The Tensile Strength of Stainless Steel Wire and Rod Butt Joints as a Function of the Brazing Alloy

Cd-free substitutes for Cd-containing filler metals are found to provide greater safety for operators at the expense of mechanical properties

BY R. M. TRIMMER and A. T. KUHN

Recent legislation in the United Kingdom has discouraged the use of cadmium-loaded silver-based brazing alloys and has forced users instead to use tin-containing silver-based brazing alloys and the AgCu type. The newer brazing filler metals are, almost without exception, higher melting alloys. Partly for this reason (which subjects the work being brazed to a much higher temperature) and partly because the alloys themselves are metallurgically different from their predecessors, it is important to ascertain how the strength of a joint brazed with these newer alloys compares with one made using previously conventional materials. The butt joint is not only one of the most commonly used, but also—because of its inherent simplicity—is one that gives less equivocal results. In this type of joint, only the joint gap is important in determination of the strength of the joint (brazing factors apart), whereas with a lap joint both gap and overlap are important parameters.

The strength of a brazed butt joint has formed the subject of many investigations (Ref. 1,2,3), most of which concentrated on tensile aspects. From these, it is known that the brazed butt joint in static tension always fractures at the braze itself—but at a location close to one of the substrate faces. The tensile strength is related to gap distance. Either too small or too large a gap gives less satisfactory results. In the former case this is because of insufficient brazing alloy flow into the gap; in the latter, it is because the added strength provided by triaxial force (Ref. 4) is largely nullified on account of the intermediate section of brazing alloy filler metal whose strength is not enhanced by this process. In the present work, measurements were made on samples of the brazing alloys themselves and then on butt-brazed joints formed under controlled conditions.

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Method

Four brazing filler metal alloys in the form of 1.25 mm (0.05 in.) diameter wire were used. They were Easy-Flo 2 from Johnson Matthey Metals Ltd. in London; Engelhard Silvaloy 1581 from Engelhard Industries Ltd. in Surrey, England; Argobraze from Eutectic Company Inc., Middlesex, England; and Masel Cd-Free from Isaac Masel Co., Inc., Philadelphia, Pa.

Tensile strengths of the four were measured in the "as-received" condition, in the annealed condition, and also following a drawing down through a steel drawplate to explore the effects of work-hardening. Annealing was done at 400°C (752°F) for 1 hour (h).

Butt joints were made in 1.25 mm (0.05 in.) diameter Type 302 stainless steel wire and rod. Two pieces of wire were clamped in a jig with a constant, recommended 0.15 mm (0.0059 in.) gap setup using feeler gauges (Ref. 5). An integral part of the jig was an air-gas torch which was rigidly mounted and directed a flame on the joint at a constant distance.

All joints were made by the same operator, allowing a constant time—i.e., 6 seconds(s)—for the operation and immediately quenched. Ten samples of each joint type or joint/braze combination were made up to original contour, and the data quoted below are the mean values for these (with standard deviation). Tensile testing was done at constant crosshead speed (0.02 cm/min).

Results

Data on Brazing Alloys

It is clear that differences exist between the tensile strengths of cadmium and cadmium-free silver-based alloys (Ref. 6). Figure 1 gives the data, and it is seen that neither cross-sectional area nor the degree of work-hardening invert this trend.

Recognizing that both as-received and drawn samples would be significantly work-hardened, micro-hardness measurements were made on samples which had not been subjected to tensile testing. As expected, a decrease in hardness was found as measurements were made from the exterior to the core of the samples. Values for these are shown in Table 1.

Care was also taken that the sectioning of brazing materials prior to microhardness measurements did not itself induce work-hardening. This was accomplished by polishing on a water-cooled polishing lathe to 1000 grit only.

Data on Brazed Butt Joints

The data in Fig. 2 relate to joints with a common gap distance of 0.15 mm

Table 1—Microhardness (in Filar Units) of 1.5 mm (0.06 in.) Diameter Easy-Flo 2 Drawn to 1.22 mm (0.048 in.) Diameter

Surface skin	85.8 – 2.28
Central core	95.0 ± 4.0
Annealed	99.2 ± 2.95

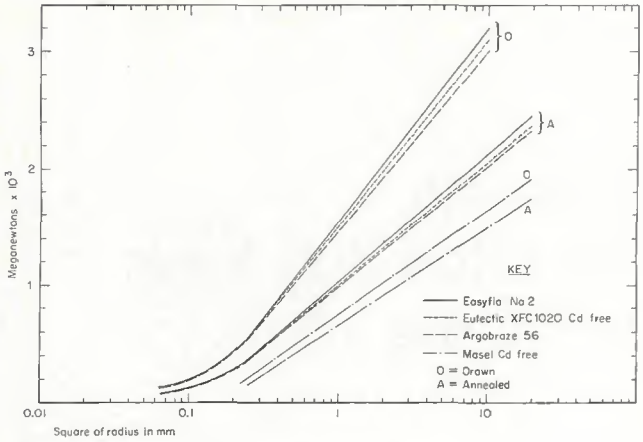

Fig. 1—Tensile strength of brazing filler metal alloys

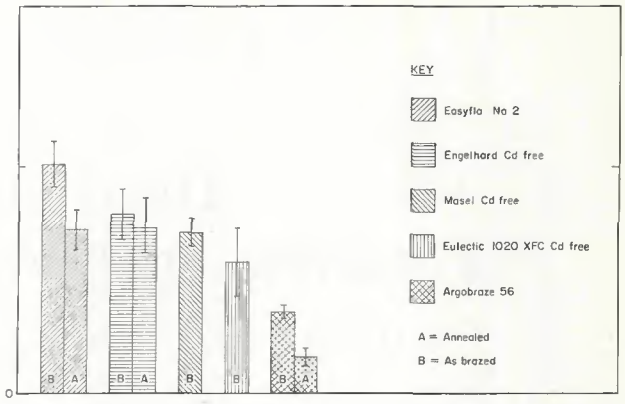

Fig. 2—Tensile strength of butt joints brazed using 1.25 mm (0.049 in.) diameter stainless steel wire filler metal

(0.0059 in.). Annealed joints were heated in a tube furnace at 400°C (752°F) for 1 h.

Discussion

Beyond all question, the data of Fig. 2 indicate that not only are the cadmium-free alloys themselves intrinsically weaker than their cadmium-containing predecessors, but so are butt joints prepared using them. This prompts two questions.

1. Was proper procedure set up?
2. Is this finding, even if valid, in any way untypical, and not capable of extrapolation to larger or smaller joints of similar geometry?

Turning to the first of these, we believe that all joints were correctly prepared. The work was mounted in a jig to ensure constant flame distance and fluxed before heat application. The gap was that recommended, and gap measurements after brazing (in the cold state) were close to the initial value. In other work similar to investigations on the variation in tensile strength with gap-distance (Ref. 2, 3), we find a decrease in tensile strength only when the initial gap is less than 0.125 mm (0.0049 in.) or greater than 0.3 mm (0.012 in.). Furthermore, it would seem that—within the range of wire and rod diameters used—there is no significant size affect.

It is well known that the cadmium-containing alloys melt at a much lower temperature than their replacements—Table 2. The effect is that, in the latter case, both braze alloy and substrates are subjected to higher temperatures, sometimes for slightly longer times. While this might be expected to lead to softening (or greater softening) of hardened stainless steels, since the stainless steel, itself, is at no time the site of fracture, this should not be relevant. One is left with the conclusion that the decrease in tensile strength is due to the inherent nature of the brazing alloy/flux combination itself.

Table 2—Liquidus Temperatures of Brazing Alloys as Confirmed by DTA, °C

Easy-Flo 2	610
Engelhard Silvaloy 1581	650
Eutectic 1020 X FC	660
Argobraze 56	710
Masel Cd Free	660

It is instructive to compare the change of strength of the brazing filler metal alloys alone with that of the joints made using the same materials. While there is a parallel trend, it is only moderately close. This is not surprising. The actual strength of a brazed butt joint can be considered to be based on the strength of the brazing alloy, but modified first by the triaxial forces (Ref. 4) and, second, by the less than perfect nature of the interfacial region.

Conclusion

It has been shown (Ref. 7) that the constituents of the braze material do not diffuse into the stainless steel. However, there have been suggestions that the flux (the composition of which is fluoroborate—tenacity 5) and fluoride type Easyflo stainless steel grade do dissolve in the braze. These are matters that will be investigated further. We conclude that the newer brazing alloys, although inherently safer for operatives working with them, have achieved such safety at the expense of their mechanical properties.

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