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FATIGUE OF WELDED 5083 ALUMINUM ALLOY

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FAILURE OF WELDED 5083 ALUMINUM ALLOY

ABSTRACT

A failure analysis was conducted on an aluminum (5083) structure subjected to fatigue testing. Failure occurred by fatigue in an electron-beam weld; the cycles to failure were reasonable for the loading conditions.

An aluminum structure (5083-0 aluminum alloy) subjected to fatigue testing failed in the vicinity of an electron-beam weld joint. In this paper we report our analysis of the failure mode.

After mechanical fabrication, the structure was annealed to eliminate the possible effects of cold working introduced during fabrication. The failure occurred in a circular electron-beam (EB) weld joint 20 mm in diam and 2.03 mm thick that had been welded from both sides, at low power, to assure 100% penetration without spiking problems. Mechanical constraints on the structure prevented direct measurement of the fatigue stress, but the effective plastic strain at the joint during fatigue was calculated to be 2 to 3%. The essential point for present purposes is that the plastic strain was significantly higher than the yield-strength definition of 0.2% but well below that expected at failure.

We studied the failed joint by optical microscopy and scanning electron microscopy (SEM). A typical cross section of the weld and fracture is shown in Fig. 1. In this particular cross section, the crack did not propagate through the thickness; however, it can be seen that failure occurred in the fusion zone, whose microstructure was exceedingly fine. The EB weld passes from each side are readily apparent. In the heat-affected zone, there was no significant coarsening or redistribution of the precipitates, and grain growth did not occur; the boundary between this zone and the fusion zone was sharp. The small amount of porosity did not significantly affect the tensile strength.

The fracture extended approximately 40 mm along the weld. Examination of this fracture surface at low magnification did not reveal any gross defects. However, SEM examination of selected areas totaling about 10 mm in length revealed evidence of fatigue. Figures 2 through 5 show the typical fracture surfaces.

In Fig. 2a (a low-magnification scanning electron micrograph), we see a portion of the fracture surface and the surface appearance of the EB weld fusion zone. The cracks in the fusion surface occurred during removal of the specimen from the structure.

Several areas of fatigue striations were found along the fracture surface. For example, the striations are clearly delineated in Figs. 2 and 3, which are views of the

Fig. 1. Typical microstructure of EB weld in 5083 aluminum alloy.

Fig. 2. Scanning electron micrograph of EB weld in 5083 aluminum alloy (Area A) at magnifications of 20X and 100X.

Fig. 3. Scanning electron micrograph of EB weld in 5083 aluminum weld (Area A) at magnifications of 500X, 1000X, and 5000X.

same area at different magnifications and angles. These areas of fatigue striations often were semi-elliptical in shape (Figs. 4a and 5a); they occurred at frequent intervals, as illustrated in Fig. 4c where we see the edges of two different fatigue areas. The fatigue crack often initiated at the weld surface on the inside of the structure (Fig. 4a), but in some cases a defect within the weld apparently was the source of the crack (Fig. 5).

The fracture surface between the fatigue areas evidenced ductile/dimple failure (Fig. 4c).

Failure occurred after 172 cycles. For many materials, the cycles to failure (N) as a function of total plastic strain (ϵ_p) can be estimated from the Coffin-Manson relation $N^{1/2} \Delta \epsilon_p = C$, where C is a material constant. A rigorous treatment would require the material constant for an EB weld in 5083 aluminum and for the exact welding conditions present in the structure. Such a value is not available; however, from results on a similar aluminum alloy,¹ a fatigue life of 100 to 300 cycles at 2.5% plastic strain was estimated. Thus the experimental value of 172 cycles appears to be a reasonable lifetime.

In summary, the fatigue initiated in many areas independently within the EB weld fusion zone. In some cases the fatigue was associated with a defect in the fusion zone; in other cases it was associated with the structure's inside surface. The final stage of failure occurred in the fusion zone in a ductile manner. The fatigue life (172 cycles) is reasonable for this aluminum alloy weld.

REFERENCES

1. J. F. Tavernelli and L. F. Coffin Jr., Trans ASM 51, 438 (1959).

Fig. 4. Scanning electron micrograph of EE weld in 5083 aluminum alloy (Area B) at various magnifications. View (b) is the left portion of (a) showing fatigue-dimple transition; view (c) is right portion of (a) showing fatigue failure zones on left and right with dimple/ductile failure in the middle.

Fig. 5. Scanning electron micrograph of EB weld in 5083 aluminum weld (Area C) at magnifications of 50X and 200X.

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