References


[8] Nickel plating thickness, Wall Colmonoy Application & Information Memo, Nicrobraz Data, NS-027.

About Wall Colmonoy

Wall Colmonoy joins parts for high-temperature and corrosion applications using Nicrobraz®, Niferbraz®, and Cubraz™ brazing filler metals and brazing aids.

The pioneer of high-temperature brazing, Wall Colmonoy’s expert brazing engineer, Bob Peaslee, invented a new brazing technology involving nickel-based filler metals and hydrogen atmosphere furnaces in 1950. As a result, the new filler metal, Nicrobraz®, October 2003.

Today, Nicrobraz®, Niferbraz®, and Cubraz™ brazing filler metals are used in a variety of industries including aerospace, oil & gas, steel, energy, food, automotive, rail and defense meeting AWS, AMS, G.E., Honeywell, Pratt & Whitney and Rolls-Royce specifications. Nicrobraz products are available as powder, rod, paste, transfer tape and sheets in a full range of sizes and specifications. Wall Colmonoy also custom formulates brazing filler metals to meet customer requirements.

Aerobraze Engineered Technologies, a division of Wall Colmonoy, manufactures engineered components and provides technological solutions for the aerospace, energy, defense and transportation industries. This division meets aerospace quality standards in applications using the process of brazing, surfaced, welding, thermal processing, fabricating, machining and overhauling. Aerobraze Engineered Technologies has the engineering expertise to take concepts from design to prototype to production.

Surface Preparation for High Vacuum Brazing

Dr. A.J. Battenbough, Dipl.-Ing. A.M. Osmanda, Dr. A.M. Staines, Wall Colmonoy, Pontardawe, UK

The quality and strength of a brazed joint is determined by many factors including fit-up (joint clearance), brazing temperature and furnace atmosphere [1].

However the surface conditions of the base metal parts, which are often ignored, can also have a decisive influence on the success of the brazing process and joint properties.

Surface Cleanliness

Base metal surface condition is a key factor in producing a sound brazed joint. Good surface cleanliness is a pre-requisite for good wettability and helps ensure the molten brazing filler metal (BFM) flows freely over the substrate materials during the brazing process.

Successful high temperature vacuum brazing requires clean and oxide free surfaces if optimum joint strengths are to be achieved. It is very common for metallic sheets and prefoms to contain organic contaminants such as lubricating oil or grease. Other surface impurities that can also inhibit capillary flow include dirt and oxide residues.

A number of surface cleaning methods are available and their effectiveness depends on a number of factors such as the nature of the contamination, base material type and oxide layers which may be present on the base metal surface. If coolants are used during any of these cleaning processes, they must be free from contaminants such as silicone residues and corrosion inhibitors.

Mechanical Cleaning

All surfaces should be chemically cleaned prior to a secondary mechanical clean. Mechanical methods such as grinding, machining, filing, wire brushing, tumbling, vibratory polishing and blasting are all used. These methods can also remove oxide layers which may be present on the base metal surface. If coolants are used during any of these cleaning processes, they must be free from contaminants such as silicone residues and corrosion inhibitors.

Research has shown that grit blasting with non-metallic materials such as aluminium oxide and silicon carbide should be avoided as surface remnants of these materials can inhibit flow and wetting capabilities [3] by providing an oxide or physical barrier. The brazing of nickel-based substrates such as IN718 can be improved by blasting with NicroBlast® grit nickel-based powder, prior to vacuum brazing. Chilled cast iron and hardened or stainless steel grits or powders, are recommended for carbon steels and stainless steels, respectively.

Mechanical cleaning processes produce surface compressive stress and a roughened surface. It is well established that wetting on a rough surface occurs much more readily than on a smooth surface of the same geometry. For most materials, the optimum surface roughness is 0.75 to 3.75 microns.

WORLD HEADQUARTERS

WALL COLMONOY CORP. (USA)

101 W. Girard
Madison Heights, MI 48071
Tel.: 248-585-6400
Fax: 248-585-7960
Email: wcc@wallcolmonoy.com

EUROPEAN HEADQUARTERS

WALL COLMONOY LTD. (UK)

Aroy Industrial Estate
Pontardawe Swansea SA8 4HL
Tel.: +44 (0) 1792 860487
Fax: +44 (0) 1792 860487
Email: sales@wallcolmonoy.co.uk

Copyright © 2011 by Wall Colmonoy Corporation. All rights reserved.

No part of this work may be reproduced, translated or reproduced in any form or by any means, electronic or mechanical, including photography, recording or incorporation into any information retrieval system, without the written permission of the copyright holder. Permission requests should be ad-

Disclaimer

Although the information presented in this work is believed to be reliable, this work is published with the understanding that Wall Colmonoy Corporation and its authors are supplying general information and are not attempting to render or provide engineering or professional services. Neither Wall Colmonoy Corpora-
tion nor any of its employees make any warrant, guarantee, or representation, whether expressed or implied, with respect to the accuracy, completeness or usefulness of any information, product, process or apparatus discussed in this work; and neither Wall Colmonoy Corporation nor any of its employees shall be liable for any losses or damages with respect to or resulting from the user of, or the inability to use, any information, product, process or apparatus discussed in this work.
Surface Conditioning

Although chemical and/or mechanical cleaning is extremely effective, some substrate materials and components require additional conditioning in order to provide a braze-friendly surface. Chemical composition and thermal history of the base metals can have an influence on the surface characteristics. For example, base materials which contain quantities of aluminium and titanium do not allow good flow of the BF. This is due to the fact that these elements form very stable oxides within the surface region which prevent satisfactory wetting by the BF.

The following surface conditioning techniques are well-known and are commonly used in the industry:

Vacuum Cleaning – is a satisfactory method for removing oxides from stainless steel and some nickel-based alloys.

The main theory behind the use of a vacuum furnace in the brazing process is that a hard vacuum aids the removal of surface oxides. The main theory behind the use of a vacuum furnace in the brazing process is that a hard vacuum aids the removal of surface oxides.

The stability and the ease of dissociation of surface oxides is described by the “Ellingham diagram”, Figure 1.

As shown in Figure 1, some of the most stable, and therefore, hard to remove surface oxides are the oxides of titanium and aluminium.

Nickel-based alloys containing titanium and aluminium form complex spinel type oxides at the free surface which, if there is sufficient quantity, can inhibit wetting and subsequent brazing of these complex alloys.

Therefore alloys containing significant amounts of Ti and Al (≥1%) combined total should be subjected to a regime of cleaning to produce a surface layer of between 20-50µm depth which is nominally depleted of Ti and Al oxides.

The Ellingham diagram reveals, with the exception of copper and nickel, that in order to achieve a decomposition of thermodynamically stable metal-oxides, oxygen partial pressures and temperatures are necessary which cannot be realized in vacuum brazing. Removal of the oxide layers in the vacuum yield can occur through other mechanisms affected by [5]:

- The mismatch of the thermal expansion between base metal and oxide layer and its brittle mechanical properties leads to the micro-cracking within the oxide layer. Molten braze filler metal can then infiltrate through micro-cracks in the oxide layer causing it to lift and detach.
- Dissolution of the thin oxide layers in the base material by diffusion processes under vacuum conditions.
- Reduction of the metal oxide by additions of elements with high oxygen affinity and high vapor pressure such as lithium, magnesium and calcium. They are introduced into the chamber as vapor or are alloyed with the filler metal and act as getter-metals, simultaneously reducing the oxygen and moisture content of the residual gas (this method is used as an example for the brazing of aluminium without flux).

Hydrogen Partial Pressure Cleaning (HPPC) – is a satisfactory method for removing oxides from stainless steels, cobalt based super alloys and some nickel-based alloys. Hydrogen provides the active ingredient to clean and also braze components, and can eliminate the need to use a flux.

The capability of pure hydrogen to reduce oxides on the surfaces of metals and alloys depends on three main factors: 1) temperature, 2) purity of the hydrogen (measured as dew point) and 3) pressure of the gas. In the case of any given metal-metal oxide, existing in equilibrium (Fig 1), at a given purity level and pressure of hydrogen, the breakdown of the oxide is favored by higher temperatures and is also time-dependent [6]. Special caution needs to be exercised with metals which have a high affinity for hydrogen e.g. titanium as their properties may be significantly affected.

Fluoride Ion Cleaning (FIC) – is the only method capable of removing titanium and aluminium oxides from gamma prime precipitation hardened nickel-based super alloys (e.g. Inconel, Rene, Nimonic type alloys). This common surface cleaning method for Ti and Al rich alloys is seen as an extremely effective process and utilizes HF gas to offer a simpler, more precise and consistent alternative to other more complex techniques [7]. The chemical reactions are illustrated by the following:

1. 4HF + Al₂O₃ = 2AlF₃ + 3H₂O
2. 4HF + TiO₂ = TiF₄ + 2H₂O
3. 6HF + Cr₂O₃ = 2CrF₃ + F₃ + 3H₂O

In addition to removal of the oxides present on the surface and within cracks, surface depletion of elements such as titanium and aluminium also occurs which enhances braze-ability by removing oxide reformers. These reactions are illustrated by the following:

1. 6HF + 2Al = 2AlF₃ + 3H₂
2. 8HF + Ti = 2TiF₄ + 4H₂

The depletion reaction is a function of the reaction temperature and time, the concentration of HF and alloy composition.

Nickel Plating – can be used in lieu of FIC. It covers, and thus prevents oxidation of base metals containing high volume of aluminium and titanium elements. Nickel plating may also be desirable for high nitrogen containing stainless steels. Nickel plating also improves surface wettability.

Plating can be carried out by either electrolytic or electroless (chemical) methods. In nickel brazing electrolytic Ni plating is often favored due to the presence of phosphorus commonly associated with the electroless process.

Electroless nickel plating phosphorus, present in the layer, acts, as a molten point depressant causing the plated layer to become molten around 870°C (1600°F). Once molten, the layer ceases to provide a stable barrier between the brazing filler metal and substrate material, leading to issues with the brazed joint.

Recommended Thickness of Electrolytic Nickel Plating

If the base metal is hot rolled and pickled with a matte finish, then it is likely that the surface has been completely depleted of Al, Ti and Cr and as such should braze without Ni plating. When the same base metal is machined or cold finished, oxides will be present and the typical colors of Al and Ti may be visible. In general, if the Al+Ti content of the material is ≥ 4% (0.0025 - 0.015 mm (0.0001 - 0.0006 in.) of nickel plating will be satisfactory for vacuum processing. However, in pure dry hydrogen, 0.01 - 0.015 mm, (0.0004 - 0.0006 in.) thickness is recommended. In base metals with a Al+Ti ≥ 4% (0.008 - 0.015 mm, (0.0003 - 0.0006 in.) is required, while in dry hydrogen, 0.02 - 0.025 mm, (0.0008 - 0.001 in.) plating thickness is recommended. As a matter of fact some processors even use a Ni flash on 347 and 304 stainless steels, to improve braze quality [8].
Surface Conditioning

Although chemical and/or mechanical cleaning is extremely effective, some substrate materials and components require additional conditioning in order to provide a braze-friendly surface. Chemical composition and thermal history of the base metals can have an influence on the surface characteristics. For example, base materials which contain quantities of aluminium and titanium do not allow good flow of the BF{sub}M. This is due to the fact that these elements form very stable oxides within the surface region which prevent satisfactory wetting by the BF{sub}M.

The following surface conditioning techniques are well-known and are commonly used in the industry: [4]

Vacuum Cleaning – is a satisfactory method for removing oxides from stainless steel and some nickel-based alloys. The main theory behind the use of a vacuum furnace in the brazing process is that a hard vacuum aids the removal of surface oxides.

Fluoride Ion Cleaning (FIC) – is used for removing oxides from stainless steels, cobalt based super alloys and some nickel-based alloys. Hydrogen provides the active ingredient to clean and also braze components, and can eliminate the need to use a flux.

Hydrogen Partial Pressure Cleaning (HPPC) – is a satisfactory method for removing oxides from stainless steels, cobalt based super alloys and some nickel-based alloys. Hydrogen provides the active ingredient to clean and also braze components, and can eliminate the need to use a flux.

The capability of pure hydrogen to reduce oxides on the surfaces of metals and alloys depends on three main factors: 1) temperature, 2) purity of the hydrogen (measured as dew point) and 3) pressure of the gas. In the case of any given metal-metal oxide, existing in equilibrium (Fig 1), at a given purity level and pressure of hydrogen, the breakdown of the oxide is favored by higher temperatures and is also time-dependent [6]. Special caution needs to be exercised with metals which have a high affinity for hydrogen e.g. titanium as their properties may be significantly affected.

Fluoride Ion Cleaning (FIC) – is the only method capable of removing titanium and aluminium oxides from gamma prime precipitation hardened nickel-based super alloys [e.g. Inconel, Rene, Nimonic type alloys]. This common surface cleaning method for Ti and Al rich alloys is seen as an extremely effective process and utilizes HF gas to offer a simpler, more precise and consistent alternative to other more complex techniques [7]. The chemical reactions are illustrated by the following:

1. 4HF + Al + O sub 3 = 2AlF sub 3 + 3H sub 2 O
2. 4HF + Ti sub 3 O sub 5 = TiF sub 4 + 2H sub 2 O
3. 6HF + Cr sub 2 O sub 3 = 2CrF sub 3 + F sub 2 + 3H sub 2 O

In addition to removal of the oxides present on the surface and within cracks, surface depletion of elements such as titanium and aluminium also occurs which enhances braze-ability by removing oxide reformers. These reactions are illustrated by the following:

1. 6HF + 2Al = 2AlF sub 3 + 3H sub 2 O
2. 8HF + Ti = TiF sub 4 + 4H sub 2 O

The depletion reaction is a function of the reaction temperature and time, the concentration of HF and alloy composition.

Nickel Plating – can be used in lieu of FIC. It covers, and thus prevents oxidation of base metals containing high volume of aluminium and titanium elements. Nickel plating may also be desirable for high nitrogen containing stainless steels. Nickel plating also improves surface wettability.

Plating can be carried out by either electrolytic or electroless (chemical) methods. In nickel brazing electrolytic Ni plating is often favored due to the presence of phosphorus commonly associated with the electroless process.

Electroless nickel plating phosphorus, present in the layer, acts as a melting point depressant causing the plated layer to become molten around 870°C (1600°F). Once molten, the layer ceases to provide a stable barrier between the brazing filler metal and substrate material, leading to issues with the brazed joint.

Recommended Thickness of Electrolytic Nickel Plating

If the base metal is hot rolled and pickled with a matte finish, it is likely that the surface has been completely depleted of Al, Ti and Cr and as such should braze without Ni plating. When the same base metal is machined or cold finished, oxides will be present and the typical colors of Al and Ti may be visible. In general, if the Al+Ti content of the material is <4%, 0.0025 - 0.015 mm (0.0001 – 0.0006 in.) of nickel plating will be satisfactory for vacuum processing. However, in pure dry hydrogen, 0.01 - 0.015 mm, (0.0004 – 0.0006 in.) thickness is recommended. In base metals with a Al+Ti >4%, 0.008 - 0.015 mm, (0.0003 – 0.0006 in.) is required, while in dry hydrogen, 0.02 - 0.025 mm, (0.0008 – 0.001 in.) plating thickness is recommended. As a matter of fact some processors even use a Ni flash on 347 and 304 stainless steels, to improve brazing quality [8].

Figure 1: The "Ellingham diagram" which shows which surface oxides are relatively easy (to the left) and difficult (to the right) to remove during vacuum brazing.
Surface Preparation for High Vacuum Brazing

Dr. A.J. Battenbough, Dipl.-Ing. A.M. Osmanda, Dr. A.M. Staines, Wall Colmonoy, Pontardawe, UK

The quality and strength of a brazed joint is determined by many factors including fit-up (joint clearance), brazing temperature and furnace atmosphere [1].

However the surface conditions of the base metal parts, which are often ignored, can also have a decisive influence on the success of the brazing process and joint properties.

Surface Cleanliness

Base metal surface condition is a key factor in producing a sound brazed joint. Good surface cleanliness is a prerequisite for good wettablity and helps ensure the molten brazing filler metal (BFM) flows freely over the substrate materials during the brazing process.

Successful high temperature vacuum brazing requires clean and oxide free surfaces if optimum joint strengths are to be achieved. It is very common for metallic sheets and preforms to contain organic contaminants such as lubricating oil or grease. Other surface irregularities that can also inhibit capillary flow include dirt and oxide residues. A number of surface cleaning methods are available and their effectiveness depends on a number of factors including the nature of the contamination, base material type and configuration. Chemical and/or mechanical techniques are used to both clean and condition the surface of the materials to be brazed.

Chemical Cleaning

Oil and grease are usually removed by dipping the part in a suitable degreasing solvent, or by vapor degreasing, alkaline (HON, NAOH, phosphates) or aqueous cleaning. Residues which remain will form a barrier between the base metal surfaces and the brazing materials. An oily base metal, for example, will repel the flux, leaving bare spots that can oxidize when heated, resulting in voids as the BFM is not able to wet the surface in those areas.

However, if the surface is oxidized, the oxide layers cannot be easily removed by the majority of chemical processes. In these instances, a mechanical or chemical cleaning process such as acid pickling may be desirable. Pickling results in the removal of a thin layer from the substrate surface which may contain oxidized material.

Research has shown that grit blasting with non-metallic materials such as aluminium oxide and silica carbide should be avoided as surface remnants of these materials can inhibit flow and wetting capabilities [3] by providing an oxide or physical barrier. The brazing of nickel-based substrates such as IN 718 can be improved by blasting with NicroBlast® grit nickel-based powder, prior to vacuum brazing. Chilled cast iron and hardened or stainless steel grits or powders, are recommended for carbon steels and stainless steels, respectively.

Mechanical Cleaning

Mechanical processes produce surface compressive stress and a roughened surface. It is well established that wetting on a rough surface occurs much more readily than on a smooth surface of the same geometry. For most materials, the optimum surface roughness is 0.75 to 3.75 microns.

References

2. http://www.aws.org/wj/amwelder/P-00/fundamentals.html
8. Nickel plating thickness, Wall Colmonoy Application & Information Memo, Nicrobraz Data, NS-027.

About Wall Colmonoy

Wall Colmonoy joins parts for high-temperature and corrosion resistant applications using Nicrobraz®, Niferobraz®, and CuBraz™ brazing filler metals and brazing aids.

The pioneer of high-temperature brazing, Wall Colmonoy’s expert brazing engineer, Bob Peaslee, invented a new brazing technology involving nickel-based filler metals and hydrogen atmosphere furnaces in 1950. As a result, the new filler metal, Nicrobraz®, October 2003.

Today, Nicrobraz®, Niferobraz®, and CuBraz™ brazing filler metals are used in a variety of industries including aerospace, oil & gas, steel, energy, food, automotive, rail and defense meeting AWP, AMS, G.E., Honeywell, Pratt & Whitney and Rolls-Royce specifications. Nicrobraz products are available as powder, rod, paste, transfer tape and sheets in a full range of sizes and specifications. Wall Colmonoy also custom formulates brazing filler metals to meet customer requirements.

Aerobraze Engineered Technologies, a division of Wall Colmonoy, manufactures engineered components and provides technological solutions for the aerospace, energy, defense and transportation industries. This division meets aerospace quality standards in applications using the process of brazing, surfacing, welding, thermal processing, fabricating, machining and overhauling. Aerobraze Engineered Technologies has the engineering expertise to take concepts from design to prototype to production.

Copyright © 2011 by Wall Colmonoy Corporation. All rights reserved.

No part of this work may be published, translated or reproduced in any form or by any means, except as incorporated into any information retrieval system, without the written permission of the copyright holder. Permission requests should be addressed to: Marketing Communications, marketing@wallcolmonoy.com

Disclaimer

Although the information presented in this work is believed to be reliable, this work is published with the understanding that Wall Colmonoy Corporation and the authors are supplying general information and are not attempting to render render or provide engineering or professional services. Neither Wall Colmonoy Corporation nor any of its employees make any warranty, guarantee, or representation, whether expressed or implied, with respect to the accuracy, completeness or usefulness of any information, product, process or apparatus discussed in this work; and neither Wall Colmonoy Corporation nor any of its employees shall be liable for any losses or damages with respect to or resulting from the user of, or the inability to use, any information, product, process or apparatus discussed in this work.