Filler Metal Management in NOCOLOK® Flux Brazing of Aluminium

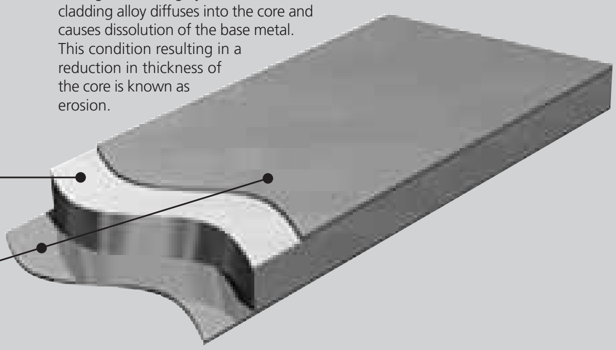
Introduction

Aluminium brazing sheet is used in the producion of automotive heat exchangers, for example in components such as tubes, headers and side supports for radiator cores. Brazing sheet consists of an Al-Si alloy clad on one or two sides to a core alloy. The core provides structural integrity while the low melting point Al-Si alloy melts and flows during the brazing process to provide upon cooling a metallurgical bond between the components.

During the brazing cycle, Si from the cladding alloy diffuses into the core and causes dissolution of the base metal. This condition resulting in a reduction in thickness of the core is known as erosion.

The extent of Si penetration and core alloy dissolution depends on several factors including time and temperature, cladding thickness, alloy composition and microstructural properties. Controlling these factors to minimize the extent of erosion is known as filler metal management. This poster display focuses on one factor most easily controlled by the brazer - temperature – and the effects of this factor on erosion.

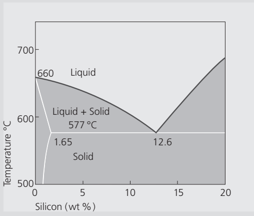
Core Alloy,
Melting point
630 – 660 °C



Al-Si Cladding
Melting point
577 – 610°C

Cladding Alloys

The melting characteristics of the cladding alloys are governed by the Al-Si phase diagram. The eutectic composition, i.e. the amount of Si required to produce the lowest melting point is 12.6 %. The melting point at this composition is 577 °C. At lower Si levels the solidus or the point at which melting begins is also 577 °C. However, melting occurs in a range and the temperature above which the filler is completely molten is called the liquidus. In between the solidus and liquidus, the filler is partially molten, existing both as liquid and solid. The difference between the solidus and the liquidus forms the basis for various filler metal alloys.



The table below shows the solidus and liquidus of common brazing alloys.

Alloy	AA-4343	AA-4045	AA-4047
%Si Nominal	7.5	10.0	12.0
Solidus	577	577	577
Liquidus	613	591	582

The higher Si alloys (e.g. AA4047) have higher fluidity and a narrower melting point range while the lower Si alloys have less fluidity with a wider, higher melting point range. Erosion of the base metal occurs when the braze alloy dissolves part of the core alloy. The extent of erosion is increased by:

- Higher Si levels in the braze alloy
- Longer braze cycles
- Excessive peak brazing temperatures
- Excessive thickness fo the braze metal layer
- A design which allows pooling of the braze metal to occur

Experimental

The effect of temperature on filler metal erosion was studied using an automotive radiator core. The alloy package consisted of:

Header:AA4343/AA3005 Tubes:AA4343/AA3003 Fins:AA3003

Brazing was carried out in a NOCOLOK batch brazing furnace with the following brazing conditions:

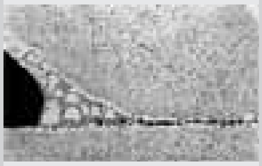
Flux loading 5 g/m² Heating rate 20 °C/minute Dewpoint < –40°C

The effect of peak temperature on core alloy dissolution is depicted below:

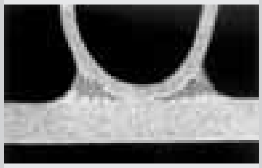
Tube to Header Joints / Fin to Tube Joints

595 °C for 5 minutes

Tube to Header Joints: 15 % peak reduction in original tube thickness

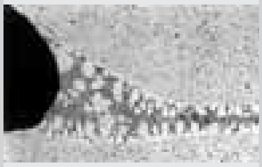


Fin to Tube Joints: 12 % peak reduction in original fin thickness



610 °C for 2 minutes

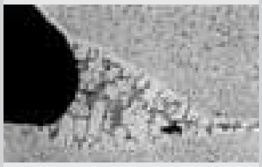
Tube to Header Joints: 40 % peak reduction in original tube thickness



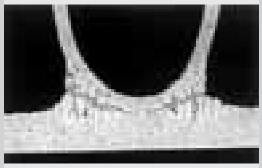
Fin to Tube Joints: 50 % peak reduction in original fin thickness

625 °C for 2 minutes

Tube to Header Joints: 60 % peak reduction in original tube thickness



Fin to Tube Joints: 80 % peak reduction in original fin thickness



The size of the filler pool at the joint area is significantly increased with higher peak brazing temperatures. As the braze alloy layer dissolves the core alloy, more filler metal is created enlarging the filler metal pool with a concomitant decrease in a base metal thickness.

Solvay Fluor

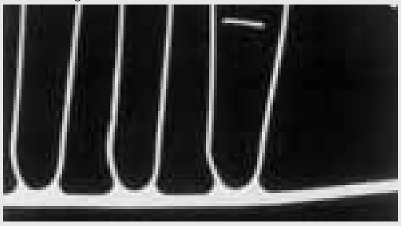
SOLVAY

Experimental

The effect of excessively high peak brazing temperatures is illustrated further on fin to tube joints close to the clad headers.

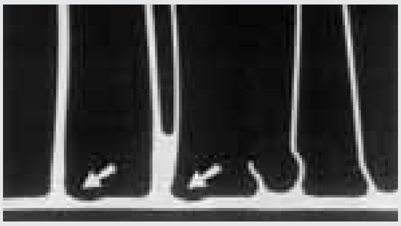
610 °C for 2 minutes

No thinning of the tube core



625 °C for 2 minutes

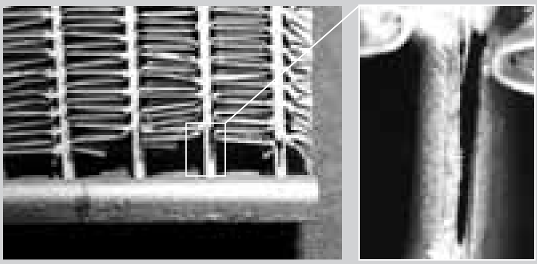
Significant erosion of the tube core



In this case, joining progresses initially as expected. The cladding layer on the tube melts and flows by capillary action to the fin to tube joint and a normal fillet forms. However, as the peak brazing temperature is allowed to rise beyond the recommended maximum (605 °C) the following occurs:

- The fluidity of the filler metal at the tube to header foint is increased and some of the liquid filler metal is released and flows to the nearest tube to fin joints.
- Excess filler metal now at the tube to fin joints accelerates dissolution of the tube core adjacent ot the fin, eroding the tube wall thickness.
- The excess filler metal pool is then drawn by capillary action in between the fins, particularly where the fin spacing is narrow. The fins are drawn together by the strong capillary forces, displacing the fin from its original fin to tube position.
- As the fins move together, drawing the filler metal pool from its original position, the denuded area is significantly reduced in cross sectional thickness.

In some instances the extent of filler metal erosion is so severe that the entire thickness of the tube is consumed resulting in catastrophic failures.



Case Study

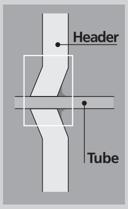
A radiator core retrieved from service was examined for a suspected premature corrosion related failure. Upon closer metallographic examination, no evidence of corrosion was found at the failed area.

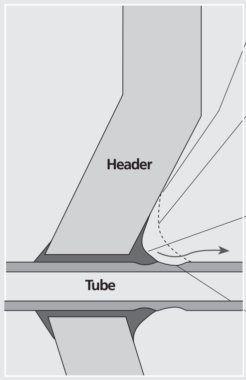
Header
AA4343 / AA3005
Tube
AA4343 / AA3003

33% tube core erosion in the failure area

It was concluded that the cause of the failure was in fact a mechanical failure occuring in the thinned wall area.

The following sequence of events proposes a rational explanation for the eroded tube area:





Upon reaching brazing temperatures of about 580 °C to 590 °C, part of the filler metal flowed to the tube to header joint.

As the temperature was increased beyond the recommended maximum peak temperature (605 °C), a large filler metal pool formed at the joint resulting in excessive tube wall erosion.

A sudden decrease in filler metal surface tension or uneven motion of the furnace mesh belt then caused a portion of the filler metal pool to flow away from the tube to header joint.

This action left an area denuded of metal resulting in a 33 % peak reduction in tube wall thickness.

In service radiators are subject to internal pressure fluctuations and expansion and contraction due to heating and cooling. Mechanical failure was imminent and occured in the weakest part of the tube, the thinned down tube wall area adjacent to the tube to header joint.

Conclusions

Erosion of the base metal is undesirable since it reduces the wall thickness of the brazed component. In addition Si penetration in the grain boundaries is known to increase the susceptibility to intergranular corrosion. Therefore proper filler metal management practices should be observed to prevent undesirable effects. One such factor easily controlled by the brazer is maximum peak brazing temperature.

31/352/04.08/007/500

Solvay Fluor GmbH
Hans-Böckler-Allee 20
30173 Hannover, Germany
Telephone +49 5 11-8 57-0
Telefax +49 5 11-8 57-21 46
www.solvay-fluor.com

Solvay Fluor

SOLVAY

a Passion for Progress®