Advantages of Flux Cored Alloys for Open Air Brazing

Flux cored wire creates a high-strength joint while limiting the amount of flux used and creating less waste

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Brazing is an important process used in many industries today including heating, ventilation, air conditioning, refrigeration, automotive, aerospace, construction, and electronics. Brazing's versatility allows numerous different assemblies and base metals to be joined together. Several brazing methods can be employed ranging from torch brazing in open air to vacuum furnace brazing. Torch and induction brazing are two of the most common brazing methods used in industry. These processes are typically performed in open air with the use of a Ag-Cu-Zn-based alloy and a flux. Traditionally, separate fluxing of the assemblies to be brazed has been a prebraze step that increases process time, postbraze cleanup time, and safety concerns, and often reduces the quality and consistency of the resulting braze joint. In recent years, Ag-Cu-Zn- and Al-based flux cored products have been introduced to the brazing industry for torch and induction brazing applications. Flux cored alloys reduce brazing process times and safety/environmental concerns while improving braze joint quality and strength.

The application of external flux when brazing with solid wire is typically performed manually by an operator prior to brazing. The solid braze alloy is then often applied by hand during heating or preplaced in the joint prior to heating. Flux cored alloys reduce the two steps of applying the flux and alloy prior to brazing into one. For flux cored products, the flux is proportionally added to the inside of a braze alloy wire so that no external flux application is required. Flux cored alloys can also be applied during heating or preplaced in the joint region prior to brazing. Figure 1 shows an example of the stages a flux cored ring goes through during heating. After the ring is placed on the assembly (1), heat is applied during brazing and the flux inside the wire becomes molten and flows out of the wire into the joint interface (2). The flux that flows into the joint interface removes and prevents oxide formation during heating allowing the molten braze alloy to wet the base material and capillary into the joint (3). Capillary attraction pulls the alloy through the joint, forcing the flux out of the joint interface and completes the braze (4). Flux cored products consisting of various braze alloy compositions and flux chemistry combinations can be produced by alloy manufacturers. Manufacturers can also vary the flux to alloy ratio within the product, providing more versatility to the end user.

The study described in the following sections was performed to provide data and support for the many claims that are made in regard to the advantages of flux cored brazing products.

Fig. 1 — Stages of flux cored alloys during heating.

Outline of Study and Methods

The study analyzed the characteristics of 304L stainless steel joints brazed with solid wire and a paste flux vs. joints brazed with a flux cored alloy. All assemblies were brazed using an oxyacetylene torch. The primary characteristics analyzed were consistency of product application, waste produced during brazing, and joint strength. The braze alloy used for the solid and flux cored wires was Braze 505™ (AWS A5.8 BAg-24). The paste flux used in conjunction with the solid wire was Handy Flux® Type B-1 (AWS 5.3 FB3C), while the flux used in the cored wire was a proprietary boron modified flux in powder form. The flux cored alloy used was Lucas-Milhaupt's Handy One® 505.

Test 1: Consistency of Flux Application and Waste Produced during Brazing

The use of flux cored alloys not only reduces process steps and time but also provides a more consistent method of flux application to the base materials being joined. Providing a consistent amount of flux to an assembly prior to brazing will re-

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Table 1 — Amount of Flux Applied and Waste Produced during Brazing

	Weight of Flux Applied (g)	Weight Loss after Brazing (g)	Weight of Residue Loss after 1st 10 min (g)	Weight of Residue Loss after 2nd 10 min (g)	Total Weight of Residue Loss after Water Soak (g)	Total Loss during Braze Process (g)
Average Value for Joints Brazed with Solid Braze™ 505 and Handy Flux® Type B-1	0.150	0.073	0.068	0.008	0.076	0.149
Average Value for Joints Brazed with Handy One® Braze 505	0.073	0.011	0.063	0.003	0.066	0.077
Percent Difference between Flux Cored and Solid Form	51.33%	84.30%	7.35%	62.5%	13.15%	48.3%

Table 2 — Reduction of Flux by Using Flux Cored Rings

	# of Rings Used per Week	# of Rings Used per Year	Average Amount Flux per Ring (g)	Amount of Flux per Year (kg)	Amount of Flux Reduced by Using Flux Cored Rings (kg)
Data for Solid Rings and External Flux	1,000	52,000	0.150	7.8	N/A
	10,000	520,000	0.150	78.0	N/A
	100,000	5,200,000	0.150	780.0	N/A
Data for Flux Cored Rings	1,000	52,000	0.073	3.8	4.0
	10,000	520,000	0.073	38.0	40.0
	100,000	5,200,000	0.073	380.0	400.0

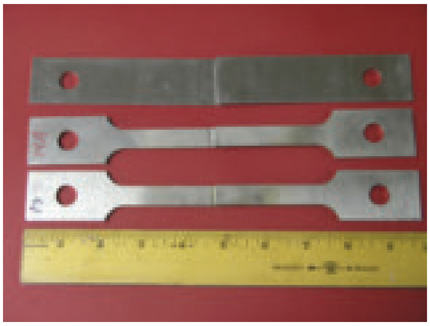

Fig. 2 — Example of specimens used for strength testing.

duce process waste and improve braze joint quality. The first test in this study looked at how much flux was applied prior to brazing using solid wire and flux cored wire along with the amount of waste produced for each form. This test was performed by torch brazing a series of 304L stainless steel coupons with a flux cored wire and also with a solid wire and paste flux. The coupons brazed were 1 in. in width with a joint overlap of 0.5 in. and were mechanically cleaned prior to brazing.

The first set of specimens was brazed with solid wire and was manually fluxed with an acid brush. The amount of paste flux applied was kept as uniform as possible by the operator. A precut slug of Braze™ 505 solid wire (0.055 in. diameter) was placed on one side of the lap joint. For the second set of specimens brazed, only a precut slug of Handy One® Braze 505 (0.053 × 0.092 in.) oval wire was placed on one side of the joint. No external flux was applied. Measurements of the amount of alloy and flux applied for each specimen were recorded. The amount of alloy applied for both sets of specimens was consistent because precut slugs of alloy were applied to the assembly. The amount of flux applied, however, between both sets of samples varied greatly. The average weight of flux applied to each specimen brazed with external flux was 0.150 g while the average weight of flux applied with the flux cored product was 0.073 g. These values and the percent difference between each set of specimens are shown in Table 1. It should also be noted that the consistency of the amount of flux applied varied between both forms. The maximum amount of flux applied for the external flux was 0.196 g while the minimum was 0.100 g. This difference in the amount of flux used can significantly affect the brazing/heating process and the overall quality of the resulting braze joint. The maximum and minimum amounts of flux applied with the flux cored slugs were 0.074 and 0.071 g, respectively. This translates into a much more consistent brazing process and braze joint when using flux cored products.

After all the specimens were brazed with the solid and flux cored wires, each assembly was weighed in order to determine the weight lost during brazing. The majority of weight lost can be attributed to the loss of flux. Flux loss can occur due to spitting and vaporization during heating. It can be seen in Table 1 that there was 84.3% less weight loss during heating when using the flux cored alloy. This limits the amount of fume exposure to the environment and operator. Each set of specimens was then cleaned in a 600-mL bath of hot water for an initial time period of 10 min. The hot water bath was held at a temperature of approximately 150°F (66°C). After the initial water soak, weights were again measured to determine the amount of weight lost during cleaning. The same

Fig. 3 — Setup used for shear strength testing.

Table 3 — Strength Data for Solid Wire

Shear strength data for BAg-24 solid
Base metal joined: 304L stainless steel
Base metal thickness: 0.125 in.
Braze alloy: Braze™ 505 solid
Joint Type: Lap
Approximate lap length: 2T
Heating method: Oxyacetylene torch

	Approx. Jt Thickness (in.)	Break Load (lb)	Strength (lb/in.^{2})
1	0.002	3027	21699
2	0.002	2992	21145
3	0.002	2846	21399
4	0.002	2988	20121
5	0.002	3128	21352
		Avg.	21143
6	0.004	3383	20883
7	0.004	3047	23171
8	0.004	3218	21817
9	0.004	3521	24283
10	0.004	3209	24128
		Avg.	22856

Table 4 — Strength Data for Flux Cored Wire

Shear strength data for BAg-24 flux cored
Base metal joined: 304L stainless steel
Base metal thickness: 0.125 in.
Braze alloy: Handy One® Braze 505
Joint Type: Lap
Approximate lap length: 2T
Heating method: Oxyacetylene torch

	Approx. Jt Thickness (in.)	Break Load (lb)	Strength (lb/in.^{2})
1	0.002	3048	21849
2	0.002	2916	20978
3	0.002	2939	21375
4	0.002	3254	22519
5	0.002	3082	22915
		Avg.	21927
6	0.004	3887	27087
7	0.004	3033	22220
8	0.004	3137	21268
9	0.004	3125	21930
10	0.004	3069	22903
		Avg.	23082

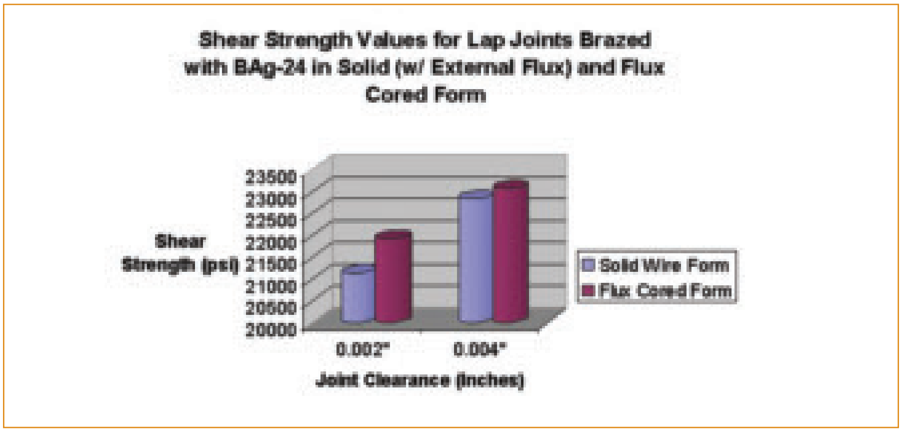

Fig. 4 — Shear strength values for lap joints brazed with BAg-24. (Further testing is being conducted to expand the number of conditions/specimens evaluated. Braze joints were produced in a lab environment under optimal conditions including the amount of external flux applied.)

procedure was repeated for a second hot water soak for 10 min. The resulting weight losses are recorded in Table 1. These weight losses, again, were primarily considered to be flux residue.

The results of these tests revealed a significant decrease in the amount of flux used and flux residue produced when brazing with flux cored wire vs. a solid wire and an external flux. The amount of residue produced per braze joint directly impacts the amount of cleaning required after brazing has to be removed. As shown by the values in Table 1, flux cored alloys reduced the total amount of losses during the brazing process by 48%. It should also be noted that 51% less flux was used with the flux cored alloys. On a production basis this can equate to a very significant decrease in waste removal and consumable cost to the end user. Table 2 shows an approximation of how much less flux would be used by a manufacturer during brazing when using flux cored rings vs. solid rings and paste flux. The data used to determine the values in Table 2 were taken from Table 1 and were calculated assuming a ring diameter of 0.32 in.

Test 2: Braze Joint Strength for Solid and Flux Cored Alloys

The second set of tests analyzed the resulting joint strengths of assemblies brazed with BAg-24 flux cored wire slugs and solid wire slugs with a paste flux. The method of evaluating the braze joint strength and the test samples and procedures used were based on the AWS C3.2 Standard (Ref. 1) for evaluating braze joint strength. The assemblies brazed consisted of 0.125 in. thick × 1.250 in. wide × 5 in. long 304L stainless steel specimens. Similar to the procedure used in Test 1, alloy slugs were applied to one side of the lap joint. Handy Flux® Type B-1 was applied as uniformly as possible across the stainless steel plates when using the solid BAg-24 alloy. The assemblies were heated by an oxyacetylene torch until the braze alloy melted and capillaried into the joint interface. Heating time, amount of alloy applied, joint dimensions, and base metal conditions were measured and recorded before and after brazing to ensure that the brazing process used was consistent. After brazing, the specimens were cleaned, sand blasted, and machined to the dimensional requirements stated in AWS C3.2. An example of the specimens used for testing is shown in Fig. 2.

After the assemblies were brazed and prepared for testing, ten pull specimens for each form of alloy used were tested in tension by an Instron 3369 machine. Figure 3 shows the machine and setup that was used to test the braze joint specimens. The brazed assemblies were pulled until failure. Failure occurred in the braze joint for all specimens. A joint overlap of two times the thickness of the base metal (2T) was used so that the braze joint failed rather than the base metal. Joint failure allowed comparison of the joint strengths for assemblies brazed with flux cored material and those brazed with solid wire and paste flux.

Break load values for each set of specimens are recorded in Tables 3 and 4. Using these values, the resulting shear stress in the filler metal was computed by dividing the break load obtained by the area of each joint. Data were compiled for lap joints of approximately 2T and joint clearances of 0.002 and 0.004 in. Shear stress values that were obtained for both sets of specimens were similar. The joints brazed with flux cored material exhibited slightly higher average shear strength values for both joint clearances as illustrated in Fig. 4. The impact flux cored products provide in joint quality and strength is realized to an ever greater extent in a manufacturing setting vs. a lab environment due to the variance between operators who manually apply flux. Excessive and varying amounts of flux applied to the braze joint area in the manufacturing setting cause inconsistencies in the brazing process and joint quality. When the amount of flux is varied from one joint to another, heating cycles will vary due to the insulating effect of the flux. Excess flux in the joint interface can lead to flux entrapment and excessive voids. Flux cored alloys provide a more consistent application of flux that stabilizes the joining process and reduces the amount of flux voids/inclusions within the joint interface that will increase joint strength. Consumers who have switched from using solid wire and manual flux application to flux cored alloys have reported significant decrease of joint voids that directly impact joint integrity (leak tightness) and strength.

Summary and Conclusion

Traditionally, solid wire and an external flux have been predominately used for torch and induction brazing in many industries. External flux is typically applied manually by an operator prior to brazing. This step increases process time and introduces inconsistency in the amount of flux applied. Oftentimes the operator applies more flux than is required, which also increases the overall cost of the brazing process. Varying amounts of flux applied can cause inconsistent braze quality and fluctuating heating cycles. With its introduction, flux cored products have helped manufacturers who utilize torch and induction heating to improve their joining process consistency and braze quality, while limiting the amount of brazing consumable used. The studies documented in this paper illustrate and confirm the many benefits that flux cored products offer. The flux cored wire used provided a more consistent amount of flux to the assemblies brazed, creating a high strength joint while limiting the amount of flux used and the waste produced during heating.◆

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