ESi

CASE STUDY

POST-FIRE STRUCTURAL INTEGRITY EVALUATION OF AN AIRCRAFT UTILIZING ASTM E 1004-02

Utilizing fire-damaged components as well as virgin aluminum alloy 2024-T3, ESi developed a clear correlation between electrical conductivity and mechanical properties of damaged and as-specified material. ESi's nondestructive metallurgical evaluation of the Beechcraft model T-34B front CT spar confirmed that its mechanical properties were not affected by the localized fire.

SITUATION

An aircraft maintenance facility was troubleshooting a fuel flow problem on a Beechcraft model T-34B that was manufactured on September 9, 1955. On engine start-up, a fuel line leak, at the fuel control unit, led to a fire in the engine compartment and on the facility floor. The engine was shut down and the nose of the aircraft was pushed out of the fire. Fire extinguishers were used to extinguish the ground fire, then the fire in the engine compartment and nose gear well.

The fuel control unit line leak followed the flange on the left keel/longeron, through an unsealed firewall gap and stopped in an area approximately 18" to 20" forward of the front wing carry-through (CT) spar. This carry-through structure is the main connection between the wing and fuselage and transmits the wing bending loads through the fuselage[1]. Heat patterns and structural damage indicated that this area was exposed to the highest fire temperature. The potentially affected components were fabricated from an aluminum alloy which was heat treated in order to achieve a certain strength required for the design of the structure. These types of alloys can be weakened if exposed to excessive temperature. Potentially damaged components were removed from this general area and made available for evaluation.

The most heat-affected areas were repaired; however, recent issues[2] with the carry-through structures on T-34 aircraft necessitated confirmation of its structural integrity.

Practice: Materials Science

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Services Utilized

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About ESi

For over 30 years, ESi has leveraged its multidisciplinary team of engineers, scientists, and professional technical staff to investigate many major accidents and disasters. Our technical expertise, hands-on experience and state-of-the-art facilities, combined with diagnostic, analytical and physical testing capabilities create an ideal environment for quickly identifying and interpreting the facts of a case.

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OBJECTIVE

ESi was asked to determine if high temperature from the fire compromised the strength of the 2024 aluminum alloy front wing carry-through (CT) spar, creating potential structural weakening and most importantly, flight safety concerns.

SOLUTION

During inspection of the aircraft, damaged components in the vicinity of the CT spar were photographed and retained for evaluation. Chemical analysis confirmed that the collected components were fabricated from 2024 aluminum alloy. Additional information regarding the composition of the CT spar components confirmed they were fabricated from 2024 in both the T3 and T4 conditions[3]. Aluminum alloy 2024 is a heat-treatable alloy commonly utilized for structural components in aircraft[4]. The T3 temper designation indicates that the material was solution heat-treated, cold-worked, and then naturally aged. The T4 temper designation is similar but involves no cold working[5].

A correlation between mechanical properties of damaged and virgin aluminum alloy 2024-T3 and T4 was developed utilizing mechanical testing (ASTM B557), hardness testing (ASTM E18), and electrical conductivity measurements (ASTM E1004). Metallographic evaluation was conducted to determine if elevated temperature exposure from the fire affected the strength of components adjacent to the front wing carry-through (CT) spar.

RESULTS

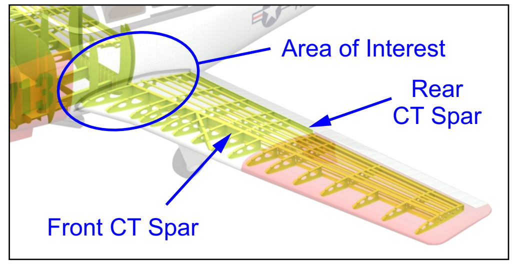
Electrical conductivity for the unaffected regions consistently measured around 33% IACS and was as high as 45.8% IACS in the heat-affected regions, a value approaching the O temper, or fully annealed condition[6]. The typical electrical conductivity value range for aluminum alloy 2024-T3 is 28.5-32% IACS, while the range for O condition is 45.5-49% IACS. Higher electrical conductivity values correlate with decreases in certain mechanical properties. The mechanical properties of the material in the unaffected regions were typical of aluminum alloy 2024-T3. The mechanical properties of the material in the heat-affected regions revealed significant decreases in strength, ductility, and hardness. The fire reached temperatures high enough to transform some of the affected material from the T3 temper to the fully annealed condition.

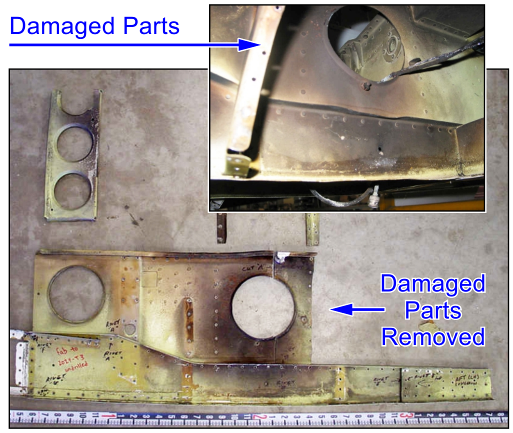
Although several items showed degraded mechanical properties, measured values for the tested regions closest to the front CT spar were consistent with the unaffected material, indicating heat damage was isolated to a region sufficiently distant from the front CT spar.

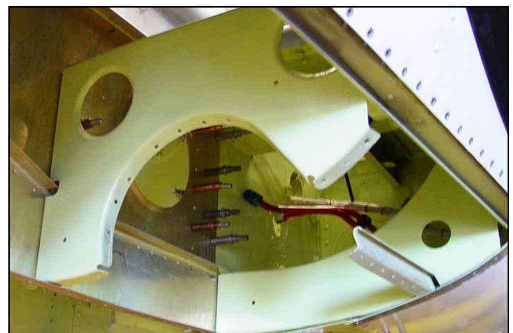
Metallographic evaluation revealed no obvious evidence of grain boundary melting or other significant differences between the unaffected and heat-affected regions; however, it was observed that the heat-affected regions on item 2 etched more markedly, suggesting that a physical change had occurred that could account for the measured decrease in ductility.

Once the persistent correlation between the mechanical properties and electrical conductivity was established, the front CT spar was tested. The results confirmed that the fire had not affected the mechanical properties of the front CT spar.

[1]Raymer, Daniel P., "Aircraft Design: A Conceptual Approach, 2nd Ed.," (AIAA, 1992), pp. 158-165. [2]FAA Emergency Airworthiness Directive, AD No.: 2004-25-51 (12/10/2004). [3]NAVAIR 01-90KDB-503, Technical Manual, Structural Repair Instructions, Navy Model T-34B Aircraft, p. 23. [4]ASM Online, Metals Handbook Desk Edition, Aluminum Wrought Products, Alloys Used for Wrought Products. [5]ASM Handbooks Online, Metals Handbook Desk Edition, Alloy and Temper Designation Systems for Aluminum, Temper Designation System for Aluminum and Aluminum Alloys. [6]Radiatronics NDT, Inc., "Eddy Current Conductivity vs. Hardness Table for Aluminum Alloys"






Damaged Parts Replaced

WHY ESi.

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