selection of the right kind of consumables depending on the working environment and base material, grain size distributions and manufacturing method for the recommended spray equipment and spraying process.

Weldwell Group, the industry leader in providing advanced and state of the art welding consumables, has collaborated with two market leaders in thermal spray consumables namely **SENTES-BIR** and **Powder Alloys** Corporation to bring the world class products locally available to the Indian industry at a market competitive price to bridge the existing gap

SENTES-BIR is a renowned European producer of gas atomized thermal spray powders having its manufacturing facilities located in Izmir, Turkey. Customer orientation, innovations and bespoke products backed by a dynamic and research oriented structure have been trademarks of SENTES-BIR since its foundation more than 30 years back.

SENTES-BIR's Cobalt and Nickel based powders engineered for different applications, processes and grain size distributions requirements, are used across the industry be it a critical spray on control valves, engine vales, glass moulds, canter etc. to get the best out of these critical machine parts going under tough wear cycles.Powders are manufactured following a strict quality control guideline and sieved for different processes such as Plasma Transferred Arc, High Velocity Oxy Fuel, Fuse and Spray, Laser Cladding and Plasma Spray. The particle size distribution differentiates the metal powders from one process to the other. Technical help is available to customers for the right selection of thermal spray powders for their applications and processes. **SENTES-BIR'S** thermal spray powders are marketed under the brand name of **FORTECOAT**.

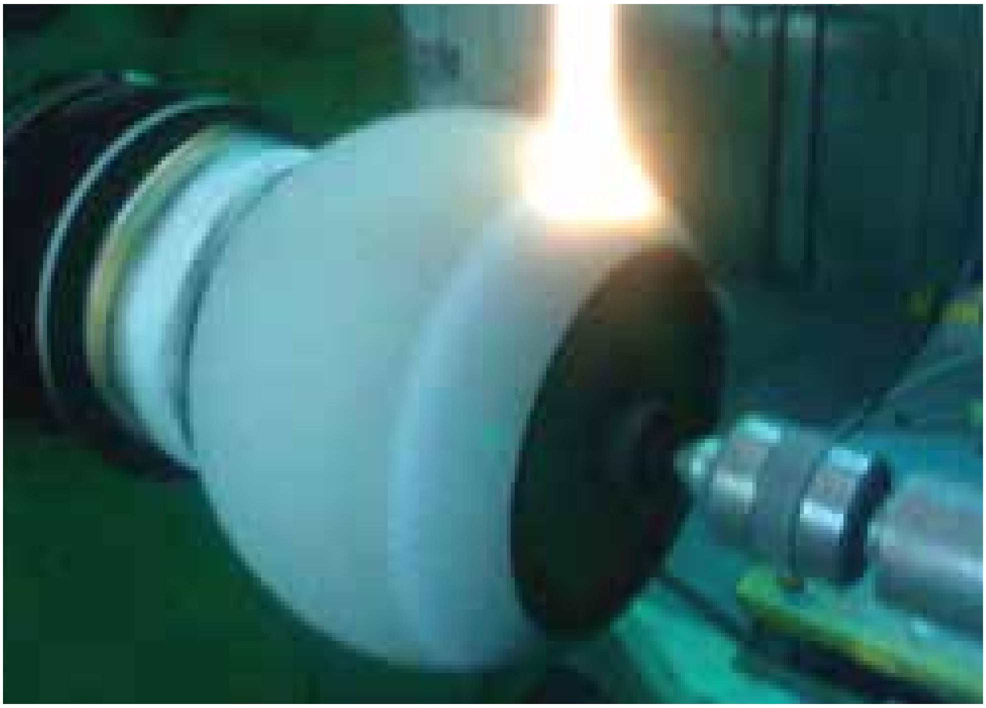


Photo 1: Plasma Transfer Arc Process

In addition to thermal spray powders, **SENTES-BIR** also makes metal powder based brazing pastes for brazing of critical parts and powders for additive manufacturing.

The second manufacturer of thermal spray powder with which Weldwell Group has collaborated is **Powder Alloys Corporation (PAC)** having its manufacturing facility in Ohio, USA. Powder Alloys Corporation is a versatile manufacturer of metal, ceramic, carbides and super alloys powders. They serve a variety of industries including oil & gas, power, steel, bio-medical, aviation, industrial gas turbine, as well as emerging markets such as additive manufacturing.

PAC is a more than 40 years old organization having deep roots in providing hardfacing and super alloys thermal spray powders to industry globally to fight industrial wear and enhance the working life of critical machine components. The technology developed by **PAC** includes inert gas atomization, composite cladding, agglomeration, sintering, plasma densification and hydride / dihydride.

PAC has a large numbers of OEM approvals across the industry including aviation. The array of approvals includes some of the world leaders like GE, Pratt & Whitney, Honeywell, Siemens, Rolls Royce etc. The exhaustive list of PAC thermal spray powders includes carbide, zirconia, ceramic, titanium, metals based powders manufactured for a complete range of processes such as High Velocity Oxy-Fuel (HVOF), Plasma Transfer Arc (PTA), Laser Cladding, Plasma and Spray / Fuse. Powders are marketed under the brand name of PAC.

For sales and product enquiries, please contact
sales@weldwell.com

Photo 2: High Velocity Oxy-Fuel Process

Dissimilar Welding of Ni and Ni base alloys

Introduction

Dissimilar metal welding of Ni and its alloys is often required to take advantage of specific properties of Ni and its alloys particularly when the application is under severe conditions of corrosion and / or high temperature. However, in many cases the comparative high cost of Ni and Ni base alloys makes their use prohibitive. Welding of these alloys to provide a protective layer on less expensive load-bearing mild or low alloy steel makes it the most realistic financial alternative. Ni and Ni base alloys are extensively used either as overlay material or as a welding consumable for dissimilar metal welding because of their compatibility with most of the engineering materials.

Welding Metallurgy and Design

Nickel-alloy joining procedures for dissimilar materials are influenced by metallurgical factors even though most common materials allows unlimited dilution by nickel without detriment. However, the concern is about dilution of nickel alloy by the base material containing copper, chromium and iron apart from potentially detrimental elements such as Pb, Sn or Zn. In addition to weld-metal dilution, the differences in thermal expansion and melting points may influence the selection of Ni and Ni base alloys as filler metal for dissimilar joints. For high-temperature service, both - metallurgical and design considerations, are important in obtaining expected life of fabricated equipment and should take into account following additional factors:

General Guidelines - Some of the common recommended procedures such as cleanliness, lower heat input, etc.; to be followed

Dilution Rates - First layer dilution from parent material, in case of overlays, has to be kept under control by appropriate choice of process, consumable size (e.g. 3.2 mm dia electrodes) and welding parameters

Dilution Limits - Choice of consumables to ensure dilution of Fe, Cr, Cu etc., are within limits

Welding Products - Generally higher alloys compared to parent material are chosen to get desirable properties even after post heat treatment, if applicable

Thermal Expansion - Extreme care is necessary when melting points and coefficients of thermal expansion are widely different, Sometimes, a mutually compatible intermediate alloy is used for such joints.

Welding Processes And Joint Design

High-quality joints are readily produced in nickel alloys by conventional welding processes. However, some of the characteristics of nickel alloys necessitate the use of somewhat different techniques than those used for commonly encountered materials such as carbon and stainless steels. Any welded joint can undergo metallurgical changes when subjected to cold work and heat treatment, even though Nickel alloys are not adversely affected by such composite overlaid materials. However, as a general rule it is best to select a welding process and procedure that produces a weld with strength and corrosion resistance superior to that of the component being fabricated. In general, it is best to join materials with over-matching composition (more highly alloyed, more corrosion-resistant) welding products.

Welding Of Ni And Ni Base Alloys With Dissimilar Metals

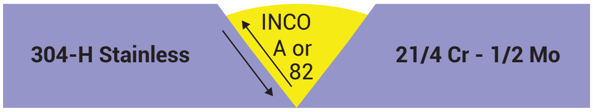
Nickel and nickel base alloys are easily welded to most commercially used metals. Exceptions are fusion welding to aluminium, titanium and most refractory metals and alloys. Welding of Nickel and nickel base alloys to some of the commonly used metals are described below.

Stainless Steel

Austenitic stainless steels typically have 16–26% chromium (Cr) and 8-22% nickel (Ni). Alloy 304, which contains approximately 18% Cr and 10% Ni, is a commonly used alloy for welded fabrications, and these alloys can be readily welded using any of the arc welding processes (TIG, MIG, MMA, and SA). It is though necessary to select the most appropriate welding consumable for the purpose. The attached table of Nickel and nickel base alloys welding consumables may be used as guideline. Other details of DMW of stainless steel is covered elsewhere in this edition of Weldwell Spectrum.

Low alloy Steel

Joining of Cr-Mo steels or low alloy steels to austenitic stainless steel requiring elevated temperature creep and thermal fatigue resistance, Ni based filler metals are used. This process for the initial runs, is known as buttering. The Ni-base alloy filler metal provides a gradation of CTE across the weld joint that better distributes stresses resulting from CTE differences at elevated temperatures. There are also metallurgical advantages by the use of Ni-base filler metals for this dissimilar combination.



Cast Iron

Nickel and its alloys are generally not welded and joined to Cast Iron. However, for cast iron salvaging and repairs, welding with nickel alloy electrodes is very popular. A nickel-iron weld is stronger, with a lower coefficient of thermal expansion reducing welding stresses and improving resistance to cracking.

Copper and copper base alloys

It is rarely, that copper requires direct welding to pure nickel, or vice versa, as copper and nickel are completely soluble in each other. They give rise to a range of copper-nickel alloys, and welding nickel to copper-nickels is common by using nickel or copper-nickel alloy welding consumables. In the unique application of welding copper to steels, since, both the metals are not mutually soluble, nickel is used as an intermediary metal. Such a transition joint can either be effected by just using a piece of nickel or depositing several layers of nickel alloy on the steel, i.e., buttering or surfacing the steel with a nickel weld metal deposit. The subsequent welding can be completed by copper-nickel welding consumables.

Overlay

This is another area where dissimilar welding plays a major role as far as Ni and Ni base alloys are concerned. Almost all welding processes used for joining alloy components can also be used for overlay. However, ESSW/SAW are most commonly used for overlaying. As with all nickel-alloy welding applications, base metal cleanliness is essential. All oxides and foreign material must be removed from the surface to be overlaid. For best results, for overlay purpose, dilution of iron must be kept to minimum levels. Excessive amounts of iron in the overlay would compromise the corrosion resistance of the overlay and may cause weld cracking.

Selection Of Welding Consumables

There are a number of situations where nickel alloy welding consumables are used for welding dissimilar combinations to provide engineering advantages. Each application in which the Ni-base welding material is used to weld other base metals usually take advantage of unique characteristics of the as-cast or as-deposited weld metal that allows it to provide equal to or better properties than that of the wrought base metal. In general, these applications take advantage of the inherent properties of Ni-base alloy welding materials and make them ideal choices for specific types of applications.

Conclusion

Nickel, because of its metallurgical characteristics and solubility, can be welded to most of the metals barring some of the reactive and refractive metals. Ni and nickel base consumables are most popular amongst the all dissimilar welding consumables. Ni and nickel base alloys are extensively used as a cladding and overlay material over steel to harness the technical advantages of both and reduce cost. The selection chart of consumables for popular dissimilar grades of Nickel Alloys is availabe separately.

Special Metals Welding Products Company offers a wide range of products for joints in and between nickel-based alloys, stainless and low alloys steels, and cast steels.

Weldwell are the authorised distributors in India for all welding products of Special Metals.

For more details and availability contact: sales@weldwell.com

Matrix of Nickel - based Welding Consumables for Welding of Dissimilar Metals

	Nickel 200	MONEL alloy 400	INCONEL alloy 600	INCONEL alloy 625	INCONEL alloy 686	INCOLOY alloys 803, 800 and 800H/HT	INCOLOY alloy 825	Carbon, Low alloy & Nickel Steels	3 - 30% Chromium Steels	Austenitic Stainless Steels	Duplex and Super Duplex Stainless Steels	Cast high-temperature alloys	Copper-Nickel alloys
Nickel 200	Nickel 61 / Nickel 141	MONEL 60 Nickel 61	INCONEL 82 Nickel 61	INCONEL 625 INCONEL 82 Nickel 61	I-W 686CPT INCONEL 625 INCONEL 82 Nickel 61	INCONEL 82 Nickel 61	INCONEL 625 INCONEL 82 Nickel 61	INCONEL 82 Nickel 61	INCONEL 82 Nickel 61	INCONEL 82 Nickel 61	I-W 686CPT INCONEL 82	INCONEL 82 Nickel 61	MONEL 60 MONEL 67 Nickel 61
MONEL alloy 400	MONEL190 Nickel 141	MONEL 60 INCONEL 625 / INCONEL 112 MONEL 190	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82 Nickel 61	I-W 686CPT INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82 MONEL 60	INCONEL 625 INCONEL 82 MONEL 60	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	MONEL 60 MONEL 67 Nickel 61
INCONEL alloy 600	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182	INCONEL 82 / INCO-WELD A INCONEL 182	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	INCONEL 617 INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 617 INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 82	INCONEL 617 INCONEL 625 INCONEL 82	INCONEL 82 Nickel 61
INCONEL alloy 625	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182	INCONEL 625 / INCONEL 112	I-W 686CPT INCONEL 625	INCONEL 617 INCONEL 625 INCONEL 82	INCONEL 625	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625	INCONEL 617 INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82 Nickel 61
INCONEL alloy 686	INCO-WELD A I-W 686CPT Nickel 141	I-W 686CPT INCO-WELD A INCONEL 112	INCO-WELD A INCONEL 82 I-W 686CPT	I-W 686CPT INCONEL 112	I-W 686CPT / I-W 686CPT	I-W 686CPT INCONEL 617 INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625	I-W 686CPT INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	I-W 686CPT	I-W 686CPT INCONEL 617 INCONEL 82	I-W 686CPT INCONEL 625 Nickel 61
INCOLOY alloys 800, 803 and 800H/HT	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 117	INCO-WELD A INCONEL 112 INCONEL 117 INCONEL 182	INCO-WELD A I-W 686CPT	INCONEL 617 INCONEL 82 / INCO-WELD A INCONEL 117	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 617 INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 82	INCONEL 617 INCONEL 625 INCONEL 82	INCONEL 82 Nickel 61
INCOLOY alloy 825 & Super Austenitic Stainless Steel	INCO-WELD A Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 182	INCONEL 112 INCONEL 122 I-W 686CPT	I-W 686CPT INCONEL 112 INCONEL 122	INCO-WELD A INCONEL 112	INCONEL 625 I-W 686CPT / INCONEL 112 I-W 686CPT	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 622	INCONEL 625 INCONEL 82	INCONEL 82 Nickel 61
Carbon, Low alloy & Nickel Steels	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182 MONEL 190	INCO-WELD A INCONEL 112 INCONEL 182	INCONEL 112 INCO-WELD A	INCO-WELD A I-W 686CPT INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 117	INCO-WELD A INCONEL 112 INCONEL 182	INCONEL 625 INCONEL 82 / INCO-WELD A INCONEL 112	INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 82	INCONEL 625 INCONEL 82	INCONEL 82 Nickel 61
3 - 30% Chromium Steels	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 117	INCONEL 112 INCO-WELD A	INCO-WELD A I-W 686CPT INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 117	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCO-WELD 112	INCONEL 625/52 INCONEL 82 / INCO-WELD A INCONEL 112/152	INCONEL 625 INCONEL 82	I-W 686CPT INCONEL 625 INCONEL 82	INCONEL 625 INCONEL 82 INCONEL 617	INCONEL 82 Nickel 61
Austenitic Stainless Steels	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182 MONEL 190	INCO-WELD A INCONEL 112 INCONEL 117 INCONEL 182	I-W 686CPT INCONEL 112	INCO-WELD A I-W 686CPT INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 117	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 182	I-W 686CPT INCONEL 82/625 / I-W A/686CPT INCONEL 112	I-W 686CPT INCONEL 82	INCONEL 82	INCONEL 82 Nickel 61
Duplex and Super Duplex Stainless Steels	I-W 686CPT INCO-WELD A Nickel 141	I-W 686CPT INCO-WELD A	I-W 686CPT INCO-WELD A	I-W 686CPT INCONEL 112	I-W 686CPT	I-W 686CPT INCO-WELD A	I-W 686CPT INCONEL 112	I-W 686CPT INCO-WELD A	I-W 686CPT INCO-WELD A	I-W 686CPT INCO-WELD A	I-W 686CPT / I-W 686CPT	I-W 686CPT INCONEL 82	I-W 686CPT INCONEL 82
Cast high-temperature alloys	INCO-WELD A INCONEL 112 INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 INCONEL 182 MONEL 190	INCO-WELD A INCONEL 117	INCO-WELD A INCONEL 117	I-W 686CPT INCONEL 117	INCO-WELD A INCONEL 117	INCO-WELD A INCONEL 112	INCO-WELD A INCONEL 112 INCONEL 182	INCO-WELD A INCONEL 112 INCONEL 117	INCO-WELD A INCONEL 112 INCONCEL 117	I-W 686CPT INCO-WELD A	INCONEL 617 INCONEL 82 / INCO-WELD A INCONEL 117	INCONEL 82 Nickel 61
Copper-Nickel alloys	MONEL 187 MONEL 190 Nickel 141	MONEL 187 MONEL 190 Nickel 141	INCO-WELD A INCONEL 182 Nickel 141	INCO-WELD A INCONEL 112 Nickel 141	I-W 686CPT Nickel 141	INCO-WELD A INCONEL 182 Nickel 141	INCO-WELD A INCONEL 182 Nickel 141	INCO-WELD A INCONEL 182 MONEL 190 Nickel 141	INCO-WELD A INCONEL 182 Nickel 141	INCO-WELD A INCONEL 182 Nickel 141	I-W 686CPT INCO-WELD A	INCO-WELD A INCONEL 182 Nickel 141	MONEL 67 / MONEL 187

NEWS from Industrty

- **Heavy Vehicle Factory (HVF) Avadi-**
  is to manufacture Russian-origin and upgraded T 90 'Bhishma' main battle tanks. 264 of these would be deployed on Pakistan front.

- **Adani Power to acquire GMR Chhattisgarh Energy-**
  GCEL owns an operational 1.370 megawatt (MW) supercritical thermal power plant in Raikheda, Raipur district, Chhattisgarh. The plant consists of 2 units of 685 MW each, commissioned in June 2015 and April 2016 respectively.

- **Panasonic partners with autonomous robotic start-**
  Up Linkwiz to enhance welding processes in manufacturing. Main products include software to control robots used for welding and paint application, and software for conducting automated inspection of each piece coming off a production line.

- **Women show their mettle with metal at welding event-**
  Eighteen Women from various heavy industries in the country participated in the National Welding Competition, held in Chennai. The event was organised by Indian Institute of Welding (Chennai).

- **NTPC Ltd along with Indian Oil Corporation (IOC)**
  Have commissioned its first Electric Vehicle charging station at an IOC petrol pump in Greater Noida, Uttar Pradesh. The EV charging station offers four charging points with fast and slow charging options conforming to Bharat DC 001 and Bharat AC 001 standards.

- **'Smart Factory Solutions'-**
  Panasonic has integrated its welding solutions and surface mount technology (SMT) machine business into a single division that will be known as Smart Factory Solutions. This integration will enable Panasonic to provide end-to-end solutions to its customers seamlessly.

- **NTPC commissions India's first ultra-super critical plant-**
  The country's first ultra-super critical Plant (2 x660) MW capacity was commissioned at Khargone in M. P. by NTPC

- **Indian Air Force to buy advanced 'bunker buster' version of Spice-2000 bombs-**
  The IAF is now planning to acquire the bunker buster or the building destroyer version with Mark 84 warhead which can decimate targeted buildings

- **NTPC, BHEL ink pact for environment friendly power plant-**
  The plant would be 800 MW technology demonstration plant (TDP) at its power plant in Sipat, Chhattisgarh. The demonstration plant shall be based on the advanced ultra-super critical (AUSC) technology.

- **India's plan for capacity addition in nuclear power generation-**
  According to DAE. nearly 21 nuclear reactors are under various stages of construction and planning which will add around 15000 MW of power generating capacity.

- **India to spend $100 billion on energy infra, says PM inviting Saudi investment**
  Transformative technologies like Artificial Intelligence, NLP and robotics are bringing about fundamental changes in our lives. India will invest a massive $100 billion in oil and gas infrastructure to meet energy needs of an economy that is being targeted to nearly double in five years.

- **Unique 5 Space Science Missions by ISRO**
  (i) A radar-imaging satellite - The NASA-ISRO Synthetic Aperture Radar (NISAR) satellite will be the first satellite with a dual-frequency radar imaging system **(ii) Autonomous docking of spacecraft -** The 'Space Docking experiment' (SPADEX) mission will demonstrate autonomous rendezvous and docking of two spacecraft in orbit. This demonstration is key to building a space station that consists of several modules working together.**(iii) First mission to study the Sun -** Launching in 2020 onboard a PSLV-XL rocket, the Aditya L-1 mission will study the Sun's surface and atmosphere (photosphere and corona).**(iv) Specialised X-ray observatory -** ISRO will be launching another space science mission, called X-ray Polarimetry Satellite (XPoSat), onboard a PSLV in 2021. **(v) A Venus orbiter in the making-** ISRO's Venus orbiter, with a payload capacity of 100 kg will be placed in a highly elliptical orbit, of 500 X 60,000 km, for closeup and global observations, respectively. Its primary scientific objectives include surface and subsurface feature studies, atmospheric chemistry, and solar wind interactions **Other missions in ISRO's pipeline include follow-ups to the Mars Orbiter Mission, Astrosat and Chandrayaan 2, all before 2025.**