STRESS ANALYSIS AND FATIGUE DAMAGE ESTIMATION FOR SEAT SUPPORT ATTACHMENT

Veeresh C Panshetty [1], Dr. Manjunath L H [2] and K. E. Girish [3]

[1]M.Tech Student, Reva University India

[2]Professor, Reva University, India

[3]Bangalore Aircraft Industries, India

ABSTRACT

Aircraft structure is the most obvious example where structural efficiency results in light weight and high operating stresses. Airframe experiences variable loading in service. The paper presents the response of fuselage seat attachment due to cabin pressure and fluctuating load on seat attachment. The stresses developed in the fuselage at the altitude during actual flight condition were simulated by using the FEA software MSC.PATRAN & MSC.NASTRAN. The response of structure for the hoop stress and longitudinal stress developed in the fuselage due to cabin pressurization is studied by using finite element analysis technique. Linear static stress analysis is carried out for the identification of the fatigue critical location. The global and local analysis is carried out. Miner's rule will be used for fatigue damage calculation with the help of the S-N diagram of the respective material used in the structure.

Keywords: *Airframe, Fuselage, Fatigue, Stress concentration, FEA, Miner's rule, Damage calculation.*

1. INTRODUCTION

An aircraft is a machine capable of flight due to support of air. During flight the aircraft experiences different loads on its components. An aircraft has four major components, which are namely,

1. Fuselage
2. Empennage
3. Wing
4. Landing gears

Fuselage is a cylindrical structure, skin, stringers, and bulkheads together constitutes a fuselage. The vertical stabilizer, horizontal stabilizer at the tail of the aircraft as shown in fig.1 make the empennage of the aircraft. The loads that the aircraft experiences are the tensile loads, compressive loads , bending loads, torsional load, shear load are all finally get transferred to the fuselage. So the fuselage should be very strong structure to take all these loads. The aircraft should be very strong not just only strong even light weight also.

The pressurization of the fuselage is one of the critical load cases considered in design cases. when the aircraft is on the ground, the pressure inside the fuselage and outside are same, but when the aircraft is at high altitude the density of a air outside the aircraft is less, so it's very difficult for human beings to breath. So at that altitude 1atm pressure is maintained within that cabin for human survival.

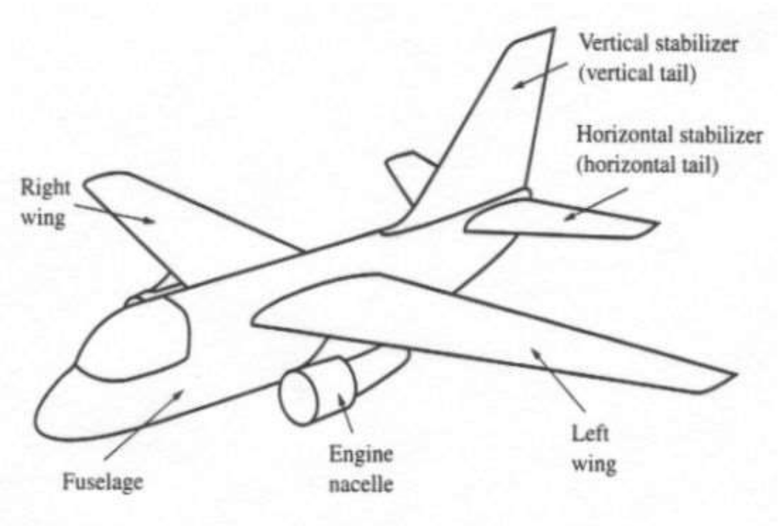


Fig.1 Aircraft Components

The current project includes stress analysis of the fuselage segment consisting of fuselage frames and skin. Fuselage frame near to the floor has an attachment to support the passenger seat. Stress analysis will be carried out using finite element method.

Fatigue:

The process of Degradation of the static load carrying capacity of a material when it is subjected to a cyclic loading is known as fatigue. When a structure is subjected to a cyclic loading it loses its static load carrying capacity, the material will fail when the crack is initiated , at what cycle the crack is initiated is called fatigue life prediction.

2. MATERIAL SPECIFICATION

Table.1 Material properties

Property	Aluminium 2024-T3
Ultimate Strength	483 MPa
Yield Strength	362 MPa
Young's Modulus	70 GPa
Poisson's Ratio	0.33

3. GEOMETRIC MODELING

The linear static analysis is carried out for fuselage frame with seat attachment and the analysis is done in MSC PATRAN which is pre-processor and post processor and MSC NASTRAN is solver.

The model from CATIA is imported in .IGES format to PATRAN software for stress analysis. The geometric model of fuselage frame is shown in Fig-2

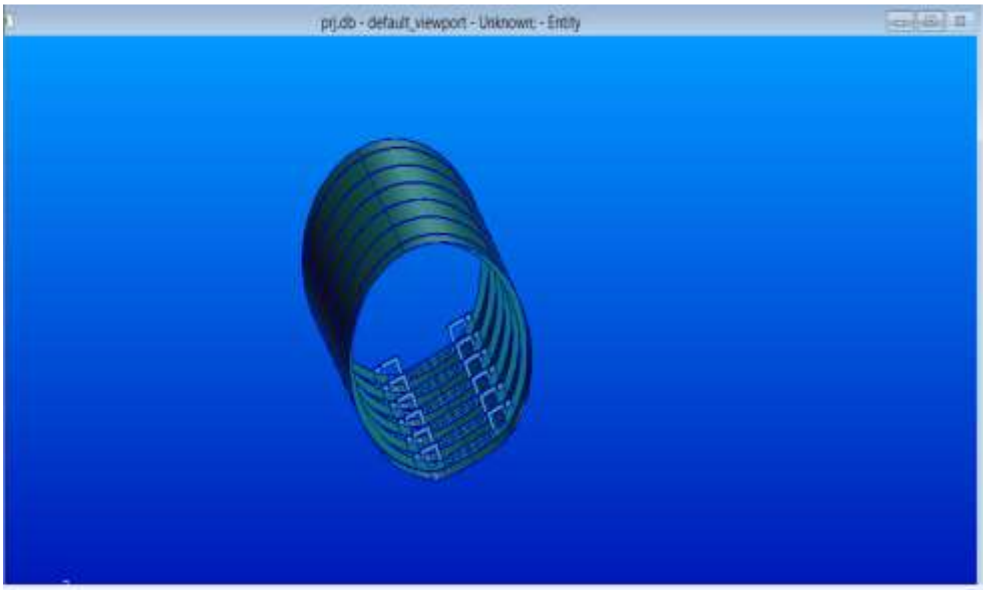


Fig.2 Geometric model

4. LINEAR STATIC STRESS ANALYSIS

4.1. FINITE ELEMENT MODEL

After importing, the finite element model is created, triangular and quadrilateral elements are used for meshing model. One dimensional and two dimensional meshing is carried out for fuselage and other components. The stringers are meshed using 1D elements. The bulkheads with seat attachment and skin are meshed using 2D elements. After meshing, the boundary condition is imposed and load is applied. The fuselage is constrained in all the degrees of freedom at both the ends (Circumferential).

There are two types of loads applied on fuselage:

1) Pressure loads

2)Total load

The pressure load of 6 psi is applied on the skin and the bulkheads for human survival, this leads to expansion and contraction of skin and bulkheads. The load of 100 kg is applied on each seat.

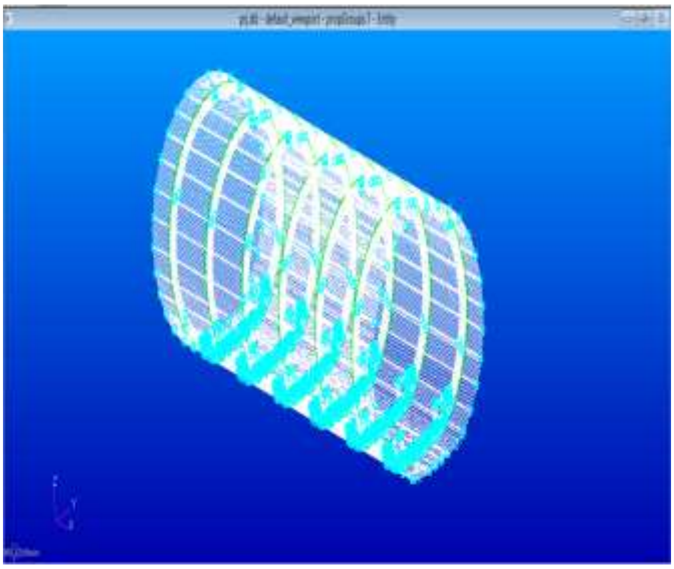


Fig.3 FEA model

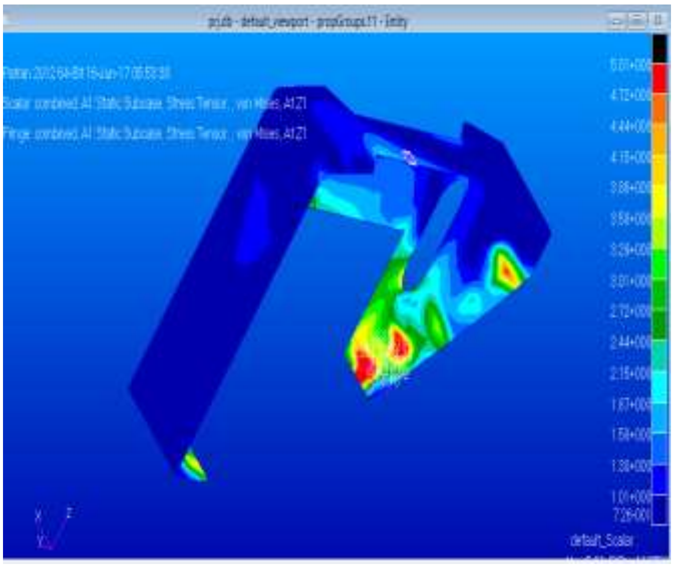


Fig.4 max stress at seat attachment

The maximum stress at seat attachment is 5.01 kgf/mm^2.

5. LOCAL ANALYSIS OF CRITICAL LOCATION

The critical location of a seat attachment is taken for further stress analysis in local analysis. The critical location where the maximum stress is obtained considered to be a plate with a hole. In local stress analysis the boundary conditions are represented. One side of a plate is constrained in all degrees of freedom and the other side is loaded axially.

$$\sigma = \frac{P}{A}$$

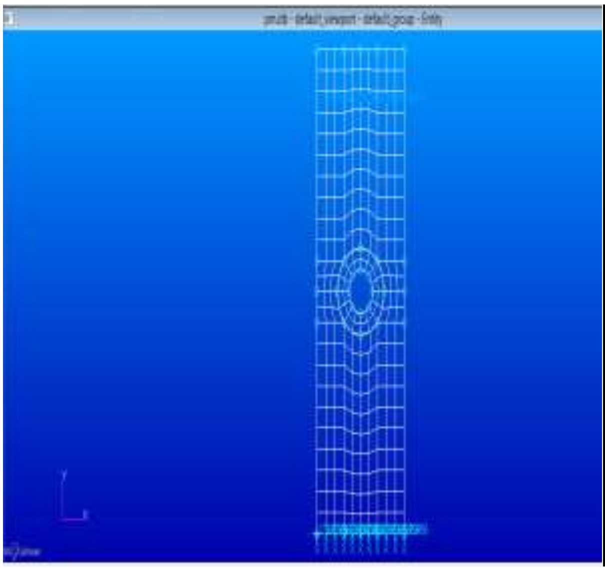
Where

σ- Stress (global analysis max stress) = kgf/mm^2

P- Load =kgf

A- Cross section area =mm^2

$$5.01 = \frac{P}{26 * 3.5} = 455.91\ kgf$$



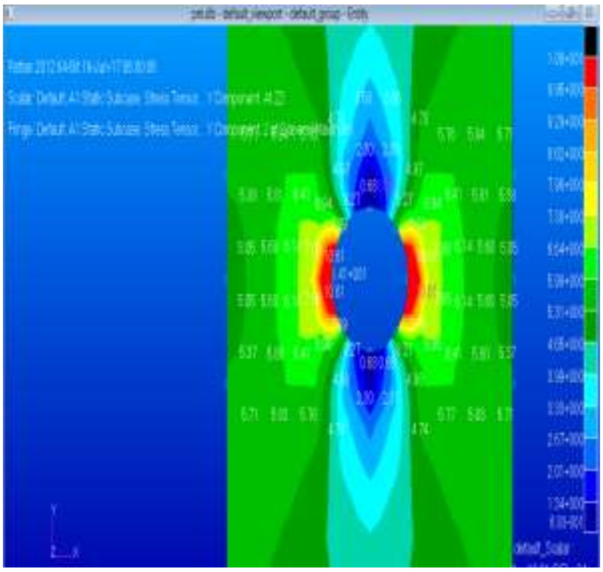


Fig.5 load and boundary condition for plate **Fig.6 Stress distribution in plate with hole**

with hole

The max stress was found to be 10.6 $kgf/mm^{2.}$

6. FATIGUE ANALYSIS

Fatigue analysis is carried out to determine the life of the seat attachment when subjected to pressure and repetitive load.

Table.1 Load Magnitude Ranges

Sl. No.	**RANGE OF "g"**	**Cycles(Ni)**
1	0.50g	40,000
2	0.75g	55,000
3	1.00g	38,000
4	1.25g	25,000
5	1.75g	500
6	2g	300
7	2.5g	250

Table.2 Stress results

g condition	Stress in kg/mm2	Stress in ksi
0.5g	5.30	7.5362873
0.75g	7.95	11.30443095
1g	10.60	15.0725746
1.25g	13.25	18.84071825
1.5g	15.90	22.6088619
1.75g	18.55	26.37700555
2g	21.20	30.1451492
2.5g	26.50	37.6814365

6.1 Calculation of Fatigue Damage

The fatigue life of fuselage frame with seat attachment is predicted by using miner's rule. It states that "Fatigue damage occurred at a given stress level is proportional to the number of cycles applied which is divided by the total number of cycles to failure".

$$C = \sum \frac{N_i}{N_f}$$

Where,

N_i= Number of cycles induced,N_f=Number of cycles to failure,C is assumed to be 1

The number of cycles to failure for different stress amplitude can be obtained from aluminum 2024-T3 sheet. The Fig-7 shows S-N curve for the aluminum alloy sheet.

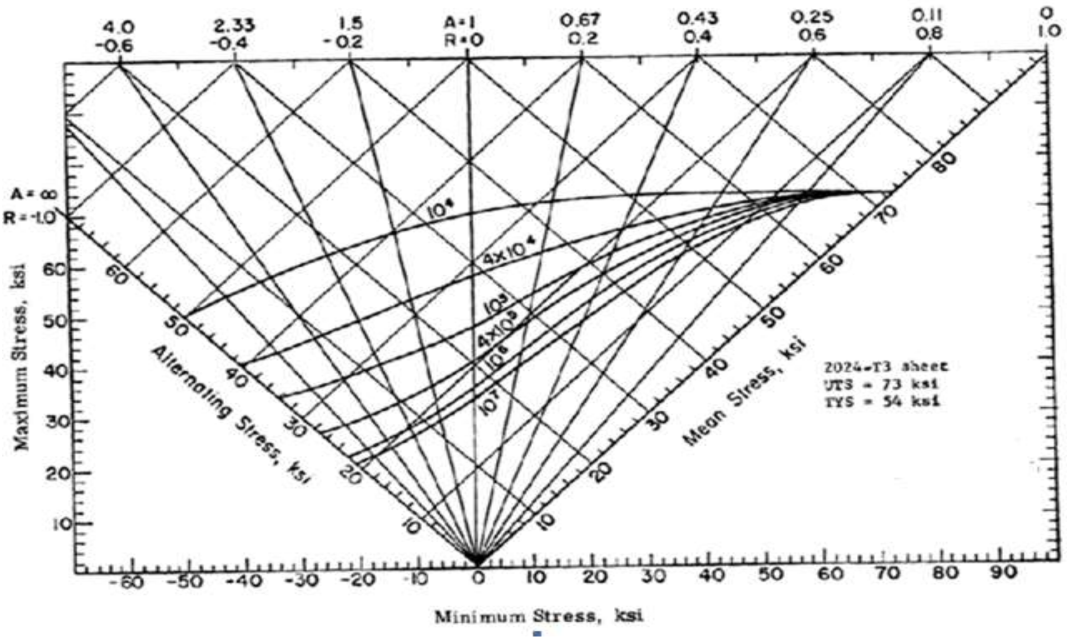


Fig.7 S-N Curve

Fig 7 shows the typical constant life diagram for un-notched fatigue behavior of 2024 T3 Aluminum alloy. Using the maximum stress and the value of R in S-N curve given in figure, the fatigue cycle for various stress level are found out[6}

Table.3 Damage accumulated

σ min	σ max	σ alt	σ ratio	N_f	N_i	damage	damage critical
7.5362873	11.30443095	1.8841	0.6667	10000000	40000	0.004	1
11.30443095	15.0725746	1.8838	0.75	10000000	55000	0.0055	
15.0725746	18.84071825	1.884	0.79999	10000000	38000	0.0038	
18.84071825	22.6088619	1.884	0.8333	10000000	25000	0.0025	
22.6088619	26.37700555	1.8845	0.85714	10000000	500	0.00005	
26.37700555	30.1451492	1.884	0.875	10000000	300	0.00003	
30.1451492	37.6814365	3.77	0.8	10000000	250	0.000025	
			Total damage			0.0159	

The total damage occurred is 0.0159 which is less than unity, the design is safe, the crack is not initiated.

7. CONCLUSION

The study conducted here based on fuselage frame with seat support attachment enabled to locate the region where stress is concentrated. The damage estimation is done to investigate structure is safe under prevailing load conditions and cycles. The structural analysis of the fuselage frame is carried out using FEA approach. The maximum stress at seat support attachment is 10.6 kgf/mm^2.Fatigue life estimated with the help of S-N curve. The damage calculation is done by using miner's rule which is 0.0159 from this it is observed that the remaining life of the structure 0.9841. The structure lost 159000 and the remaining cycle is 9841000.

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