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SPOT-WELD BONDING ON THE BLACKHAWK[TM] HELICOPTER

by

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The Sikorsky S-67 Blackhawk[TM] attack helicopter utilizes spot-weld bonding for stringer to skin attachment on more than 5 per cent of its surface area. The aircraft, seen in Figure 1, was first flown in 1970 and presently holds the absolute speed record for a helicopter. It is the first American aircraft to utilize spot-weld bonding, although the process has been used for some years in the USSR for the AN-24 and the AN-22 aircraft (Reference (1)). In addition, spot-weld bonding (also known as glue-welding, weld-bonding, and glue spot-welding) has been extensively investigated by Lockheed Aircraft under Air Force Materials Labs' sponsorship for fuselage structures and is used in production for missile tankage (References (2) and (3)). The process consists of applying adhesive on the surfaces to be joined, spot welding through the adhesive, then curing the adhesive.

Prior to incorporation into production on the S-67 in 1970, Sikorsky spent eight years developing and evaluating spot-weld bonding on 6061, 2024, and 7075 aluminum alloy components. Techniques were developed for joining two, three, and four layers of material which ranged in thickness from 0.020 to 0.110 inches. Materials of differing thicknesses were also joined.

The adhesives which were evaluated included FM-1000 film, XB-66 film, Epon 6 paste, AF-6 film, and 2214 paste. The film adhesives were found to be impractical because spot welds could not be made consistently. This was due to a large extent to the carrier. Both paste adhesives were successful, but 2214 was chosen for the S-67 because of its higher strength.

Prior to cleaning, the assemblies were prefit to assure good bonding contact between details. As the surface preparation for spot welding is different from that for adhesive bonding, it was necessary to determine which was the more critical. Because the spot-weld quality is highly dependent on the surface eletrical resistance, it was determined that the surface preparation would be determined primarily by the requirements for spot welding. The process used for Alclad aluminum sheet is depicted in Figure 2 with that for bare aluminum sheet being somewhat modified. The adhesive was applied to a thickness of 0.004 inches by using either an impregnated felt roller or by using a squeegee with tape dams of the appropriate thickness as is depicted in Figure 3. The parts were then assembled using Clico clips and spot welded as seen in Figure 4. After spot welding, the tape was removed and the adhesive oven cured.

Extensive testing was conducted using both coupons and panels in tension, shear, combined shear-compression, and fatigue in order to qualify the process. The static tensile strength, depicted in Figure 5, is considerably higher than that of the riveted construction which it replaced. It should be noted that the primary contributor to the increased strength is the adhesive bond, not the spot-weld, as comparative tests of riveted-bonded and spot-welded construction seen in Figure 5 indicate. The fatigue behavior of spot-weld bonded coupons compared with other constructions is summarized in Figure 6. Note that although spot-welding alone is poor in fatigue, the adhesive bond substantially improves this behavior.

An additional advantage of spot-weld bonding over conventional riveting was noted during combined shear-compression testing of panels. Because the panel skin is stabilized over the whole bonded area, there is less area of unsupported skin between stringers. This allows much higher loads to be achieved before skin buckling occurs.

The application of spot-weld bonding on the S-67 is seen in Figure 1. The process was limited to those applications shown because it was introduced late in the develoment of that aircraft. Nearly flat panels, such as the access door seen in Figure 7, the pilot's canopy glare shield, and several fairings were readily fabricated using spot-weld bonding. More complex structures such as the vertical stabilizer trailing edge seen in Figure 8 and leading edge seen in Figure 9 required unique tooling to accomplish the spot welds.

In addition to the improved properties afforded by spot-weld bonding, a major motivation for developing the process was cost reduction. For structures having light gage skins, where there is a requirement for a flush aerodynamic surface, thicker gages are often used to accommodate countersinking, and the majority of the skin area is chemically milled to the required thickness. For such applications, spot-weld bonding of the required finished thickness precludes the requirement for costly chemical milling and results in considerable savings, as seen in Figure 10. If flush surfaces are not required, however, automatic riveting using round head rivets is more economical. This cost comparison becomes more favorable toward spot-weld bonding as more rapid techniques using seam rollers are utilized. Thus, the improved economics coupled with increased reliability indicate increased usage for spot-weld bonding in future systems.

REFERENCES

1.) A. Dobler, H. Koenigsberg, and D. Van Winkle, SAE Journal, Vol. 78, No. 3, Mar. 1970, pp. 56-61.

2.) F. Ridgeway, American Machinist, April 20, 1970, pp. 92-94.

3.) F. Sullivan, G. Faulkner, and F. Clauss, Materials Eng., Jan. 1971, pp. 14-15.

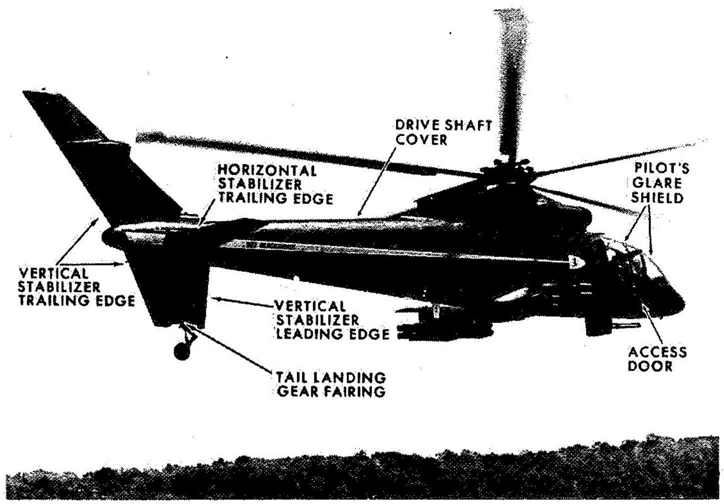

FIGURE 1. APPLICATIONS OF SPOT-WELD BONDING ON THE S-67 BLACKHAWK™ ATTACK HELICOPTER

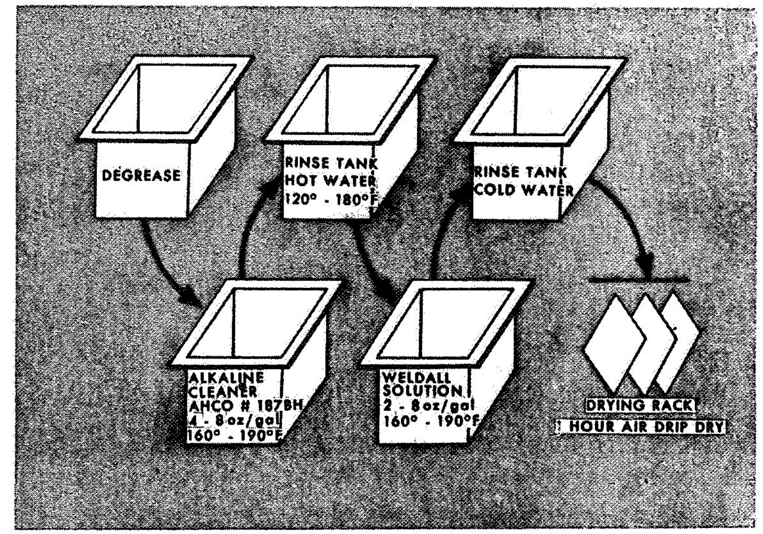

FIGURE 2. CLEANING SEQUENCE FOR ALCLAD ALUMINUM

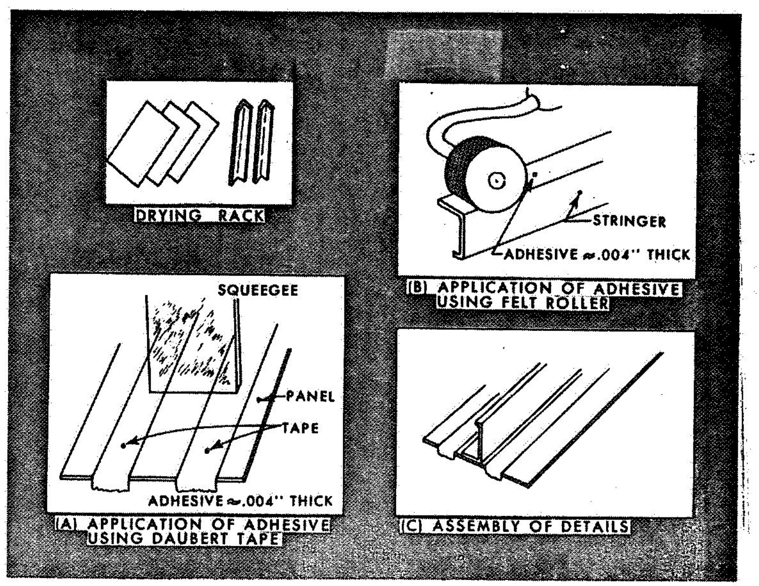

FIGURE 3. ADHESIVE APPLICATION

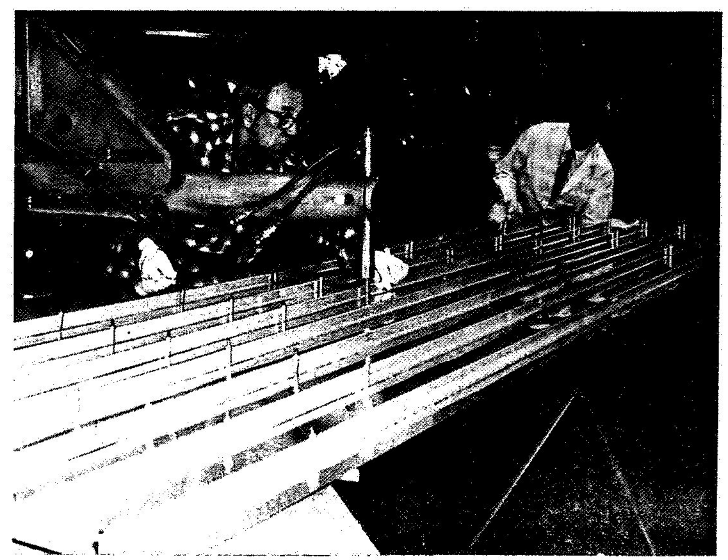

FIGURE 4. SPOT WELDING AFTER APPLICATION OF UNCURED ADHESIVE

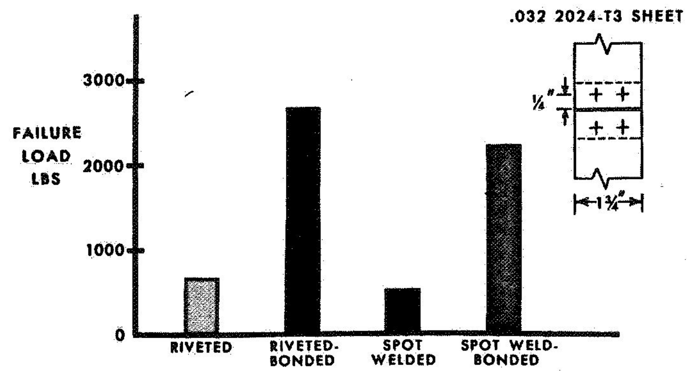

FIGURE 5. STATIC TENSION TESTS OF COUPONS

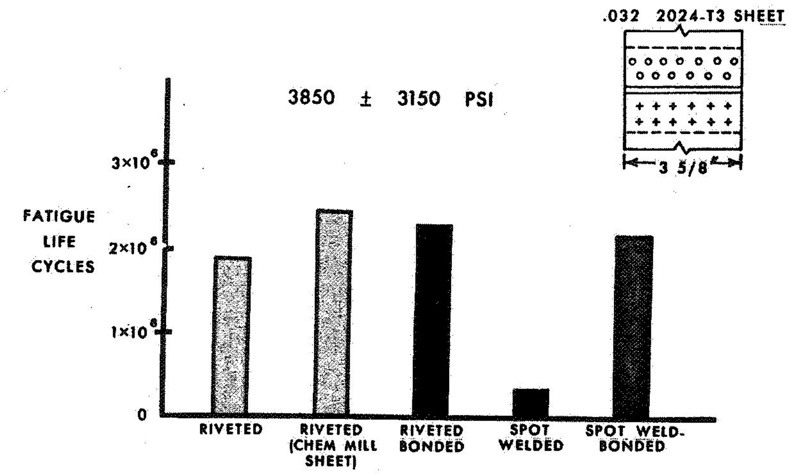

FIGURE 6. TENSION-TENSION FATIGUE TESTS OF COUPONS

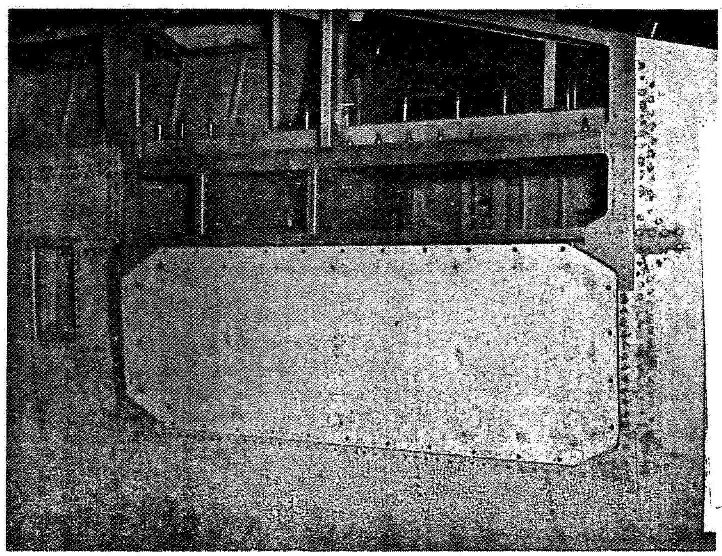

FIGURE 7. ELECTRONIC COMPARTMENT ACCESS DOOR

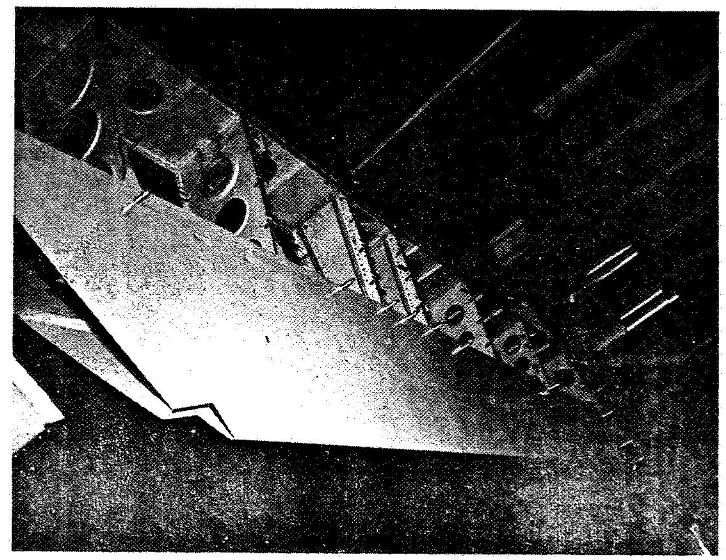

FIGURE 8. VERTICAL STABILIZER TRAILING EDGE

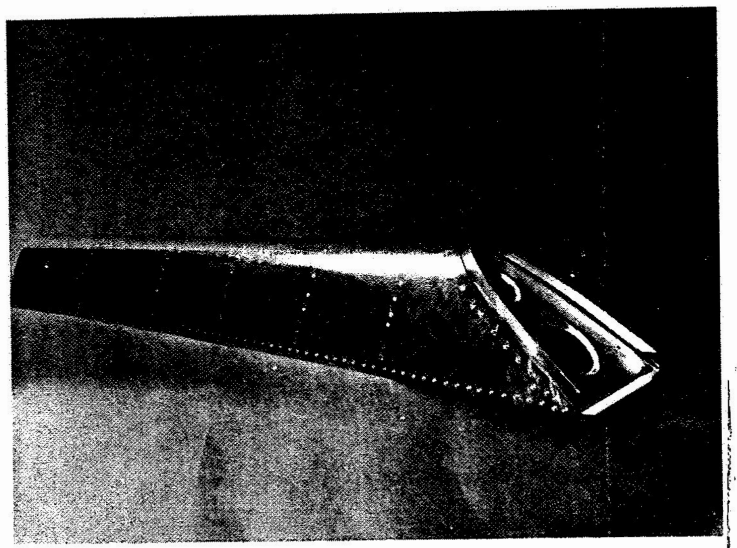

FIGURE 9. VERTICAL STABILIZER LEADING EDGE

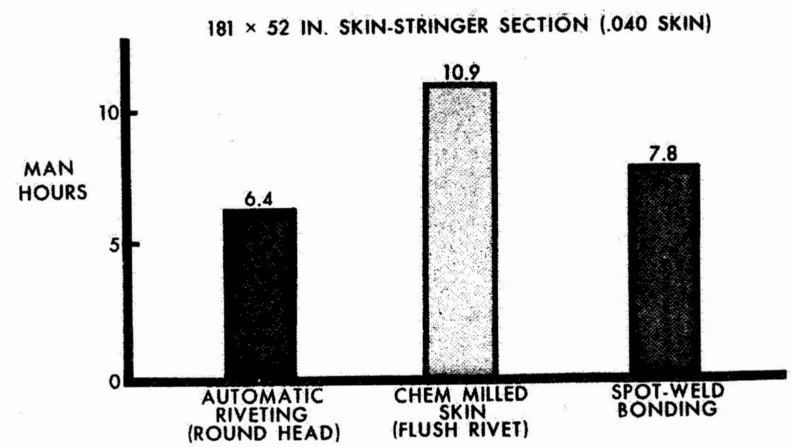

FIGURE 10. COST COMPARISON OF SPOT-WELD BONDING WITH RIVETING