WELDWELL

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SERVICE TO THE WELDING COMMUNITY

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SPECTRUM

Mr. Christopher Bloch, the nominated faculty from AWS delivering lecture during The IIW-India AWS Lecture Series VIII tour on Heat Treatment of Welded Structures at New Delhi on 23rd January, 2017

INSIDE

HIGHLIGHTS

- Welding of Copper and its Alloys
- ABCs of NDT
- Corrosion of Weld Joints

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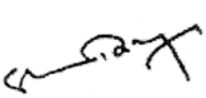
Editorial

Dear Reader,

The financial year has just ended. Again there is no clear indication of industrial revival though a number of initiatives of the government is likely to propel it a higher orbit. Opening up of defence production to privatisation organisations will definitely help welding industry. We have to bid for our time.

Copper and copper alloys offer a unique combination of material properties that makes them advantageous for many manufacturing environments. They are widely used because of their excellent electrical and thermal conductivities, outstanding resistance to corrosion, ease of fabrication, and good strength and fatigue resistance. The lead article covers some of the basic aspect of welding of copper and its alloys. Just welding a metal is not enough. Often strong and reliable welding joints can be compromised by faults. The detection of a significant fault is the scope of non-destructive testing (NDT) or inspection process. An understanding of the benefits and limitations of each form of non-destructive examination can help one choose the best method for the application. The Education section is about ABCs of NDT. Corrosion of weld joints is a major cause of concern in severe working environments. The technical section covers some of the causes and remedial measures one should take to eliminate / reduce corrosion losses. Conducting IIW-India AWS Lecture Series VIII on Heat treatment of Heat Treatment of Welded Structures in January was an important event in the calendar of the Indian welding fraternity. The brief report on the same is given in the Event category.

We hope you will enjoy reading this edition. We again request you to send us your feedback to help us improve our efforts to make your Newsmagazine more engrossing and useful.



S.Bhattacharya
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Event

IIW-India AWS Lecture Series VIII

The IIW-India AWS Lecture Series VIII on "Heat Treatment of Welded Structures", organised by The Indian Institute of Welding (Foundation) - a division of The IIW-India and supported by the American Welding Society, was held between 15th and 27th January, 2017. The purpose of holding this technical lecture series is to disseminate technical knowledge to the Indian welding fraternity through an intensive program in partnership with the AWS.

The AWS nominated Mr. Christopher Bloch as the faculty who is an acclaimed authority on heat treatment of welded structure, an advisor to the AWS D10 Committee for welding of tube and piping and a member of the ASME peer review group for welding of ferritic creep resistant steels used in construction of new power plants. He was formerly Chairman of the Houston Section of the American Welding Society.

Mr. Bloch delivered his lecture in a very lucid professor like manner which charmed the Indian welding fraternity. In his lecture he covered various aspects of heat treatment like metallurgy, energy conservation, furnace design etc. His depth of knowledge and experience was evident while interacting with the participants which was often very intense and thought provoking. The lectures were held at six locations all over India to over 650 delegates. He also visited a number of fabrication facilities where he interacted with the welding engineers and provided many useful tips on improving the performance and energy conservation. He was impressed with the functioning of Indian welding industry. The lecture series was sponsored by a number of industries including Weldwell Specialities Pvt. Ltd.

Mr. Bloch was accompanied by his wife. Both had enjoyable sightseeing visits and were well taken care of during their stay in India. He expressed his desire to visit India again.

WELDING OF COPPER & ITS ALLOYS*

Copper and copper alloys offer a unique combination of material properties that makes them advantageous for many manufacturing environments. They are widely used because of their excellent electrical and thermal conductivities, outstanding resistance to corrosion, ease of fabrication, and good strength and fatigue resistance. Other useful characteristics include spark resistance, metal-to-metal wear resistance, low-permeability properties, and distinctive colour

INTRODUCTION

Of all metals copper is the most ancient, having been first used to fabricate tools and weapons since about 3500 years BC. Alloying with a range of metals improved the mechanical properties and / or corrosion resistance, resulting in their wider applications.

The typical characteristics of high thermal conductivity (i.e. preheat is required), high co-efficient of expansion (i.e. distortion can be an issue with root gaps rapidly closing) and the fact that it does not undergo phase changes on heating, are important considerations for joining.

Copper and its alloys can be welded with most of the conventional welding processes though brazing is equally popular. Some important differences in the popular processes of joining such as brazing and welding are; Brazing depends on the ability of the filler metal to penetrate, by capillary attraction. However, in welding the base metal and the consumable melt and solidify into a single metallurgical joint.

WELDING PROCESSES

Most of the common arc welding processes such as SMAW, GTAW, GMAW, PAW, and SAW are used for joining. Gas welding is also used for joining thin sheets used for non-critical applications. This process is not discussed in this article.

Arc Welding Processes

Argon, helium, or mixtures of the two are used as shielding gases for GTAW, PAW, and GMAW processes. Generally, argon is used when manually welding material is less than 3 mm thick, has low thermal conductivity, or both. Helium or a mixture of 75% helium and 25% argon is recommended for machine welding of thin sections and for manual welding of thicker sections of alloys that have high thermal conductivity. Small amounts of nitrogen can be added to the argon shielding gas to increase the effective heat input.

SMAW Process

SMAW process is not very frequently used process. Although it can be used for many noncritical applications. Shielded metal arc welding can be used to weld a wide range of thickness of copper alloys. Covered electrodes for SMAW of copper alloys are available in standard sizes ranging from 2.4 to 4.8 mm.

GTAW Process

This Process is well suited for copper and copper alloys because of its intense arc, which produces an extremely high temperature at the joint and a narrow HAZ.

In welding copper and the more thermally conductive copper alloys, the intensity of the arc is important in completing fusion with minimum heating of the surrounding highly conductive base metal. A narrow HAZ is particularly desirable in the welding of copper alloys that have been precipitation hardened.

Many of the standard tungsten or alloyed tungsten electrodes can be used in GTAW process. The selection factors normally considered for tungsten electrodes apply in general to the copper and copper alloys. Except for the specific classes of copper alloys, alloyed tugnsten (contains rare earth) is preferred for its better performance, longer life, and greater resistance to contamination.

GMAW Process

GTAW processes is used to join copper and copper alloys for thicknesses less than 3 mm, while GMAW is preferred for section thickness above 3 mm and for the joining of aluminium bronzes, silicon bronzes and copper-nickel alloys. Selection of consumables is similar to that of GTAW.

PAW Process

The welding of coppers and copper alloys using PAW process is comparable to GTAW of these alloys. Argon, helium, or mixtures of the two are used for the welding of all alloys. Hydrogen gas should never be used when welding copper.

Plasma arc welding has two distinct advantages over GTAW:

- the tungsten is concealed and entirely shielded, which greatly reduces contamination of the electrode, particularly for alloys with low-boiling-temperature constituents such as brasses, bronzes, phosphor

**Total Material, website*

bronzes, and aluminium bronzes, and

- the constructed arc plume gives rise to higher arc energies while minimizing the growth of the HAZ.

As with GTAW, current pulsation and current ramping may also be used. Plasma arc welding equipment has been miniaturized for intricate work, known as microplasma welding. Plasma arc welding of coppers and copper alloys may be performed either autogenously or with filler metal. Filler metal selection is identical to that outlined for GTAW. Automation and mechanization of this process is readily performed and is preferable to GTAW where contamination can restrict production efficiencies. Welding positions for PAW are identical to those for GTAW. However, the plasma keyhole mode has been evaluated for thicker sections in a vertical-up position. Generally, all information presented for GTAW is applicable to PAW.

SAW Process

The welding of thick gauge material, such as pipe formed from heavy plate, can be achieved by continuous metal-arc operation under a granular flux. Effective deoxidation and slag-metal reactions to form the required weld-metal composition are critical and the SAW process is still under development for copper-base materials. A variation on this, process can be used for weld cladding or hardfacing. Commercially available fluxes should be used for the copper-nickel alloys.

RECOMMENDED WELDING PROCEDURE

Welding of copper and its alloys is not difficult but high thermal conductivity and high coefficient of thermal expansion of these alloys makes it necessary to take certain precautions. Following are some of the recommended welding parameters:

- Preheat: While welding with steel it is recommended to preheat it (steel) about to 300° C, especially on parts with large mass
- Preheat: Bronze to 300° C is required
- On Steel a buffer layer of ERCuAl-A2 is required before applying other grades
- Wire stick-out is approx. 15 mm
- Direction of Gun travel: dragging (trailing) the gun is better than pushing the gun
- Grinding away the oxidized surface after each layer is necessary. Brushing with steel brush is not enough
- Interpass temperature: maintain an interpass temperature between 280-350°C during the entire welding process
- Post weld treatment: cool part slowly with a welding blanket or other similar method
- Use enough ventilation and sufficient exhaustion of welding smoke and fumes
- Welding Technique: Either forehand or backhand welding may be used for copper. Forehand welding is preferred for all welding positions and provides a more uniform, smaller bead than with a backhand weldng.
- Stringer beads or narrow weave beads should be used for copper. Wide oscillation of the arc should be avoided.
- Stress relieve or anneal after welding to reduce stresses if required.
- Typical butt weld preparations are:-
    * Up to 1.5mm thickness - square edge, no gap
    * 1.5 to 3mm - square edge with 1.5mm gap
    * 3 to 12mm single -V, included angle of 60° to 90°, feather edge and up to a 1.5mm gap
    * 12mm to 25mm single V, included angle of 60 to 90°, 1.5 to 3mm root face, 1.5mm maximum gap
    * Over 25mm thickness double V, included angles of 60 to 90°, 1.5 to 3mm root face, 1.5mm maximum gap
- Carbon, stainless steel or ceramic tiles or tape can be used as temporary backing strips to control root bead shape.
- Argon, helium, or mixtures of the two are commonly used as shielding gases for GTAW and GMAW welding of copper and high copper alloys.
- Direct current electrode negative (dcen) is preferred with this process although alternating current high frequency (achf) can be used.
- GMAW - Pure Argon is normally used for thickness up to 6.4 mm. For higher thicknesses a mixture of 75% helium - 25% argon is recommended.
- A sharp pointed tungsten electrode is the preferred style.

POPULAR WELDING CONSUMABLES & ITS APPLICATIONS

Recommended welding consumables for welding of copper and its alloys and their AWS specifications are mentioned below:

Class CuAl-A1 (Ampco-Trode 7) – overlaying bearing and corrosion – resistant surfaces

Class CuAl-A2 (Ampco-Trode 10) – joining of like and dissimilar metals and for overlay of bearing, wear and corrosion resistant surfaces

Class CuAl-A3 (Ampco Trode 150) – for use in overlaying bearing surfaces requiring medium hardness, high strength and good ductility

Class CuMnNiAl (Ampco Trode 40) – for joining and overlaying of corrosion resistant alloys like MIL-B-21230A alloy 2 for marine applications

Class CuNiAl (Ampco Trode 150) – recommended for corrosion, erosion and cavitation applications requiring joining or overlaying alloys like MIL-B-21230A alloy 1

Class Cu (COPR-TRODE) – joining and overlaying copper plate, castings and wrought products where maximum electrical and thermal conductivity are required

Class CuSi-A (SIL TRODE) – for GTAW of copper-silicon, copper-zinc, copper to itself and also to mild steel. Used extensively in welding of galvanized steel

ALLOY METALLURGY AND WELDABILITY

Many common metals are alloyed with copper to produce the various copper alloys. The most common alloying elements are aluminium, nickel, silicon, tin, and zinc. Other elements and metals are alloyed in small quantities to improve certain material characteristics, such as corrosion resistance or machinability.

Several alloying elements have pronounced effects on the weldability of copper and copper alloys. Small amounts of volatile, toxic alloying elements are often present in copper and its alloys. As a result, the requirement of an effective ventilation system to protect the welder and/or the welding machine operator is more critical then when welding ferrous metals.

Impact of some of the common elements in welding of copper alloys are:

Zinc reduces the weldability of all brasses in relative proportion to the percent of zinc in the alloy. Zinc has a low boiling temperature, which results in the production of toxic vapours when welding copper-zinc alloys.

Tin increases the hot-crack susceptibility during welding when present in amounts from 1 to 10%. Tin, when compared with zinc, is far less volatile and toxic. During the welding tin may preferentially oxidize relative to copper. The results will be an oxide entrapment, which may reduce the strength of the weldment.

Beryllium, aluminium, and nickel form tenacious oxides that must be removed prior to welding. The formation of these oxides during the welding process must be prevented by shielding gas or by fluxing, in conjunction with the use of the appropriate welding current. The oxides of nickel interfere with arc welding less than those beryllium or aluminium. Consequently, the nickel silvers and copper-nickel alloys are less sensitive to the type of welding current used during the process. Beryllium containing alloys also produce toxic fumes during the welding.

Silicon has a beneficial effect on the weldability of copper-silicon alloys because of its deoxidizing and fluxing actions.

Weldability of Unalloyed (Pure) Copper

Metallurgically, welding copper by gas-shielded processes presents no special difficulty, but the tough-pitch grades of copper do require additional care during welding. Commonly used welding consumables are ERCu (COPR-TRODE) which typically contains 0.4% of Si and Mn with 0.8% of Sn to aid fluidity and ERCuSi-A (SIL TRODE) contains 1%Mn and 3%Si and is the preferred filler metal for tough pitch and P-deoxidised copper.

Shielding gases for welding are argon, helium and nitrogen or mixes of two or more of these. Pure argon may be used for TIG welding up to a thickness of some 2mm and for MIG welding up to approximately 5 mm - above these thicknesses an argon-helium mixture will give better results with greater heat input and less risk of lack of fusion defects.

Copper Alloys

Copper alloys, in contrast to copper, seldom require pre-heating before welding. Heat input difficulties are, therefore, largely eliminated but correspondingly greater attention must be given to the welding process. It may be noted that in many cases deoxidation of the weld pool is achieved by elements already present in the parent metal. In particular instances, however, deoxidants such as titanium and aluminium are added to the filler metal to ensure complete deoxidation and freedom from weld metal porosity.

Brasses - The main alloying element in the brasses is zinc (Zn). With the exception of brasses containing lead (Pb) all the brasses are weldable, the low zinc (<20%) alloys being the easiest.

Brasses may be welded using MMA, MIG or TIG. Filler metals are available although these are generally based on copper-silicon or copper-tin alloys due to the problems of transferring zinc across the welding arc. Included angle 60° for Cu-Si filler metal and CuSn weld metal at least 70° is advisable. The shielding gas used for MIG or TIG welding of thin section components is high purity argon. In thicker sections, over 5mm thick, the addition of helium will greatly assist in providing sufficient heat for full fusion. TIG welding is generally limited to joint thickness of around 10mm, MIG being the preferred process for thicker sections. Preheating to between 100° and 300°C, depending upon section thickness can be helpful in reducing zinc loss, particularly in the high zinc alloys.

Bronzes - The group of alloys, known as bronzes, are those that are alloyed with tin, generally described as phosphor bronze, silicon or aluminium.

From a weldability point of view the main problem is that the Phosphor Bronze alloys are sensitive to hot cracking and the lower P content alloys are also prone to form oxide films on the weld pool. High welding heat inputs, high preheat and slow cooling rates should therefore be avoided. MIG and TIG welding are the preferred welding processes with argon or helium-argon mixtures. MIG is more suitable than TIG for welding heavier section joints and positional welding is best achieved using pulsed current. Filler metals matching the composition of the parent metal, e.g. EN ISO 24373 CuSn6P, are available. Although MMA welding consumables are available the process is not widely used. A stringer bead welding technique is generally necessary and heavy sections require preheat and interpass temperatures of around 200°C.

Silicon bronzes are probably the easiest of all the bronzes to weld. Unlike many of the other copper alloys thermal conductivity is relatively low and this makes it possible to use high welding speeds and to dispense with preheat for the thicker joints. One undesirable characteristic, however, is that the silicon tends to form an oxide film on the weld pool surface that requires vigorous wire brushing of individual weld passes during multi-run welding. There is also a slight tendency to hot shortness at elevated temperatures. It is advisable to stress relieve or anneal components prior to welding and to cool rapidly through the 1000-850°C temperature range. As with the other bronzes, MIG or TIG welding are the processes of choice using pure argon as the shield gas and consumables that match the parent metal composition, e.g. EN ISO 24373 CuSi3Mn1. Low thermal conductivity means that helium mixes are not necessary and the TIG process can be used for welding components up to 25mm thickness.

The strong tenacious aluminium oxide film that forms on the surface of aluminium bronze causes lack of fusion during welding and must be removed. Scraping and wire brushing the surfaces before welding is necessary. With respect to the welding processes, MIG and TIG are preferred. With MIG there is no problem in dispersing the oxide film, the DC+ve current breaking up and dispersing the film. DC-ve TIG welding does not provide this cleaning action and it is necessary to use AC-TIG. Inverter-based square wave TIG power sources will give the best control. Argon is the recommended shield gas although a helium/argon mixture may be useful when welding very thick section joints with the MIG process. MMA welding is possible although the fluxes required to remove the oxide film are very aggressive and may cause corrosion problems if not completely removed before the item enters service. Aluminium bronzes with less than 8% aluminium it is recommended to use low heat input procedures and limit interpass temperature to 150°C. A filler metal with around 8 to 10% aluminium such as AWS A5.7 CuAl-A2 is the best choice. The alloys with more than approximately 9% Al are, however, readily weldable and relatively insensitive to hot cracking. The recommended consumable is ER CuAl-A3.

Cupro-nickels - Cupro-nickel alloys are readily weldable and may be welded using MMA, MIG, or TIG welding processes, generally without preheat. High quality welds can be obtained with all these welding processes. Electrodes and filler metals conforming to 70/30 copper-nickel are readily available. These conform to specifications such as AWS A5.7 types ECuNi (MMA) and ERCuNi (MIG and TIG). Filler metal conforming to 90/10 copper-nickel is listed in BS 2901-3 as type C16. Fillers for cupro-nickels usually include titanium as deoxidant, to prevent the formation of porosity. Argon shielding gas is generally preferred for MIG and TIG welding, the latter often being carried out using DC electrode negative.

FACTORS AFFECTING WELDABILITY

Besides the alloying elements that comprise a specific copper alloy, several other factors affect weldability.

Effect of Thermal Conductivity

The behavior of copper and copper alloys during welding is strongly influenced by the thermal conductivity of the alloy. When welding commercial coppers and lightly alloyed copper materials with high thermal conductivities, the type of current and shielding gas must be selected to provide maximum heat input to the joint. This high heat input counteracts the rapid head dissipation away from the localized weld zone. Depending on section thickness, preheating may be required for copper alloys with lower thermal conductivities. The interpass temperature should be the same as for preheating.

Welding Position

Due to the highly fluid nature of copper and its alloys, the flat position is used whenever possible for welding. The horizontal position is used in some fillet welding of comer joints and T-joints.

...continued on Page 11

The ABCs of Non-destructive Weld Examination *, ** (Part 1)

Strong and reliable welding joints can be compromised by faults. The detection of a significant fault is the scope of non-destructive testing (NDT) or inspection process which normally forms part of the whole quality assurance /quality control (QA/QC) scheme. An understanding of the benefits and limitations of each form of non-destructive examination can help one choose the best method for the application.

INTRODUCTION

The philosophy that often guides the fabrication of welded assemblies and structures is "to assure weld quality." However, the term "weld quality" is relative. The application determines the weld quality as good or bad. A standard should be established based on the service requirements. Non-destructive examination or testing (NDE or NDT) methods of inspection make it possible to verify compliance to the standards on an ongoing basis by examining the surface and subsurface of the weld and surrounding base material. There are five basic NDT methods commonly used to examine finished welds viz. visual, ultra-sonic, radiographic (X-ray), liquid penetration or dye penetration, and magnetic particle. A review of each of the common method will help in deciding which process or combination of processes to use for a specific job and in performing the examination most effectively.

COMMON NDT METHODS

The different types of non-destructive testing methods commonly used to inspect weld joints are:

- Visual Inspection (VT)
- Radiographic Inspection (Graphs)
- Ultrasonic Testing (UT)
- Liquid or Dye Penetration (Dye Pen)
- Magnetic Particle Inspection(MPI)

DESCRIPTION AND APPLICATION OF COMMON NDT METHODS

Visual Inspection (VT)

Visual inspection is often the most cost-effective method, but it must take place prior to, during and after welding as well. Visual inspection requires little equipment. Aside from good eyesight and sufficient light, all it takes is a pocket rule, a weld size gauge, a magnifying glass, and possibly a straight edge and square for checking straightness, alignment and perpendicularity. The limitation is that it can only locate defects in the weld surface.

Pre welding VT

Before the first welding arc is struck, materials should be examined to see if they meet specifications for quality, type, size, cleanliness and freedom from defects. Grease, paint, oil, oxide film or heavy scale should be removed.

VT during welding

During fabrication, visual examination of a weld bead and the end crater may reveal problems such as cracks, inadequate penetration, and gas or slag inclusions. Among the weld defects that can be recognized visually are cracking, surface slag inclusions, surface porosity and undercut.

Visual inspection at an early stage of production can also prevent under welding and over welding. Welds that are smaller than called for in the specifications cannot be tolerated. Beads that are too large increase costs unnecessarily and can cause distortion through added shrinkage stress.

Post weld VT

After welding, visual inspection can detect a variety of surface flaws, including cracks, porosity and unfilled craters, regardless of subsequent inspection procedures. Dimensional variances, warpage and appearance flaws, as well as weld size characteristics, can be evaluated.

Radiographic Inspection

Radiography (X-ray) is one of the most important, versatile and widely accepted of all the non-destructive examination methods (Fig.1). X-ray is used to determine internal soundness of the welds. The term "X-ray quality," widely used to indicate high quality in welds, arises from this inspection method.

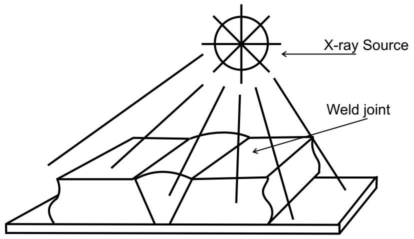

Fig. 1 *Schematic diagram of radiographic technique*

When X-rays or gamma rays are directed at a section of weldment, not all of the radiation passes are through

* *Introduction to the Non-destructive Testing of Welded Joints, Second edition, R Halmshaw, ABINGTON PUBLISHING, UK*
** *The ABC's of Nondestructive Weld Examination, Reprinted courtesy of Welding Journal magazine, Lincoln Electric website*

the metal. Different materials, depending on their density, thickness and atomic number, will absorb different wavelengths of radiant energy. The degree to which the different materials absorb these rays determines the intensity of the rays penetrating through the material. When variations of these rays are recorded, a means of seeing inside the material is available. The image on a developed photo-sensitized film is known as a radiograph. Thicker areas of the specimen or higher density material (tungsten inclusion), will absorb more radiation and their corresponding areas on the radiograph will be lighter.

Whether in the shop or in the field, the reliability and interpretive value of radiographic images are a function of their sharpness and contrast. To be sure that a radiographic exposure produces acceptable results, a gauge known as an Image Quality Indicator (IQI) is placed on the part so that its image will be produced on the radiograph. IQI's used to determine radiographic quality are also called penetrameters. A standard hole-type penetrameter is a rectangular piece of metal with three drilled holes of set diameters. The thickness of the piece of metal is a percentage of the thickness of the specimen being radiographed. The diameter of each hole is different and is a given multiple of the penetrameter thickness. Wire-type penetrameters consist of several pieces of wire, each of a different diameter. Sensitivity is determined by the smallest diameter of wire that can be clearly seen on the radiograph. A penetrameter is not an indicator or gauge to measure the size of a discontinuity or the minimum detectable flaw size. It is an indicator of the quality of the radiographic technique.

An X-ray image of the interior of the weld may be viewed on a fluorescent screen, as well as on developed film. This makes it possible to inspect parts faster and at a lower cost, but the image definition is poorer. Computerization has made it possible to overcome many of the shortcomings of radiographic imaging by linking the fluorescent screen with a video camera. Instead of waiting for film to be developed, the images can be viewed in real time. This can improve quality and reduce costs on production applications such as pipe welding, where a problem can be identified and corrected quickly.

Radiographic equipment produces radiation that can be harmful to body tissue in excessive amounts, so all safety precautions should be followed closely. Shielding from x-ray and gamma-ray radiation is a strict requirement.

Ultrasonic Testing (UT)

Ultrasonic inspection method is extensively used to detect surface and internal irregularities in ferrous and non-ferrous metal welding. Both surface and subsurface detects in metals can be detected, located and measured by ultrasonic inspection, including flaws too small to be detected by other methods.

In this method discontinuities are detected by directing a high-frequency sound beam through the base plate and weldment on a predictable path. When the sound beam's plate path strikes an interruption in the material continuity, some of the sound is reflected back. The reflected sound is collected by the instrument, amplified and displayed as a vertical trance on a video screen (Fig.2).

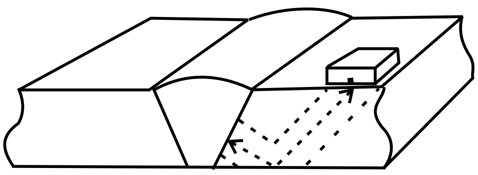

Fig.2 *Schematic diagram of ultrasonic inspection technique*

The ultrasonic unit contains a crystal of quartz or other piezoelectric material encapsulated in a transducer or probe. When a voltage is applied, the crystal vibrates rapidly generating ultrasonic waves. As an ultrasonic transducer is held against the metal to be inspected, it imparts mechanical vibrations of the same frequency as the crystal through a couplet material into the base metal and weld. These vibrational waves are propagated through the material until they reach a discontinuity or change in density. At these points, some of the vibrational energy is reflected back. As the voltage that causes the vibration is shut off and on at 60-1000 times per second, the quartz crystal intermittently acts as a receiver to pick up the reflected vibrations. These cause pressure on the crystal and generate an electrical current. Fed to a video screen, this current produces vertical deflections on the horizontal base line. The resulting pattern on the face of the tube represents the reflected signal and the discontinuity.

Ultrasonic testing is less suitable than other NDE methods for determining porosity in welds, because round gas pores respond to ultrasonic tests as a series of single point reflectors. However, it is the preferred test method for detecting plainer-type discontinuities and lamination.

Compact portable ultrasonic equipment with digital operation and microprocessor controls is available for field inspection.

(End of Part 1. Part 2 will be in next issue)

INTRODUCTION TO CORROSION OF WELD JOINTS

Corrosion is the deterioration of a metal as a result of chemical reactions between it and the surrounding environment. The definition is true for the weldments as well. However, generally we mention corrosion of weld joint only when the corrosion of the weld joint is preferential and more than the base metal. It is a cause of major concern to all using welding process for joining.

Corrosion failures of welds occur in spite of the fact that the proper base metal and filler metal have been selected, industry codes and standards have been followed, and welds have been deposited that possess full weld penetration and have proper shape and contour. It is not unusual to find that, although the wrought form of a metal or alloy is resistant to corrosion in a particular environment, the welded counterpart is not. However, there are also many instances in which the weld exhibits corrosion resistance superior to that of the unwelded base metal. There also are times when the weld behaves in an erratic manner, displaying both resistance and susceptibility to corrosive attack.

TYPES OF CORROSION OF WELDS

There are many different types of corrosion, each of which can be classified by the cause of the metal's chemical deterioration.

Listed below are 10 common types of corrosion:

1. General Attack Corrosion

Also known as uniform attack corrosion, general attack corrosion is the most common type of corrosion and is caused by a chemical or electrochemical reaction that results in the deterioration of the entire exposed surface of a metal. Ultimately, the metal deteriorates to the point of failure. General attack corrosion accounts for the greatest amount of metal destruction by corrosion, but is considered as a safe form of corrosion, due to the fact that it is predictable, manageable and often preventable.

2. Localized Corrosion

Localized corrosion targets one area of the metal structure. Weld discontinuities like surface flaws can act as preferential sites that lead to local corrosion attacks.

Localized corrosion is classified as one of three types:

- Pitting: Pitting results when a small hole, or cavity, forms in the metal, usually as a result of de-passivation of a small area. The deterioration of this small area penetrates the metal and can lead to failure. This form of corrosion is often difficult to detect. This form of corrosion is common in weld joints.
- Crevice corrosion: Similar to pitting, crevice corrosion occurs at a specific location. This type of corrosion is often associated with a stagnant micro-environment.
- Not common in weld joints.

3. Galvanic Corrosion

Galvanic corrosion or dissimilar metal corrosion occurs when two different metals are located together in a corrosive electrolyte like in welded joint of dissimilar metals. Variations in the composition of the base metal, HAZ and weld metal result in a condition that favours galvanic corrosion.

Fig. 1 *Corrosion of a copper-steel weld joint*

4. Environmental Cracking

Environmental cracking is a corrosion process that can result from a combination of environmental conditions affecting the metal. Chemical, temperature and stress-related conditions can result in the following types of environmental corrosion:

- Stress Corrosion Cracking (SCC); Welding residual stresses lead to SCC
- Corrosion fatigue
- Hydrogen-induced cracking; Susceptibility to

hydrogen-containing environments will often lead to cracking. The presence of hydrogen in the welding process leads to hydrogen-induced cracking of the weldments. Hydrogen can arise from improperly baked or poorly stored electrodes, the presence of impurities and moisture in the components to be welded, or the presence of moisture in the flux

- Liquid metal embrittlement

5. Flow-Assisted Corrosion (FAC)

Flow-assisted corrosion or flow-accelerated corrosion results when a protective layer of oxide on a metal surface is dissolved or removed by wind or water or any other flowing substance.

6. Intergranular corrosion (IGC)

Intergranular corrosion is a chemical or electrochemical attack on the grain boundaries of a metal. This is quite common in welded joints of stainless steels due to depletion of chromium content at the gain boundaries. This type of corrosion in stainless steel can be avoided by addition of stabilising elements like titanium, niobium etc.

7. De-alloying

De-alloying, or selective leaching is the selective corrosion of a specific element in an alloy. The most common type of de-alloying is dezincification of unstabilized brass during welding.

8. Fretting corrosion

This is not related to any weld joint.

9. High Temperature Corrosion

Low melting vanadium compounds and sulphates are very corrosive towards metal alloys normally resistant to high temperatures and corrosion, including stainless steel. High temperature corrosion can also be caused by high temperature oxidization, sulfidation and carbonization. Welds experience all types of corrosion. However, they are more susceptible to the forms arising from variations in composition and microstructure. Specific corrosion types are galvanic, stress corrosion, hydrogen cracking, intergranular and pitting corrosion.

CAUSES OF CORROSION OF WELDS

A welded joint can have a low resistance to corrosion due to the varying chemical composition, residual stress and metallurgical structure of the weld zone. The metallurgical, physical and chemical changes are caused by the welding process. This leads to both the heat affected zone (HAZ) and the weld metal corroding faster or slower than the base metal. Corrosion of weld joints can be minimised by careful selection of materials to be welded, the filler metal, welding techniques and finishing. However, even after closely matching the metals and using the best techniques, weld corrosion may still occur due to variety of other reasons.

The following figure (Fig. 2) shows the cause-effect relationship of weld joint Corrosion.

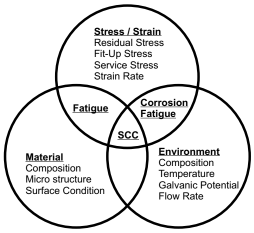

***Fig. 2** Cause-effect relationship of weld joint corrosion*

Some of the major causes of corrosion are summarised below:

1. The Metallurgical Factors

Some of the factors that reduce corrosion resistance are contamination of the solidifying pool, recrystallization and grain growth in the weld HAZ, formation of unmixed zones, precipitation of secondary phases and microsegregation.

However, corrosion resistance can still be maintained by balancing the alloy composition to prevent precipitation, shielding the hot and molten metal surfaces from reactive gases from the weld environment, choosing the appropriate welding parameters, removing chromium-depleted base metal, and removing the chromium-enriched oxides from the heat-tinted surfaces.

2. Galvanic Couples

Different compositions of the base metal and the filler metal may lead to galvanic couples. This gives rise to an electrochemical potential difference and causes some regions in the weld to be more active. Galvanic corrosion is particularly an issue when the weld joint is used in a harsh environment such as in seawater and in dissimilar welds.

3. Weld Decay of Stainless Steel

During the welding of stainless steels, regions which are susceptible to corrosion may develop. The process, called sensitization, is caused by the formation of chromium carbide along the grain boundaries. Sensitization depletes the chromium from the regions adjacent to the grain boundary, leading to the formation of localized galvanic cells. This attack results in weld decay and is most common in the HAZ. Sensitization can be minimized by post-weld high-temperature annealing and quenching.

The attacks on HAZ can be minimized by post-weld heat treatment (PWHT) stress relief, using a low-carbon stainless steel and by using stabilized grades.

4. Preferential Weld Corrosion (PWC)

Preferential weld corrosion occurs in welds when exposed to seawater and other corrosive environments. The weld metal compositions are usually optimized to enhance their mechanical properties; this makes them more anodic than the base steel, causing them to corrode at higher rates compared to their base metals.

WELDING PRACTICES TO MINIMIZE CORROSION

Optimized material selection and welding procedures can assist in producing a corrosion-resistant weld. Full weld penetration, post-weld dressing and avoidance of excessive weld reinforcement are some of the effective ways of minimizing the weld geometrical effects.

Proper selection of the following parameters will help in reducing weld joint corrosion:

- Material Selection
- Surface Preparation
- Weld Design
- Welding Process
- Use of Backing Material
- Weld Surface Finishing
- Removing the Sources of Hydrogen
- Application of Surface Coating
- Post-Weld Heat Treatment (PWHT)

CONCLUSION

A weld joint may corrode or decay in very many way and their cause/s could be as varied. It is economically extremely difficult to altogether prevent corrosion of a weld joint. However, there are some practices which may minimise corrosion of the joints. It is, therefore, necessary at every stage to carry out a risk factor analysis for probable solution.

...Lead Article continued from Page 6

Precipitation-Hardenable Alloys

Care must be taken when welding precipitation-hardenable copper alloys to avoid oxidation and incomplete fusion. Whenever possible, the components should be welded in the annealed condition, and then the weldment should be given a precipitation-hardening heat treatment.

Hot Cracking

Copper alloys, such as copper-tin and copper-nickel, are susceptible to hot cracking at solidification temperatures. Hot cracking can be minimized by reducing restraint during welding, preheating to slow the cooling rate and reduce the magnitude of welding stresses, and reducing the size of the root opening and increasing the size of the root pass.

Porosity

Vaporization of some elements, like Zinc, during welding may result in porosity. When welding copper alloys containing these elements, porosity can be minimized by higher weld speeds and a filler metal low in these elements.

Surface Condition

Grease, paint, crayon marks, shop dirt, and similar contaminants on copper-nickel alloys may cause embrittlement and should be removed before welding. Miliscale on copper-nickel alloys must be removed by grinding or pickling; wire brushing is not effective.

CONCLUSION

Welding of copper and its alloys is not difficult but due to its characteristics of having high thermal conductivity and co-efficient of expansion precautions need to be taken. The alloying elements play a significant role in its weldability. It is important to have good ventilation while welding cupper alloys because some of the alloying elements emit toxic fumes.

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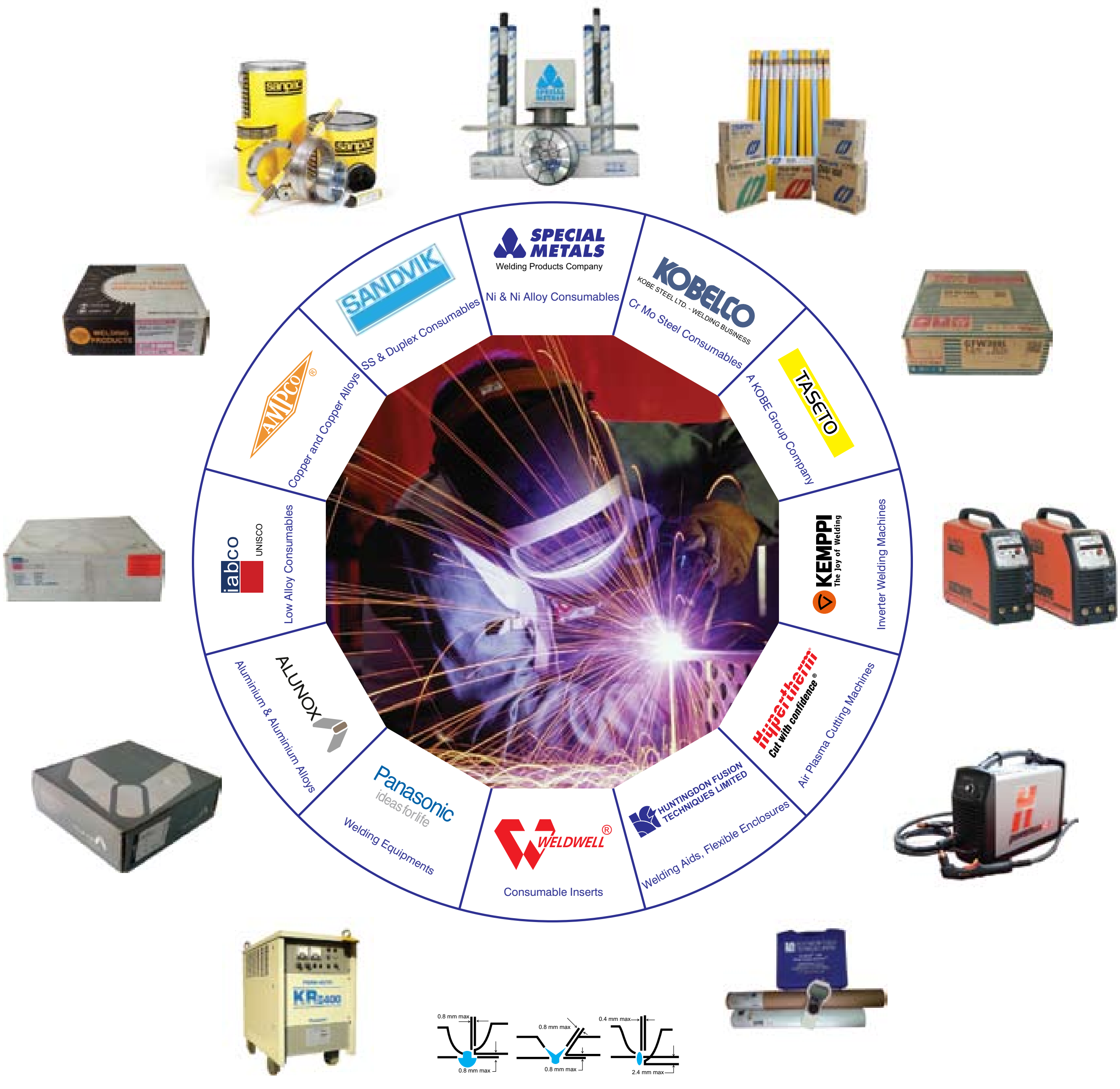

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