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Brazing of Aluminium Alloys with Higher Magnesium-content

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I. Introduction

Successful brazing of any Al alloy requires prior removal of the native surface oxide film, which is usually done by employing a flux.
The flux must be capable of displacing the oxide film barrier during brazing and allow the filler metal to flow freely and must prevent the alloy surface from re-oxidizing.
Mg-additions in Al-alloys, although helpful in achieving stronger alloys, lead to a decrease in brazeability.
During the brazing cycle Mg deteriorates oxide removal and a Mg-level only up to 0.5 % can be safely brazed with the standard brazing flux [1].
The present work is focused on brazing of higher Mg-content 6xxx series Al alloys, namely heat-treatable AA-6082 alloy (0.7-1.2 % Mg; 0.9-1.3 % Si; 0.5 % Fe; 0.5-1.0 % Mn; 0.25 Cr; 0.20 Zn; 0.1 Ti), with a near-eutectic Al-Si filler metal using non-corrosive fluxes.

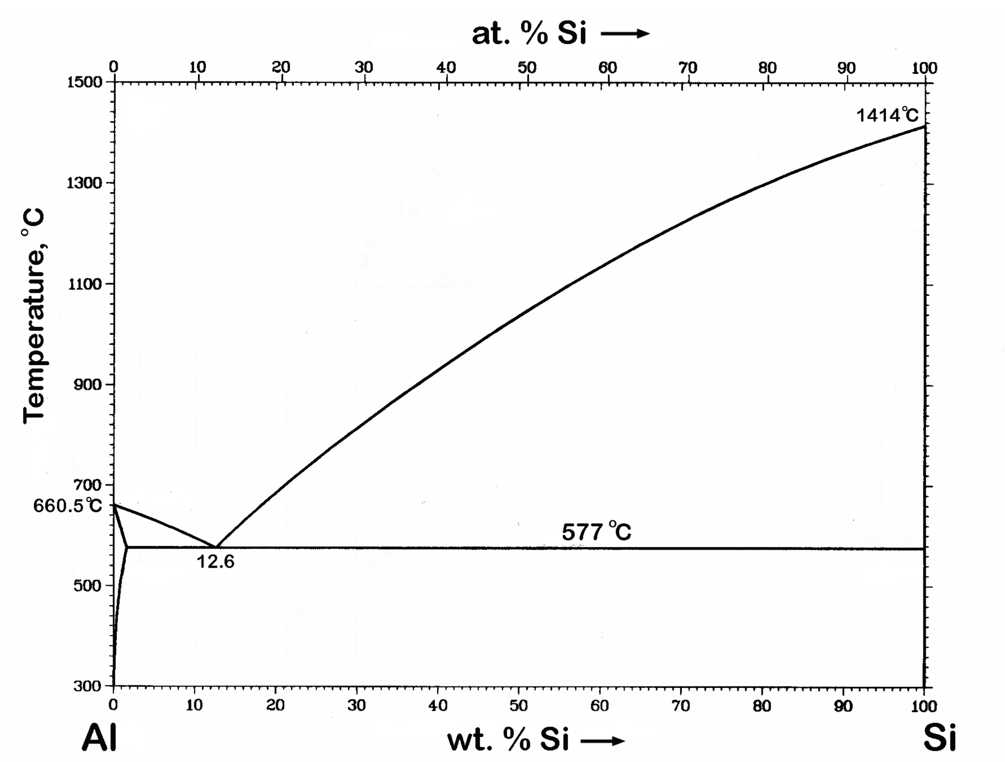

***Fig. 1:** The binary Al-Si phase diagram [3]*

II. Brazing Alloys

The standard brazing process involves joining of components with a brazing alloy, typically Al-Si filler metals as shown in Table 1. [2]
The eutectic isotherm in the binary Al-Si system lies at 577 °C and the eutectic alloy composition is 12.6 wt. % of Silicon (Fig. 1).
The choice of brazing filler depends upon the Al alloys being used, brazing process and the joint design, including clearance of the parts.

Table 1: *Composition (wt. %) and brazing temperature range of filler metals commonly used for joining Aluminium alloys [2]*

AWS Classification	UNS Number	Si	Cu	Mg	Fe	Zn	Mn	Al	Brazing range, °C
BAlSi-2	A94343	6.8-8.2	0.25	-	0.8	0.20	0.10	Bulk	599-621
BAlSi-3	A94145	9.3-10.7	3.3-4.7	0.15	0.8	0.20	0.15	Bulk	571-604
BAlSi-4	A94047	11.0-13.0	0.30	0.10	0.8	0.20	0.15	Bulk	582-604
BAlSi-5	A94045	9.0-11.0	0.30	0.05	0.8	0.20	0.05	Bulk	588-604
BAlSi-7	A94004	9.0-10.5	0.25	1.0-2.0	0.8	0.20	0.01	Bulk	588-604
BAlSi-9	A94147	11.0-13.0	0.25	0.1-0.5	0.8	0.20	0.10	Bulk	582-604

III. The use of Brazing Fluxes and Atmospheres

Two kinds of fluxes are available: corrosive and non-corrosive.
Corrosive fluxes (e.g. FIRINIT 200 [5], etc.) are water-soluble and usually hygroscopic, containing both chloride and fluoride salts, and residues can be washed off the part after brazing, and the resulting joint has a clean appearance.
The benefit of **non-corrosive** flux is the elimination of both post-brazing washing and corrosion from the corrosive (hydroscopic) flux residues.
Fluoride-based non-corrosive fluxes of the KF-AlF_3 system (Fig. 2) [4] are used to displace the surface oxide film on Al alloy during brazing process.
A commonly used non-corrosive flux of the general formula $\mathbf{K_{1\div3}AlF_{4\div6}}$ is known as NOCOLOK® Flux with a melting range 565 - 572 °C [1], which is below the eutectic isotherm in the binary Al-Si system (Fig. 1) [3]
There is, however, a limit to the amount of Mg in Al alloy (of about 0.5 %) that can be tolerated for NOCOLOK® Flux brazing.

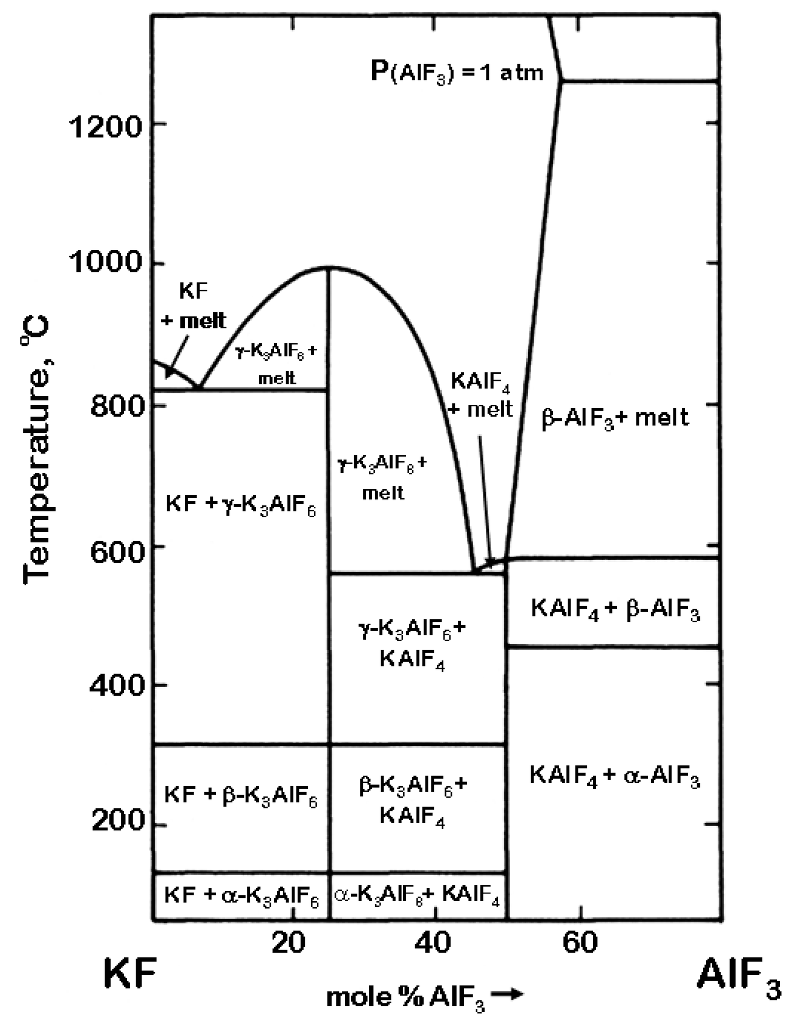

***Fig. 2:** The KF-AlF_3 phase diagram [4]*

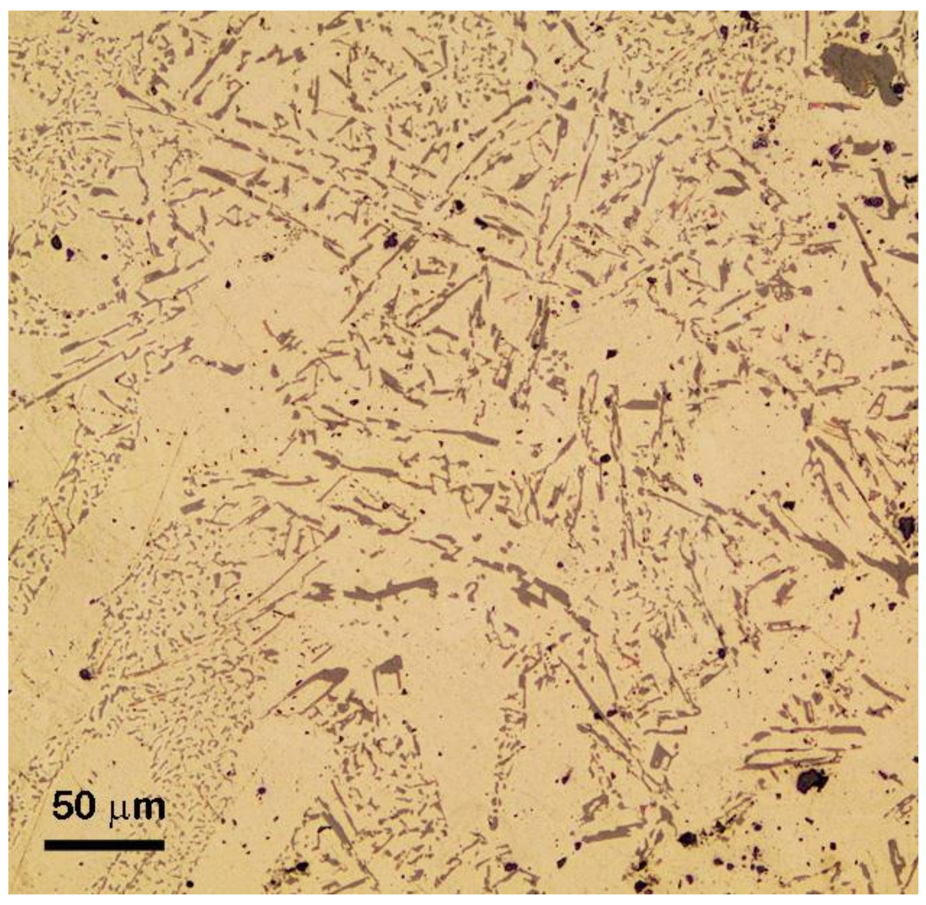

***Fig. 3:** Microstructure of the ("as-cast") near-eutectic BAlSi-4 (A94047) brazing alloy. (Bright-field optical image)*

IV. A Typical Example of Aluminium Brazing

Near-eutectic BAlSi-4 (A94047) alloy was used as a filler metal (Fig. 3).
Brazing of test 6082 alloy coupons to non heat-treatable AA-1005 alloy with BAlSi-4 (A94047) filler metal was performed at 620 °C in flowing N_2 using Cs-containing (non-corrosive) NOCOLOK® Cs Flux and a sound brazement was obtained (Fig. 4).

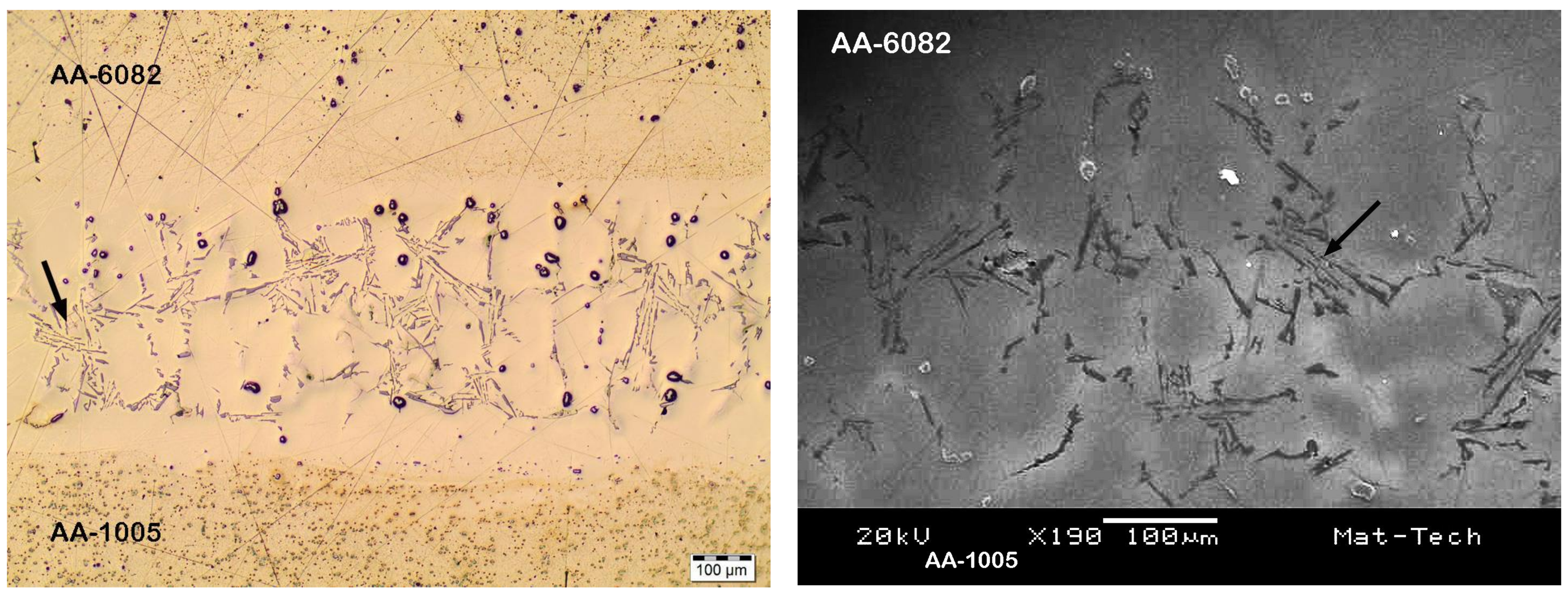

***Fig. 4:** Morphology of the AA-6082/AA-1005 joint developed during brazing with BAlSi-4 (A94047) filler metal at 620 °C in flowing Nitrogen using Cs-containing NOCOLOK® Cs Flux: a) bright-field optical image and b) Secondary Electron Image taken from the central part of the brazement. (The eutectic constituent of the brazing seam microstructure is indicated by arrows.)*

V. Concluding Remarks

A higher Mg-content AA-6082 alloy can be brazed successfully with a near-eutectic BAlSi4 (A94047) filler metal employing a NOCOLOK-type process and using a commercially available NOCOLOK® Cs Flux.

- Careful control of the flux quality is vital to providing quality joints.
- No post-brazing washing of the brazed joints is required.

To recover an initial temper of the heat-treatable 6082 alloy, a post-brazing thermal treatment (ageing) of the product joints can be considered.

V1. References

[1] The NOCOLOK® Flux Brazing Process, Solvay Special Chemicals (www.solvay.com)
[2] Specification for Filler metals for Brazing and Braze Welding, 10th edition, AWS A5.8M/A5.8:2011-AMD1, American Welding Society, 2011
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[4] W.T. Thompson and D.G.W. Goad, Can. J. Chem., 54 (1976) 3342-3349
[5] Hygroscopic Fluxes for Aluminium Brazing and Welding, www.firinit.de
[6] J. Garcia, C. Massoulier and Ph. Faille, Brazeability of Aluminium Alloys Containing Magnesium by CAB Process Using Cesium Flux, Society of Automotive Engineers, 2001
[7] Aluminium Brazing with NOCOLOK® - 7