RAAF P3 ORION MULTI-SITE DAMAGE ASSESSMENT

Paper # 12

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1.0 ABSTRACT

This paper outlines work undertaken to analyse the stress effects caused by interactions of multiple repairs on the horizontal stabiliser of a P3-Orion aircraft. It will also determine regions adversely affected by the interaction of multiple repair sites. With the stress distributions and transmission paths known, it will be possible to assess whether the multiple repair sites are still capable of meeting damage tolerance specifications. Investigation of the horizontal stabilizer will be undertaken using the Finite Element Analysis (FEA) software, Strand 7.

2.0 KEYWORDS:

P3 Orion Aircraft
Multi Site Repairs
Horizontal Stabiliser
Finite Element Analysis Model
Stress Analysis

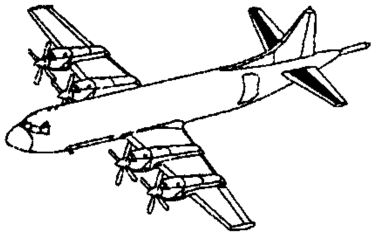

Figure 1 – P3 Orion

3.0 BACKGROUND

3.1 Introduction

Due to Australia's vast coastline, The Royal Australian Air Force allocates a large proportion of their resources to the safekeeping and patrolling of our coast. The P3-Orion aircraft is the main resource used for this job. The P3-Orion aircraft is predominantly operated as a maritime patrol aircraft [6]. Powered by four Allison T56-A-14 Turboprop engines achieving a maximum speed of 405kts. It was designed by Lockheed Aircraft Corporation, California, U.S.A. in the early 1960's. In performing its role in Maritime Patrol, a large percentage of the Orion's flying time is allocated to flying over or near the ocean. The air-sea environment is very corrosive, and when combined with strenuous pilot training exercises, can take a heavy toll on the design life of the aircraft. For this reason, a number of the RAAF's P3-Orion fleet were rapidly approaching the end of their design lives.

To lower the burden on their Maritime Patrol fleet, in 1996, the RAAF purchased three P3B-Orion (TAP-3) aircraft from the United States Navy for conversion to training planes. On inspection of the newly acquired TAP-3's, it was found that there were considerable numbers of adjacent repairs carried out on the surface of each of the horizontal stabilisers. One particular aircraft, tail number A9-434**,** was found to have 33 individual repair sites on its horizontal stabiliser. No details of the repair types or for what reason they were applied were available.

It is unknown what effects these repairs have, and concerns surround the possible loss of structural integrity resulting from the interaction of multiple repairs. One possible solution is to re-skin the complete horizontal stabiliser. This is an expensive and time consuming process that the New Zealand Defence Force is currently undertaking in order to upgrade and extend the life of their fleet of P3-Orions. It is the purpose of this project to investigate the effect of repairs on load transfer and stress distribution. This is to be achieved by completing a finite element model of the horizontal stabiliser, and applying flight loads

3.2 Horizontal Stabiliser

For an aircraft to sustain controllable flight it must be able to counteract moments generated about the three main axes of the aircraft. The stability surfaces of the aircraft are the wings, the vertical stabiliser and the horizontal stabiliser. The horizontal stabiliser is located at the aft end of an aircraft and its primary function is to counteract the moment generated by the main wing about the aircraft's centre of gravity. This counter-moment is produced as a result of differing pressure gradients acting across the upper and lower stabiliser surfaces. The elevators, attached at the rear spar through five hinge locations, alter the straight and level flight of the aircraft.

1. Box beam ribs
2. Trailing edge ribs
3. Rear spar
4. Tip
5. Stringers
6. Leading Edge Ribs
7. Front spar
8. Skin
9. Fillets

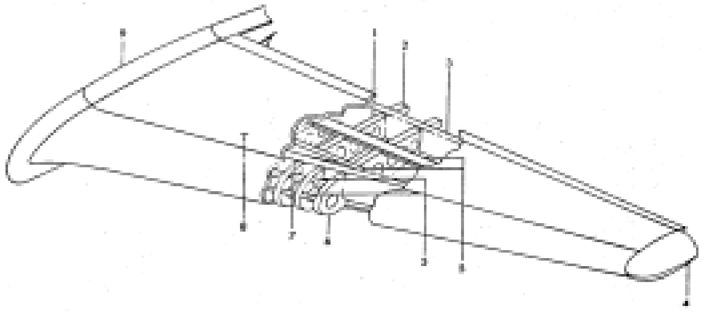

Figure 2 – P3 Orion horizontal stabiliser cutaway

3.3 Materials

Components that make up the horizontal stabiliser of the P3 Orion are all made from an aluminium alloy, constructed using different methods. The front and rear spars are constructed from [3] extruded 7075-T56 aluminium sections, stiffened along their length using webs and angles. The rear spar is a continuous section while the front spar is created in two independent sections spliced together.

There are 15 ribs, all constructed from 7075 – T56 aluminium with beaded or angled stiffeners. To reduce weight the ribs are equipped with lightening holes. The ribs are fitted with extruded caps, notched to accommodate the integrally stiffened skin. The first nine rib spacings are 13.5 inches with the remaining 5 at 17.0 inches.

The leading and trailing edges are constructed from 7075-T56 aluminium with integral stiffeners. The skin is constructed from extruded 7075-T6 aluminium. It comprises of three panels top and bottom top and bottom approximately 18 inches wide with integral stiffeners. The panels are chemically milled to provide a tapered thickness.

4.0 EXPERIMENTAL WORK

4.1 Modelling

D'Agostini and Withall [2] commenced a finite element model in 2000. Their model included the basic geometry of the horizontal stabiliser and was imported into Strand 7 from AutoCAD r14. To implement the model, the authors had to obtain and apply the material properties and all component geometries. Also, a number of missing elements were found, due to the transfer from AutoCAD. The most important task was aligning the model (for the FEA method to work all of the plate normal directions and axis must align, or singularities and incorrect results will be produced).

4.2 Verification

After applying the required material and geometrical properties to the D'Agostini and Withall model [2], it was necessary to verify that the Strand 7 software was producing results consistent with the Lockheed Designs. Lockheed Report 13641, Section 17 [4], contained original static test loads and deflections for a variety of simulated, in flight conditions was located. After consulting RAAF Aeronautical Engineer Smith [5], it was determined that verification of the model would be completed for a flight condition called positive checked upwards pitch. This condition was chosen for 2 reasons:

1. It is a flight manoeuvre that produces some of the most significant loading on the horizontal stabiliser. The main aim of this project is to determine the maximum stresses occurring between repairs on the horizontal stabiliser, hence a high loading manoeuvre is required to produce maximum stresses.
2. The original horizontal stabiliser model produced by D'Agostini and Withall [2] was modelled in the checked position. This means that elevators, on the aft side of the horizontal stabiliser, are level.

The authors applied the static loading to 8 ribs in the horizontal stabiliser, as seen below in Figure 3. Lockheed Report 13641 [4], did not specify exactly how the loads had been applied in testing. However, it specified 4 separate loads of known magnitude, and the horizontal stabiliser station where the loads were applied.

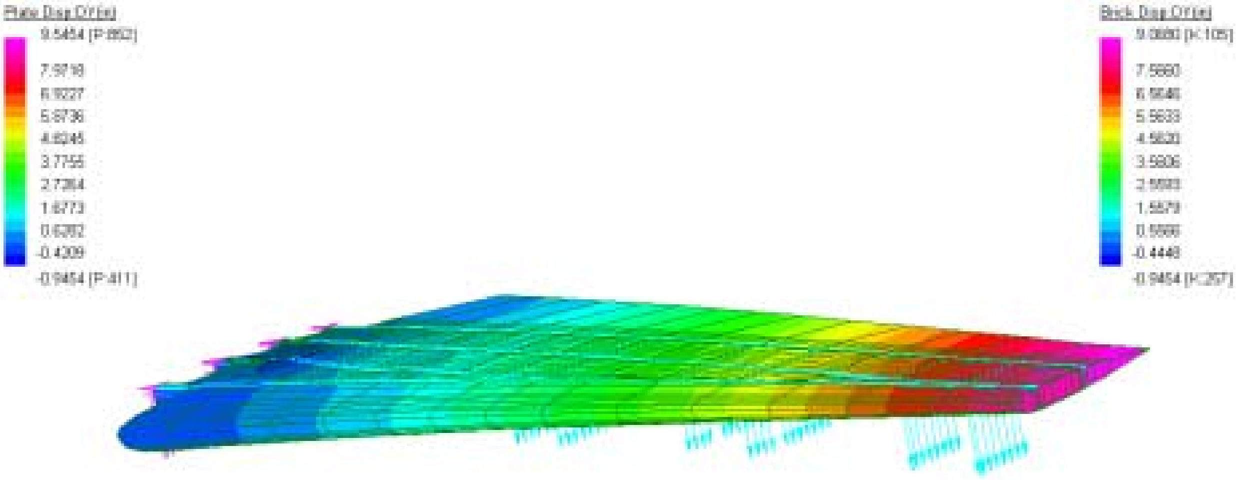

Figure 3 – Successful verification of model (note max plate displacement, 9.55 inches)

(Figure 3) Maximum plate displacement was found to be 9.55 inches. Lockheed static load deflections for the same loading conditions produced maximum deflection (i.e. at the outboard end of the horizontal stabiliser) of 9.40 inches [4]. This comparison indicates the accuracy of the present model. The percentage error obtained is shown in equation 1. This degree of accuracy ensures the model will be a valid tool for analysing stress concentrations between repairs.

$$\text{Percentage error} = \frac{9.55 - 9.40}{9.40} = 1.6\% \qquad \text{eqn.1}$$

4.3 Aerodynamic data

At present the authors are applying aerodynamic data, which simulates a positive 3G manoeuvre (checked upward pitch). The data is being applied as components of lift and drag, which was generated by Smith of MPLMSQN [5].

4.4 Repairs

There are various reasons for carrying out repairs on an aircraft, each requiring a specific type of treatment. The precise details and procedures for conducting repair work are beyond the scope of this project. For further information please consult the Lockheed publications. However, there is one process involved in repair construction that is relevant to this investigation; this is the attachment of doubler plates to the external surface of the skin of the horizontal stabiliser. Figure 4 below is an extract from the Lockheed standard repair procedures manual [3].

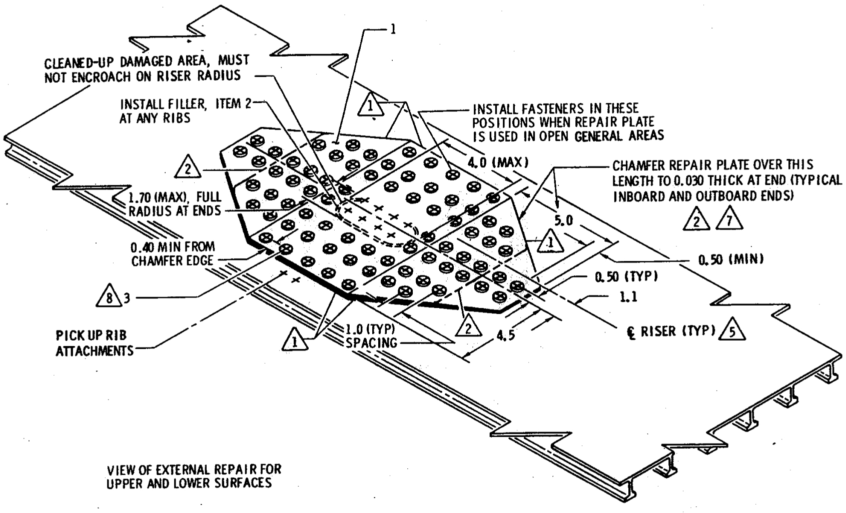

Figure 4 – Lockheed approved standard doubler plate repair

In order to create an accurate finite element model that effectively replicates an approved repair, and its interactions, D'Agostini and Withall [2] identified the primary elements. These included an integrally stiffened skin section, two doubler plates and numerous rivets. Complicating the modelling process are the variations in skin thickness and stiffener geometry that occurs along the length of any one of the six panels that comprise the horizontal stabiliser. From D'Agostini and Withall [2] it was possible to determine an equivalent thickness model that simplifies the analysis greatly. This model concluded that a repair could be modelled by applying the equivalent thickness of the repair to the global model, to produce the associated stresses.

This equivalent thickness model is currently being applied, in conjunction with the aerodynamic flight data, to the global model by Telford and Tucker. In order to model a realistic repair scheme, the authors have chosen the tail plane of aircraft A9-434, due to its excessive number of repairs. A corrosion map of A9-434 can be seen below in Figure 4.4.2.

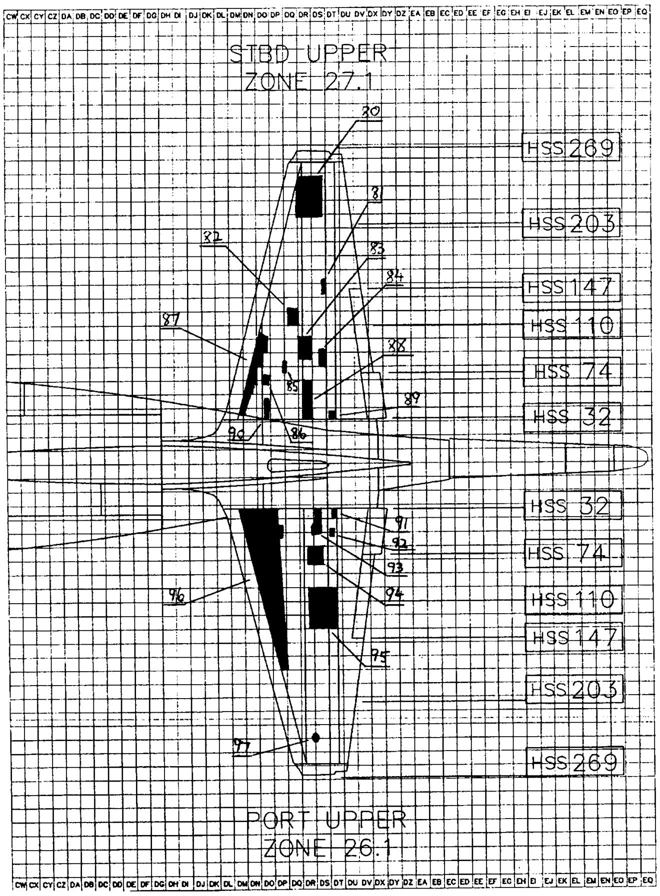

Figure 4.4.2 – Corrosion map of A9-434

5.0 FUTURE WORK

To successfully complete this project, the authors must still apply the flight-loading data. A model can then be completed of the repair scheme of each horizontal stabiliser of aircraft A9-434. The repairs will be modelled using the equivalent thickness model developed by D'Agostini and Withall [2]. On completion of the model, an analysis of the affects of multiple repairs on stress concentrations in the horizontal stabiliser will be undertaken.

6.0 SUMMARY

The verification of the finite element model was successfully completed, with an accuracy of 1.6 percent of the experimental results obtained by Lockheed [4]. This will lead to a successful in flight analysis of the effects of multiple repairs on the surface of the horizontal stabiliser.

7.0 ACKNOWLEDGEMENTS

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