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Cold-Brazing: A Low Energy - Consuming Metal Joining Technique

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ABSTRACT

Metal-joining plays an important role in the industry and virtually all servicing and manufacturing concerns, directly and indirectly, benefit from it. However, not all kinds of joining processes are suitable for thin metals and light works due to the sensitivity of light metals to heavy heat, rapid corrosion of most metals at high temperatures and very high quantities of heat energy needed to fuse parts. It has been observed that the heat energy required to melt and establish continuity across parts is even higher with welding and brazing-which utilize fillers of high tensile strengths and melting points-such as iron (0.8% steel-800 MNM^{-e} 1535^oc), copper (210 MNM^{-z} $10\text{-}83^oc$) and silver (125MNM^{-e} 961^oc). In this study, therefore the cold-brazing Joining technique which does not utilize heat in its operation, was studied using experimental designs. Light copper wires of about 0.01mm diameter, zinc electrode and concentrated zinc tetraoxosulphate (vi) solution ($Zn2So_4$) were used and, results from the investigation and calculations show that thin metals and light parts can be easily joined using cold-Brazing joining technique with energy consumption for depositing a zinc filler of 1kg using high temperature process and the same amount of zinc filler using cold-Bracing, in the ratio of 71:269 KJ. Thus, it is certain that other electrolytically depositable metals with higher tensile strengths and melting points than silver-solders and brass, such as copper, can be used with this technique. And if fully made better, the present innovation will not only rival, but surpass most joining methods.

Introduction

Metal-joining techniques are essentially used to bring two or more surfaces into intimate contact in order to establish continuity across the resulting interface. And there is a broad range of it, viz; mechanical means, welding, soldering and brazing. Basically, brazing is a metal-joining process which uses another mater or alloy that has a melting point substantially lower than that of the metal to be joined (Chaoudary 2007:273). According to Samarthenggwork (n.d), brazing is a metal-joining process whereby a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action.

Brazing is one of the more flexible methods of joining similar and dissimilar materials and, many brazing alloys exhibit light temperature and corrosion resistance, lending themselves towards many aerospace and automotive applications. Generally, brazing differs from other joining processes in terms of its operating temperature (450^oc – 800^oc), and non-melting of base metals during the process (Brazing and welding-important differences n.d.).

However, very high amount of heat energy is required to raise a filler-metal to such a high temperature as 800^oc and further melt it completely at that temperature. Based on this and the notion that less energy is needed to deposit the same mass of filler-metal at cold, the cold-brazing joining technique was developed. It is basically the first of a new class of metal joining techniques that perform at cold and require less energy to deposit filler-metals. It operates entirely on electrolysis which makes it possible to work on all sizes of metals without the fear of creating holes or causing any form of damage to the work. In this study, the researchers examine the concept of brazing, the operation of cold brazing and the minimum quantity of energy required to deposit 1kg of zinc-filler using conventional high temperature brazing and cold-brazing.

Significance of the Study

Soldering and brazing are thought to have arisen very early in the history of metal-working, probably before 400 BC, as Sumerian swords makers had already perfected their skills before 3000 BC in assembling swords using hard soldering (Soldering n.d). By 2000 B.C, the Egyptians, also had learnt how to make small buttons from gold sheet, with fillet brazed joints and around 2200 B.C, drinking vessels with handles brazed to the body were created in Troy (Franklin Brazing and Metal treating 2014).

While no one is quite sure of how brazing came into use, it is known that in early times brazing was nothing more than “crude”. It was basically performed using charcoal fire and blowpipe. The low temperature of the fire required the use of filler metals with low melting points and work took longer to complete because it was performed piece by piece in open air regardless of the metal used. Consequently, ancient brazing work was limited to objects such as statuettes and jewelry made from gold and utensils and wheels made from bronze and brass.

Today, metal joining and brazing in particular, is a refined process that is performed using various types of equipment, from high-powered torches to atmosphere-controlled furnaces. Advancement in furnace technology has eventually

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made it possible to use stronger filler-metals and create more utilitarian object. However, the major set-back on the use of this process is "high energy consumption; A very high amount of heat energy is necessary for the process and part of the energy is lost through conduction, radiation and other means. So, as a contribution to the subject on brazing this study analysis the minimum energy necessary for conventional brazing and the operation of the less power-consuming cold-brazing.

Conceptual Clarification

The fundamental application of brazing in any metallic or nonmetallic structure is basically to join parts together. Brazing is a permanent metal-joining technique where two or more metals are joined by the use of a third dissimilar material such as braze alloy or silver solder. According to Choudary (2007), brazing is a metal-joining process which uses another metal or alloy that has a melting point substantially lower than that of the metal to be joined. In a similar view, Brazing Practice (2010), sees brazing as a metal-joining process where a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action.

Brazing provides design and manufacturing Engineers with a versatile and cost-effective method of joining similar and dissimilar metals and nonmetallic materials (Brazing and solder today 2009). A brazed joint has good properties that enable it to stand up to normal wear and tear and to any excessive force it may be subjected to. In order to obtain high-quality brazed joints, parts must be closely fitted and base metals must be exceptionally clean and free from oxides. Joint clearances can be of 0.03mm to 0.03mm (0.0012 to 0.0031 in) for the best capillary action and joint strength (Brazing Practice 2010). The two main methods for cleaning parts prior to brazing are chemical cleaning and abrasive or mechanical cleaning.

As brazing work requires high temperature, oxidation of metal surface occurs in an oxygen-containing atmosphere. To prevent this, atmospheric environments other than air must be employed. These include;

1. Combusted fuel gas (low hydrogen, AWS type I, "exothermically generated atmospheres"): 87% $N_{2.}$ For silver, copper-phosphorus and copper-zinc filler metals.
2. Ammonia (AWS type 5, also called fuming gas): Dissociated Ammonia (75% hydrogen, 25% nitrogen)- can be used for Marcy types of brazing and annealing. For copper, silver, nickel, copper-phosphorus and copper-zinc filler metals.
3. Nitrogenic, cryogenic or purified (AWS type 6C): Non-oxidizing and economical. For brazing copper, brass, low-nicked alloys, money, mediums and high carbon steels.
4. Noble gas (usually argon, AWS type 9): Non-oxidizing. For copper, silver, nickel, copper-phosphorus and copper-zinc filler metals(Brazing Practice 2010).

There are varieties of heating methods and techniques available to accomplish brazing operations, namely; torch brazing, furnace brazing, brazing, induction brazing, dip brazing, resistance brazing, infrared brazing, blanket blazing and braze welding. However, the most important factor in choosing a heating method is achieving efficient transfer of heat throughout the joint and doing so within the heat capacity of the metals used. Another consideration that is equally important is the melting point of the filler metal, because most metals have very high melting points which require large amounts of heat energy, so making the brazing operation energy intensive.

Minimum Energy Required For Conventional High Temperature Brazing

High temperature brazing requires a very high amount of heat energy to melt a filler metal. The heat energy needed for this process varies according to the metallurgical property of the braze metal and comprises the quantity of heat needed to raise the temperature of the total mass of filler-metal to its melting point and, the amount of heat needed to melt the filler metal completely at that temperature.

These can be expressed as;

$H = mc\theta$

Where

H = quantity of heat

M = mass

C = specific heat capacity

Q = change in temperature

And

H = m1

Where

H = heat involved

M = mass

C = specific latent heat of fusion

To calculate the minimum quantity of heat energy needed for conventional high temperature brazing, using pure zinc metal as a sample filler-metal, and given that;

Mass of zinc = 1 kg

Melting point = 420^{o}c

Specific heat capacity = 384 $Jk^{-1}\,k^{-1}$

Specific latent heat of fusion = 118000, 1kg

1st required to calculate the quantity of heat needed to raise the temperature of the given mass of zinc to its melting point.

Since $H = mc\theta$

Substituting the values of m, c and k in

$H = mc\ \theta$ gives;

H = 1 x 384 x (4 20-25)

= 1 x 384 x 395

:. H = 151680 J

2nd Required to find the amount of heat needed to malt the given mass of zinc complexly at its melting points.

H = m1

By replacing m and I with their respective values we have;

H = 1 x 118000

:. H = 118000

Therefore, the minimum quantity of heat needed for zinc brazing = quantity of heat needed to raise the given mass of zinc to its melting point + the quantity of heat needed to melt it completely at that temperature (provided there are no losses of any kind);

= 151680 + 118000

= 269680

= 270 KJ

Cold-Brazing

Cold-brazing is completely a new form of brazing developed based on its low energy consumption during brazing operation. It is aimed at solving problems of high energy consumption and energy wastage associated with high-temperature brazing processes. And very much unlike its counterparts, it does not employ heat in its operation. It operates wholly on electrolysis, utilizing a solution of an electrolyticallydepositable metal.

A Cold-Brazed Joint

In this study, however, concentrated zinc-tetraoxoulphate (vi) was employed as a medium for the transfer of zinc-filler, and excess acid was added to prevent hydrolysis and dendritic deposition during operation. During the process, two base metals of pure copper-0.01mm diameter each were joined at both ends and one end was connected to the negative terminal of a 12 volts direct current source, while the other end was dipped into the solution of the filler salt.

A negative electrode composed of pure zinc metal was also connected to the direct current source and, when current was passed through the solution, the filler metal began to build on the base metals. The quantity of the filler metals formed and the strength of the joint increased with time and the quantity of electricity passed through the set-up, thus obeying Faraday's first law of electrolysis.

Therefore, the interaction of ions responsible for the operation can be expressed as;

Ions from zinc-tetraoxosulphate (vi) zn^2+ (aq) $S0_4^{2-}$ (aq)

Ions from water H^+(aq) Oh(aq)

Cathode	anode
Zn^{2+} (aq)	$S0_4^{2}$-(aq)
H^+ (aq)	OH-(aq)

At the cathode both Zn^{2+} and H^+ migrate to the cathode where Zn^{2+} is discharged due to high concentration. The Zn^{2+} acquires two electrons from the cathode to be deposited as metallic grayish zinc on the copper metals.

With a zinc-filler as an anode, any one of the interactions below could take place;

1. $S0_4^{2-}$(aq) in the solution could be deposited as salt on the zinc filler $S0_4^{2-}$(aq) -> $S0_4$(s) + 2^{e-1}
2. OH- ions in the solution could interact to form oxygen and water.

40H- (aq) -> Zn^{2+} (aq) + Ze^-

But in this instance, the dissolving of zinc in solution as ions was easily favored. The total concentration of $S0_4^{2-}$ and Zn^{2+} in solution was constant. Thus, there was only a transfer or zinc from anode to copper metals.

Minimum Energy Required For Cold- Brazing

To calculate the amount of energy needed to transfer 1kg of zinc from a zinc filler to a base metal, given voltage impute and electrochemical equivalence of zinc as 24volts and $3.368x10^{-4}$ g/coloumb.

From Faraday's first law of electrolysis, m = zIt

Where;

m = mass of metal deposited during electrolysis.

z = electrochemical equivalence

I = current

t = time

(Holderness and lamberts 1986)

By making I the subject of the expression m = zit, we have;

$$I = \frac{m}{zt}$$

Since w = Ivt

Where;

w = work done in a given circuit

I = current

v = voltage

t = time (Anyakoha 2007)

Substituting $\frac{m}{zt}$ for I in w = Ivt, gives;

$$W = \frac{m}{zt} x vt$$

$$= \frac{mvt}{zt}$$

$$:.\ W = \frac{mv}{z}$$

By substituting the values of m,v and z in the formula w = $\frac{mv}{z}$ we have;

$$W = \frac{1x24}{3.368x10^{-4}}$$

$$= \frac{24}{0.0003368}$$

= 71258 . 906

:. W = 71.26kJ

Metal	Latent heat of meting Kj/kg	Specific heat capacity $J.kg^{-1}.k^{-1}$	Melting point ^oc	High temperature brazing energy kj	Electrochemical equivalence gc^{-1}	Cold - brazing energy kj
Cu	207	390	1080	618	$3.3/6x10^{-4}$	72
Zn	118	384	419	269	$3.368x10^{-4}$	71
Sn	58.5	226	232	105	$6.166x\ 10^{-4}$	39
Pb	22.4	129	327	61	$10.726x10^{-4}$	22
Brass (60% cu,40 %zn	168	280	900	501		

Summary of Minimum Energy for Conventional High Temperature Brazing and Cold-Brazing

The table below shows corresponding minimum energy needed for conventional high temperature brazing and cold-brazing, for a selected group of electrolytically, depositable metals and spelter. (Mass of filler metal= 1 kg, room temperature = 25^oc)

Summary

Metal-joining is a very important technology that is needed in almost all areas of the industry. However, most processes are energy intensive, such as welding and brazing with very high amounts of energy often lost through conduction and radiation during operation. A more economical and less energy-consuming method is the cold-brazing metal joining technique.

It is the first of a class of brazing that does not utilize heat and operates almost entirely on electrolysis, with energy consumption as low as 71kj for copper filler, comoared to the 501kj for 60% cu, 40% zn brass employed in conventional high temperature brazing.

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