MANUFACTURING EXERCISE INVOLVED IN THE REDESIGN
OF THE HAWKER SIDDELEY TRIDENT (TRI-JET) FUSELAGE

John Fielding
Chief Materials Engineer
Hawker Siddeley Aviation Limited
Woodford, Cheshire, England

Design Exercises

The purpose of certain design studies was to examine the application of titanium construction to replace existing aluminium alloy structure using the same design loadings, applying the same structural philosophies, and accepting the same practical constraints on geometry. Under these design conditions weight savings result from the relative specific material properties of titanium alloys and aluminium alloy, the reduction in sizes permissible in titanium and, also from the exploitation of the weldability of titanium to produce more efficient configurations. Ti 8Al, 1Mo, 1V was specified (Duplex Annealed). The relatively thin fuselage skin (0.022 in.) was expected to be sufficiently free from stress corrosion hazards under aqueous conditions. Three particular areas were chosen for evaluation, viz., the sheet/stringer/frame structure in the keel area, the upper fuselage, and a window panel area. The usual attention was given to fatigue strength, critical crack length, and residual strength. Fusion welding was used whenever practicable, i.e., for skin to stringer joints and panel butt welds, with a little electrical resistance spot welding for the frame to fuselage skin attachment. The weight savings possible with the titanium design as compared with the aluminium structure were as follows:

- Fuselage keel area - 26.3%
- Upper fuselage area - 17.6%
- Window panel area - 28.0%

The overall weight saving on the complete fuselage section was 23.6%.
Chemical Milling

Chemical milling (also known as chemical machining or contour etching) has been extensively used for shaping various materials for many years. Basically, the process consists of chemically etching away (using a suitable medium) the unwanted material, areas to be preserved being protected by a suitable maskant which is usually elastomeric in nature.

An initial consideration of nine etching solutions including various combinations of hydrofluoric, nitric and chromic acids and ferrous sulphate indicated two interesting possibilities. One being 25% hydrofluoric acid (by volume) and the other 3% hydrofluoric, 30% nitric acid (by volume). The 3% HF, 30% HNO₃ mixture was found to be too slow in action and when heated the solution rapidly went out of balance. The 25% HF solution used at ambient temperature was very active and this feature combined with the exothermic nature of the reaction required adequate circulation and water cooling facilities. Satisfactory control was quite practicable and the process is now used for production work.

Panels to be chemically milled are hand degreased, and sprayed with "Coverlac" synthetic rubber maskant 0.008 in. thick. The shape to be etched is marked out, cut, etched in the 25% HF solution, rinsed and dried. The process works well with both 6Al, 4V, and 8Al, 1Mo, 1V titanium alloys with a normal rate of metal removal of 0.025 in. to 0.030 in. per hour. Several hundred H₂ analyses gave results between 35 and 90 ppm. A considerable amount of data has accumulated from the chemical machining at Hawker Siddeley Hamble and the conclusions were that the H₂ due to chemical milling was concentrated near to the sheet surface. This meant that the sheet thickness after milling had a marked affect on the average H₂ content determined by analysis, the H₂ content not being related to surface area. It was considered advisable to restrict chemical milling on titanium as follows:

a) To give a minimum thickness remaining after etching of 0.020 in. irrespective of the original thickness

b) Every effort to be made to use material with an initial hydrogen content of less than 80 ppm when etching to a final thickness below 0.025 in.

c) To restrict etching to one side only when reducing to a thickness below 0.025 in.