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RE-DESIGN and ANALYSIS of FUEL FLOW VENT HOLE in WING PIVOT FITTING ASSEMBLY of F-111 AIRCRAFT

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ABSTRACT

The paper presents to determine the shape of the cutout that will maximize its fatigue life and minimize the weight of the Fuel Flow Vent Hole under the operating loading conditions. Using the shape optimization process, changing the length of the fuel flow vent hole gives a better fatigue life. The design space near the optimal region is found to be flat that is around 40% shape optimization(80mm hole), the original weight is 0.44343kg and obtained reduction in weight is 0.27018, this allows us to achieve a considerable enhancement in fatigue life and weight reduction.

Keywords: shape optimization, weight reduction, fatigue life, damage tolerance, industrial and aerospace application.

1. INTRODUCTION

A wing pivot assembly for variable sweep wing aircraft for movably securing a wing of the aircraft to the fuselage. The wing pivot assembly has a pivot pin supported by a pair of inboard lugs secured to the fuselage of the aircraft. The wing is, in turn, movably secured to the pivot pin by bearings interposed between the pivot pin and a pair of outboard lugs.

The design of the aircraft meant that all wing loads were transferred into the fuselage through the wing pivot mechanism. Furthermore, with the wing at a fully swept back position, the elevators in the empennage control not only the pitch of the aircraft, but also its roll. This means that rear fuselage of the aircraft has to withstand twisting as well as bending loads. The whole concept of the aircraft called for high strength materials in the airframe with high strength/weight and strength/volume ratios in the critical structural areas.

The F-111 aircraft is composed of many components, systems, and sub-systems. The Wing Pivot Fitting is critical to the structural integrity of the aircraft, and is located near the fuselage of each wing. It consists of an upper plate and a lower plate, which are connected by integrally forged stiffeners to form a box-type structure. The stiffeners are positioned along the inner side of the wing skin to provide strength against buckling of the wing surfaces.

Figure1: Aircraft wing showing the locations of the Fuel Flow Vent Holes.

2. STRUCTURAL MODEL

A generic model of the rib-stiffened vent hole structure is considered in the present optimization study. Since our focus is to optimize the vent hole only, we consider a (full-scale) sub-model of the local geometry of interest developed from the full 3D finite element model shown in Figure 1a. One (upper) plate and a stiffener with a vent hole are modeled here, see Figure 1b. Due to symmetry about the mid (xy) plane, one-half of the structure is considered for analysis. A half finite element model along with the geometric dimensions of the stiffener (rib), the upper plate and the vent hole (cutout) is shown in Figure 2a. The length and height of the stiffener are 300 and 50 mm respectively, and the thickness of the upper plate is 7.5 mm.

The initial geometry of the vent hole is shown in Figure 2a with its top surface located 5 mm below the upper plate. The stiffener and the plate are made of an aluminum alloy with a Young's modulus of 72 GPa, a Poisson's ratio of 0.3, an ultimate strength of 448 MPa and a yield strength of 365 MPa.

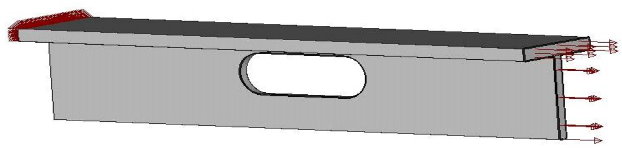


Figure2: Half finite element model of the stiffener structure

2.1: PROJECT AIM AND METHODOLOGY

PROJECT AIM:

The primary aim of this project is to determine the shape of the cutout that will maximise its fatigue life under the operating loading conditions. The optimum shapes of the vent hole are determined considering the fatigue life as the distinct design objective in the presence of numerous three-dimensional cracks located along the vent hole boundary. An improved fatigue life is achieved for the optimal designs..The project concerns to determine the stress and fatigue life. And to increase the fatigue life and minimize the stress in the corners of the vent hole and increase the life of fuel flow vent hole.

PROJECT METHODOLOGY:

This thesis adopted extensive structural model and finite element (FE) modeling,coupled with the use of numerical results. All modeling in this research project was conducted using the CATIA and pre-processor HYPERMESH and than translated in to ANYSIS used to visualize the results. This commercial FE package iscapable is capable of finding out the extending the fatigue life of fuel flow vent hole and minimize the stress concentrating reason in the cornering of the fuel flow vent hole.

Throughout this thesis, separate FE models was developed for different geometry of the fuel flow vent hole:

For 50mm hole
For 60mm hole
For 70mm hole and
For 80mm hole.

3. DESIGN AND ANALYSIS OF MODELS

ANSYS is parametric Design language, a scripting language that you can use to automate common tasks or even build your model in terms of parameters. While all ANSYS commands can be used as part of the scripting language.

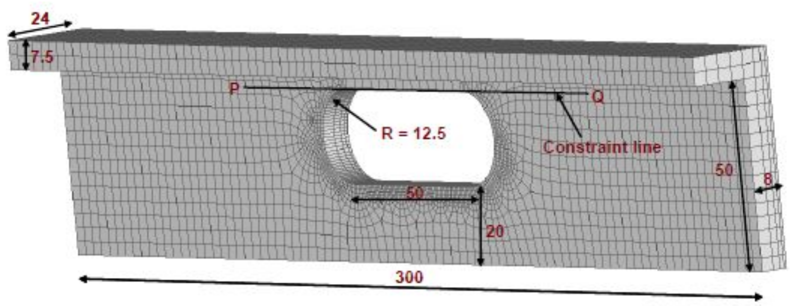
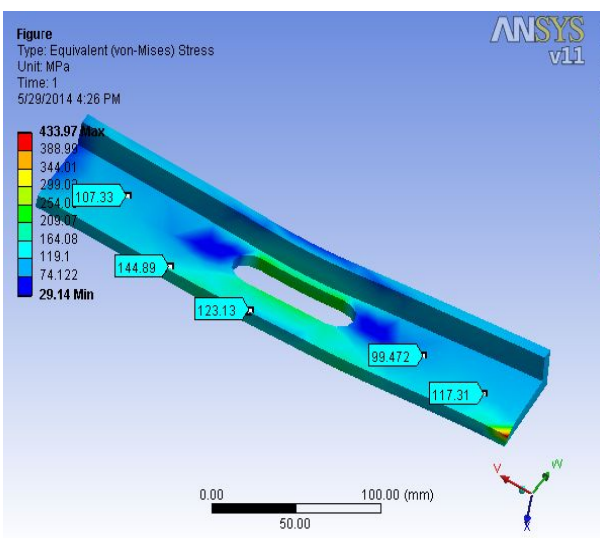


Figure 6: Geometric dimensions (in mm) and a half finite element model of the stiffener structure (the boundary of the vent hole is not allowed to move beyond line PQ).

1 1st ITERATION OF THE MODEL (10% of shape optimization ie 50mm hole)

As the aluminum alloy is the ductile material so we can check for the von-mises stresses for to know exact stress locations in the model, or else we can call it as equivalent stresses.



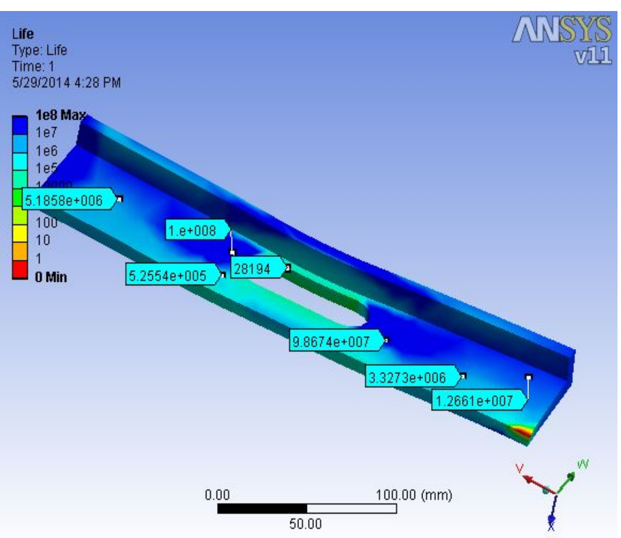


Figure 7 Equivalent stress or von mises stresses(50mm Hole) Figure 8: Fatigue Life of the hole(50mm Hole)

RESULT OF 1st ITERATION

Hole- 50mm
Shape optimization- 10%
Original Mass- 0.44343kg
Optimized Mass- 0.39845kg
Marginal Mass- 0.00256kg

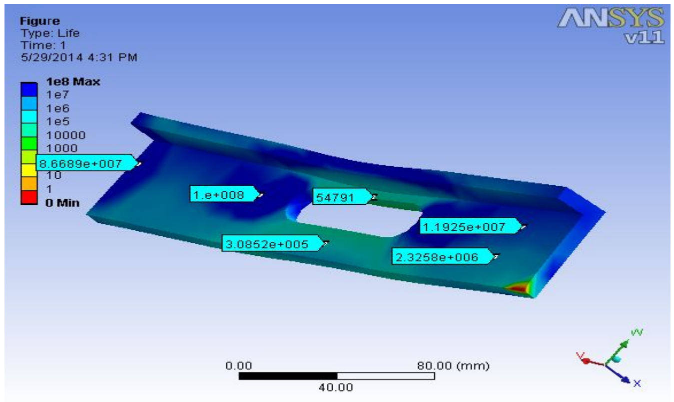


Figure 9: Fatigue Life of the Hole(60mm)

RESULT OF 2nd ITERATION

Hole- 60mm
Shape Optimization- 20%
Original Mass- 0.44343kg
Optimized Mass- 0.35611kg
Marginal Mass- 0.0086164kg

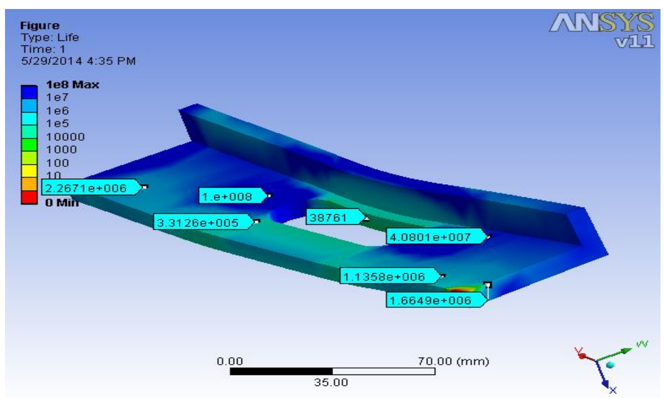


Figure 10: Fatigue Life of the Hole(70mm)

RESULT OF 3rd ITERATION

Hole- 70mm
Shape Optimization- 30%
Original Mass- 0.44343kg
Optimized Mass- 0.30876kg
Marginal Mass- 0.018465g

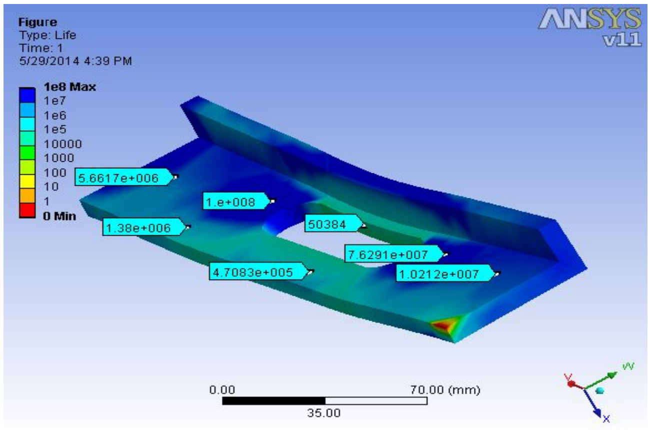


Figure 11: Fatigue Life of the Hole(80mm)

RESULT OF 4th ITERATION
Hole- 80mm
Shape Optimization- 40%
Original Mass- 0.44343kg
Optimized Mass- 0.27018kg
Marginal Mass- 0.018465kg

4. THEORETICAL CALCULATION

Theoretical calculation for the fatigue life.

Goodman criterion can be used for finding the fatigue life of Fuel Flow Vent Hole

- Fatigue Strength = = a

Where N = Cycles to Failure

a and b = Constants are defined by points

= =

=110.52 mpa

Where σmax = Maximum shear stress, Σmin = Minimum shear stress

= =

=127.31 mpa

a = =

= 716.17 mpa

Where f = Fraction of minimum tensile strength

= Minimum Tensile Strength = Endurance Limit

b = - log () = - log ()

= -0.0832

- Number of cycles to failure can be expressed as

ϑ= = sf = = = 154.39 mpa

- Number of cycles to failure can be expressed as

ϑ= =

=1.022* cycles.

5. VALIDATION RESULTS

Hole	Shape optimization	Original mass	Optimized mass	Marginal mass
50mm	10%	0.44343kg	0.39845kg	0.002556kg
60mm	20%	0.44343kg	0.35611kg	0.0086164
70mm	30%	0.44343kg	0.30876kg	0.001096
80mm	40%	0.44343kg	0.27018kg	0.011465

Table 1: Comparison of Original and Optimized Mass Using Shape Optimization

	MINIMUM	MAXIMUM
ANALYSIS	0	1
THEORETICAL	0	1.022*

Table 2: Comparison of Analysis and Theoretical Results

6. CONCLUSION

The geometry of the fatigue life optimized shape is nearly elongated, which will depend on the length of the vent hole. It was found that the greater the criticality of the flaws, the larger is the optimized shape. The fact that the vent hole shapes obtained with damage tolerance approaches are more elongated than those obtained using stress optimization may make them more sensitive to other load cases.The present study used single load case optimization, based on the load case commonly encountered in service for the component.

The optimum zone was found to be somewhat flat, nearly about 40% shape optimization that is (80mm hole), Here the fatigue life is increased compared to original shape. This can reduce computational time, aid in weight reduction and other design modifications by allowing us to choose an alternative design in the vicinity of the optimum point that will better satisfy the design and functionality requirements (e.g. a light-weight design), yet will perform close to the actual optimum design. Shape optimization may contribute to the reduction in the weight of a structure. This is an important consideration in many applications, especially in the aircraft and rail industries. In this problem, the optimum designs produced by the fatigue life optimization are lighter than both the existing structure (initial geometry) and the stress optimized design.

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