TECHNICAL NOTE

Effect of Hole in Brazing Sheet on Vacuum Brazability of Aluminum Tubes†

Tadashi TAKEMOTO *, Krishnasamy SAMPATH ** and Ikuo OKAMOTO ***

KEY WORDS: (Vacuum) (Aluminum) (Brazability) (Brazing) (Joint Preparation) (Openings)

Vacuum brazing of aluminum is becoming more and more pupolar especially for components like heat exchangers used in automotive air conditioners. As in conventional flux brazing, in fluxless vacuum brazing also, a brazed joint is obtained only when the "readily forming" tenacious oxide layer is removed from bond area for the liquid filler to wet the substrate and then spread over it. In vacuum brazing of aluminum, the oxide is mechanically separated while heating – as the thermal expansion of aluminum is about three times that of aluminum oxide – and further oxidation is avoided by using a higher degree of vacuum and "getter" elements like magnesium[1), 2)]. Magnesium, for example, has a higher affinity for oxygen and moisture than aluminum, and is normally added to the brazing filler[3)]. The brazability depends on a number of factors and a study was carried out to observe the effect of hole, which may be present in certain industrial components, on fillet formation in the vacuum brazing of aluminum.

Aluminum tubes (A 3003) of 20 mm diameter, 1.4 mm wall thickness and 20 mm height were brazed to square brazing sheet end caps (25 x 25, mm). The brazing sheet is composed of BA 4004 filler alloy clad layer, thickness is 0.1 mm on either side, and A 3003 core material, the total brazing sheet thickness is 1 mm. **Table 1** gives the chemical compositions of materials used. The particular crosssection is chosen to give almost equal volume of filler metal for fillet formation on both the inner and outer sides of the tube. The joint area of tube was polished smooth on No. 600 emery paper, and then cleaned in an acetone-sonic bath. The brazing sheet end caps, with or without center holes were also cleaned in acetone bath and the specimens were assembled with stainless steel wire holding the parts in position. Care was taken to avoid the impression of finger prints on the specimen surface. The temperature of the specimens were measured using a separate dummy. The specimens were placed inside the furnace with horizontal brazing sheet end caps, evacuated to 2×10^{-5} torr, held at 600°C for 3 min and then cooled to room temperature. The brazed specimens were then cut

Table 1 Chemical compositions of tube and brazing sheet end cap (wt%)

Materials		Elements							
		Si	Mg	Mn	Cu	Fe	Zn	Ti	Al
Tube	A 3003 *	<0.6	–	1.0~1.5	<0.20	<0.7	<0.10	–	bal.
End cap (brazing sheet)	BA 4004 (cladding)	9.8	1.5	0.03	0.02	0.21	0.02	0.01	bal.
	A 3003 (core)	0.23	0.02	1.08	0.14	0.57	0.005	0.02	bal.

* : Nominal composition

† Received on October 31, 1983

* Research Instructor
** Research fellow, Welding Research Institute, Tiruchirapalli, India
*** Professor

Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

across the fillet. The fillet size was measured using a profile projector with a digital read-out facility. Similar study was also carried out using aluminum tubes of 30 mm diameter, 1.5 mm wall thickness and 20 mm height brazed to square brazing sheet end caps of size 38 x 38 mm crosssection.

The vacuum brazing results showed that the brazing condition used is good, and there is no significant erosion of the end caps and pipes. **Table 2** shows some examples of the braze reuslts on 20 mm diameter tubes. Almost equal size fillet are formed on either side of the tube wall of top and bottom ends when there was no hole in either end caps **(Fig. 1)**. However, a hole in any one of them drastically reduced the inside fillet size but with a little increase in the external fillet size **(Fig. 2)**. The tendency seems to deteriorate when the hole size was increased further and also when holes were made, one each, on both top and bottom end caps.

Similar tendency was observed in the case of 30 mm diameter tubes also as shown in **Table 3**. However, the tendency was slightly different from that of 20 mm diameter tubes. Within the shown examples, only the tendency of hole size appears. The presense and the increase in hole size decreased the inside fillet size irrespective of the hole position. Due to the size effect, the dimensions of the fillets were larger than those of 20 mm diameter tubes. Further experiments were carried out using nitrogen carrier gas brazing process at 10^{-1} torr. The tendencies almost remained the same.

From the results obtained, the following conclusions may be observed. In fluxless vacuum brazing of aluminum tubes to brazing sheet end caps, 1): almost equal size fillets form on either side of the tube wall when no holes are present in either end caps or in the tube wall, 2): when holes are present, the internal fillet size decreases drastically.

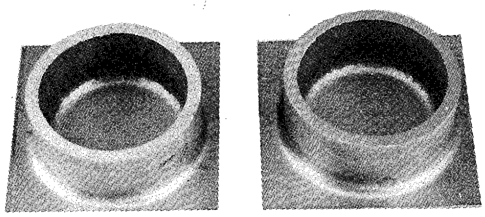

Fig. 1 Appearance of brazed specimen without holes on end caps, cut into two pieces

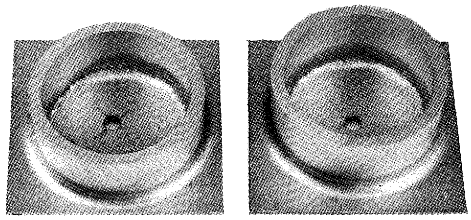

Fig. 2 Appearance of brazed specimen with holes on both top and bottom end caps, cut into two pieces

Table 2 Some examples of throat thickness of vacuum brazed 20 mm diameter tubes

Hole position	Side of caps	Specimen number	Hole size (mm)	Throat thickness (mm) Inside	Throat thickness (mm) Outside	Specimen number	Hole size (mm)	Throat thickness (mm) Inside	Throat thickness (mm) Outside
No hole	Top	12	0	1.02	0.76				
	Bottom			0.97	0.98				
Top only	Top	4	2	0.48	0.90	17	4	0.21	1.15
	Bottom			0.54	0.86			0.31	1.17
Bottom only	Top	13	2	0.21	1.44	16	4	0.25	1.07
	Bottom			0.15	1.05			0.17	1.06
Both top and Bottom	Top	15	2	0.21	1.27	18	4	0	1.24
	Bottom			0.20	1.23			0	1.10
Tube wall	Top	27	2	1.09	0.63	36	4	0.43	1.22
	Bottom			1.19	0.87			0.47	1.03

Table 3 Some examples of throat thickness of vacuum brazed 30 mm diameter tubes

Hole position	Side of caps	Specimen number	Hole size (mm)	Throat thickness (mm) Inside	Outside	Specimen number	Hole size (mm)	Throat thickness (mm) Inside	Outside
No hole	Top	19	0	1.49	0.92				
	Bottom			1.35	0.98				
Top only	Top	20	2	1.08	1.50	39	4	0.41	0.94
	Bottom			1.08	1.32			1.12	1.16
Bottom only	Top	29	2	0.84	1.48	34	4	0.65	1.79
	Bottom			0.85	1.47			0.77	1.64
Both top and Bottom	Top	28	2	1.15	1.32	35	4	0.59	1.05
	Bottom			0.83	1.24			0.56	1.31
Tube wall	Top	21	2	0.63	1.69	40	4	0.60	1.33
	Bottom			0.69	1.94			0.83	1.32

References

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