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STRESS ANALYSIS OF THE LANDING GEAR-WELL BEAMS AND DAMAGE CALCULATION DUE TO LANDING CYCLES

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Abstract

Landing gear is a structure, which supports the aircraft on the ground. Landing gear structure experiences the load during take-off and landing of the aircraft. These loads are transferred to the airframe through landing gear beams. Wing box near the root will have cutout at the bottom surface to accommodate the retraction of the landing gears. Landing loads are absorbed by the landing gears and diffused to the larger area of the wing through connecting members. In the current project two landing gear beams with a root rib are considered for the analysis. On either sides of the cutout region landing gear beams are used to transfer the landing load from landing gears to the wing and fuselage structure. Landing gear beams are in the span wise direction of the wing. Linear static analysis of the beams along with the root rib will be carried out to identify the fatigue critical location in the structure. Local analysis will be carried to capture the stress concentration and stress distribution near the high stress location. It is very rare that these structural members will fail by static over load. Due fluctuating loads during the service fatigue cracks will get initiated at the high tensile stress location. Landing gear beams will experience constant amplitude load cycles because of every landing during service. Fatigue life to crack initiation will be calculated using Miner's rule based on the S-N data of the material being used.

***Keywords**:* Stress analysis, Finite element method, Fatigue, Fatigue life estimation, Crack initiation.

1. Introduction

An aircraft fly using lift generated by the wing as it is pushed by the thrust developed by the jet engine. Earlier major focus of structural design in the early development of aircraft was on strength. But at present days structural designers also deal with fatigue life, corrosion resistance, maintenance, producability and structural integrity. The rigidity of wing is provided by the spar beams and ribs which gives support to the aircraft structure. Now a day's aircraft structures are designed using a semi-monocoque structure concept. It consists of load carrying frames, longerons and skin which are in turn supported by spars and ribs members. An aircraft is to be designed in such a way that it should be light in weight and strong enough to withstand loads acting on it. An aircraft is subjected to various kinds of loads and forces during takeoff, landing and in flight. These loads cause high stress in the aircraft structure. The main aim of design is to reduce or completely eliminate stress concentration, detect critical crack region, arrest crack, and avoid failure of the component under service life of an aircraft.

Stress analysis is used to locate the critical region in the structure where there is a possibility for the crack to occur. Stress analysis gives the maximum magnitude of stress in the structure. Crack initiate at the region of maximum stress.

Fatigue is experienced by the material when it is subjected to repeated loading both cyclic and non cyclic. Fatigue is progressive and localized structural damage that happens when a material is subjected to cyclic loading. Fatigue cracks are caused generally by tensile stress but sometimes can occur by compressive stress also. Fatigue life is influenced by various factors such as surface roughness, temperature, residual stress, microstructure of material used. Fatigue is a cumulative process, it cannot be reversed. Fatigue failure can be avoided by various method like fail safe approach, damage tolerant design, choosing correct material etc.

1.1 SOFTWARE DISCRIPTION

Software used in this work is MSC Patran and MSC Nastran.

MSC Patran: It is graphical software pre and post processor used for finite element analysis. It is widely used in aeronautical industry. It easy to use and gives efficient result. Here three dimensional models can be converted into two dimensional models. The solid model can be meshed using various elements like tria, quad, hex etc. material properties and boundary condition can be assigned to the finite element model.

MSC Nastran: It is developed by NASA and later acquired by MSC. It is a finite element solver. It does not have the meshing capability. MSC Nastran is commonly utilized for performing structural analysis. It is widely used in aerospace and automobile industries. We can perform various analyses such as dynamic, rotor dynamic, non linear thermal, impact and fatigue analysis using these software.

1.2 MODEL, MATERIAL PROPERTIES, LOAD CALCULATION AND BOUNDARY CONDITION:

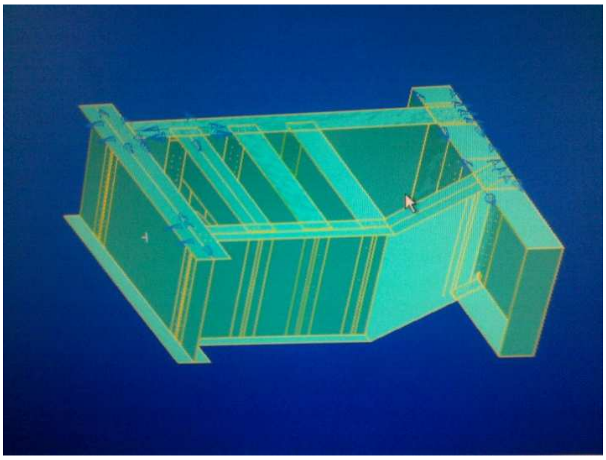

Fig -1: Model Landing Gear Well Beams

The material taken for the landing gear wells beams is assumed to be made of Aluminium Alloy AA 2024 T351 and material properties of the Aluminium Alloy AA 2024 T351 are taken as

Young's Modulus	7000 MPa
Poisson's Ratio	0.3
Yield Strength	324. MPa
Ultimate Tensile Strength	427. MPa
Load Factor	1.5 G

Load calculation:
Type of aircraft: 13 seater aircraft
Total weight of aircraft: W= 6.1 ton = 6100 kg

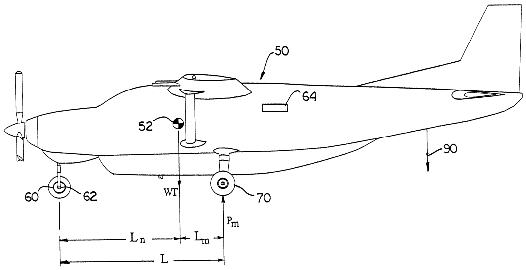

Fig 2: Typical Position Of Landing Gear In Aircraft.

Base =B= 6.465 m

F_m=

H_{cg} =1.88 m

F_{mdy}=

aT = vertical sink rate.

Hcg = Height from ground to center of gravity.

F_{mdy} = 2660.79 kg

Total load on main landing gear during normal touch down:

F = 2660.79 + 6100 = 8760.79 kg

Force per landing gear : F = 8760.79/2 = 4380.4 kg

Force acting on pin diameter: =46.4775

Force acting on each side of pin: = 23.23

The flange region of rib is constrained with six degree of freedom.

1.3 FINITE ELEMENT ANALYSIS

The **Finite Element Method (FEM)** is a numerical technique for finding approximate solutions to boundary value problems for differential equations. Finite element method uses variational methods (the calculus of variations) to minimize an error function and produce a stable solution. The main idea that connecting many tiny straight lines can approximate a larger circle, in the same way FEM encompasses all the methods for connecting many simple element equations over many small sub domains, named finite elements, to approximate a more complex equation over a larger domain.

The elements used for meshing of landing gear well beam are QUAD 4 and TRIA. But most of the elements are QUAD 4 type and only few are TRIA elements. Using more QUAD elements will more accurate result.

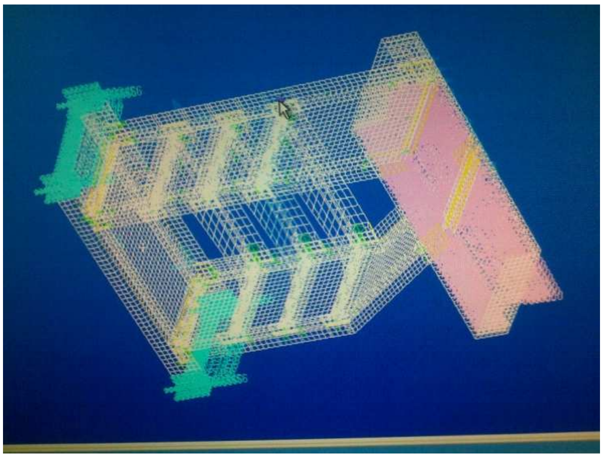

Fig 3: Finite Element Model Of LG Well Beams.

2. STRESS ANALYSIS:

After applying the load and boundary condition and running the analysis stress in the model is found. Maximum stress is found at the region near the rivet location at the beam and rib part neat the fixed end. The maximum value of stress is found to be 94.2 kg/mm^2 near the rivet location. Since the rivet is not simulated, the stress value is taken little away from the rivet to get average value of stress which is found to be 22.725 kg/mm^2.

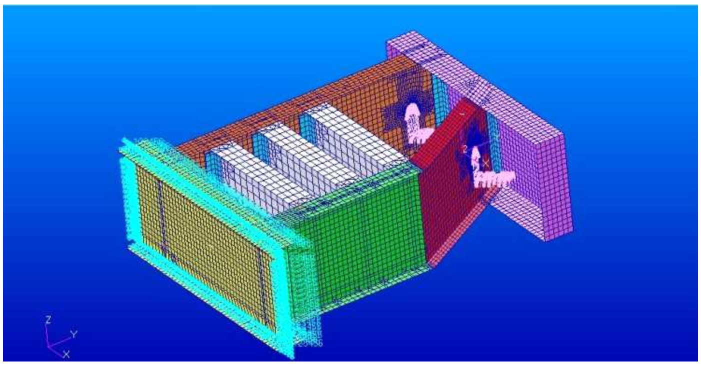

Fig 5: Meshed Model

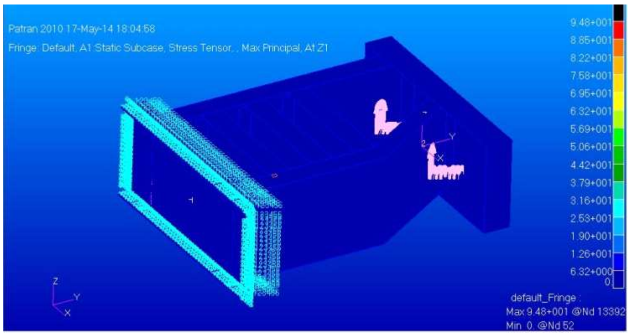

Fig4: Maximum Stress In The Model.

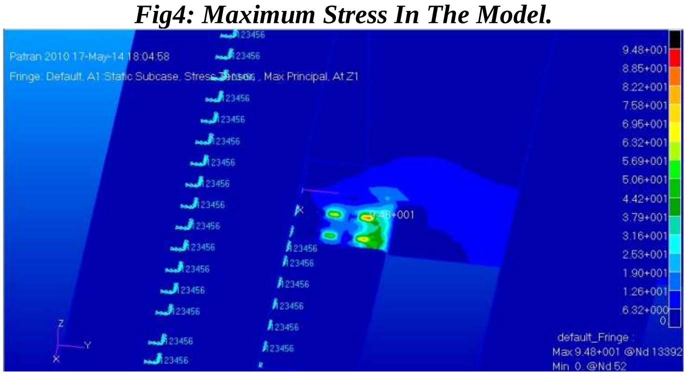

Fig 5: Two Dimentional Model and Analysis Model

From global stress analysis we find the maximum stress location. Mostly crack initiates at the region of maximum stress location, since tensile stress is high at that region. In this model maximum stress is found to be at the rivet location. We need to know the stress around the rivet location. For that we need to know the stress at elements around the maximum stress location. We use marker option for knowing the stress of individual element and take average stress, since stress is distributed unevenly in the model.

2.2: THEORETICAL VERIFICATION:

For local model analysis, a plate with hole is taken of length = 50mm, width = 25mm and thickness = 8mm. Nominal stress acting on global model is 14.9+14.5+29.3+32.2 = 22.725kg/mm^2

Load acting on the local model:

Stress average = Load / Area

Load = Stress avg*Area

= 22.725*25*5

= 2840.625 kg

One side of plate with hole is fixed and other end load applied is 2840.6/25= 113.625 kg/mm2

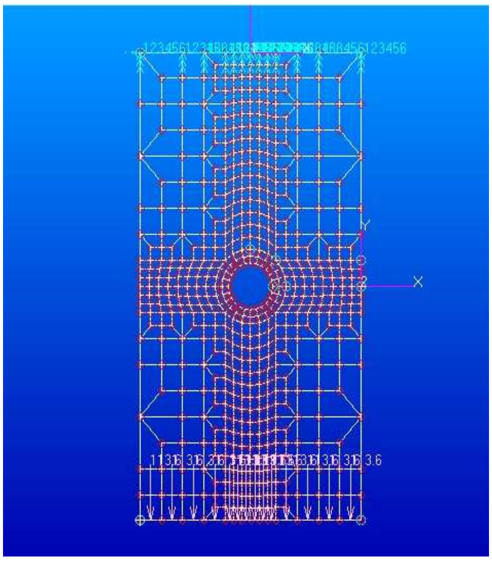

Fig 7: Mesh and boundary condition applied to local model

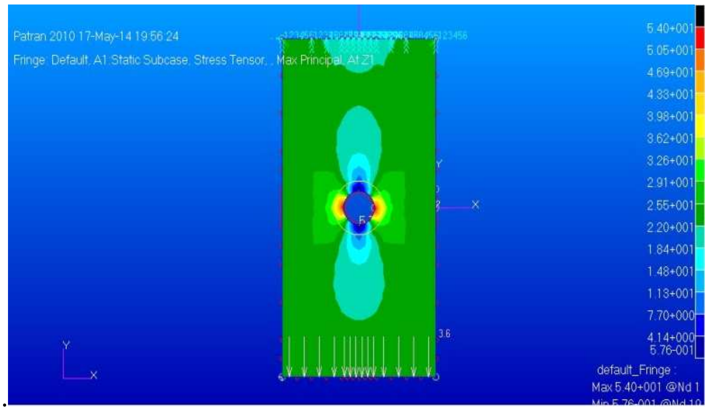

Fig 8: Local Analysis

The magnitude of maximum stress in local model is 54 N/mm^2. now we have to compare the stress result with theoretical value for validation of analysis result.

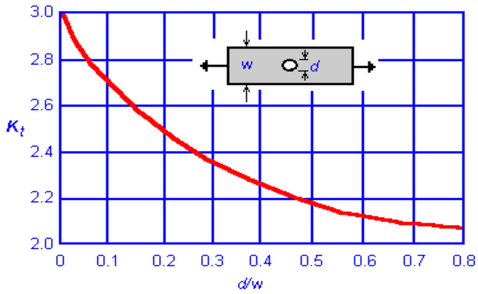

Fig 9: No Of Cycles To Failure.

The fig 9 gives the stress concentration for plate with hole. Here y axis represents stress concentration and x axis represents d/w ratio. Where d is diameter of hole and w is width of the plate. Ratio is calculated and is checked in the graph and stress concentration is found out.

From the S-N curve of plate with a hole of d/w ratio 0.2.
d/w = 5/25 = 0.2.
Kt = 2.5
Kt= max stress/nominal stress
Max stress = Kt* nominal stress
= 22.725*2.5
Max stress = 56.8 kg/mm2.

3. FATIGUE LIFE ESTIMATION

Normally aircraft landing gear beams experiences variable spectrum loading during takeoff and landing. A typical transport aircraft is considered for flight load spectrum is for the fatigue analysis of the landing gear well beams structure. Calculation of fatigue life estimation is carried out by using Miner`s Rule. Damage calculation is carried out for the full service life of the aircraft. The load factor "g" is defined as the ratio of the lift of an aircraft to its weight. This gives a measure of the load which aircraft experiences. As we know the maximum stress value obtained from the analysis is corresponding to 1.5 g condition.

Therefore the stress value corresponding to 1.5 g condition is obtained as 53.7 N/mm^2. Correction factors for fatigue life calculations of landing gear well beams structure are

- Surface Correction Factor = 1
- Loading Type = 1
- Design Reliability = 0.897
- Surface Roughness = 0.8

Load spectrum for fatigue life estimation:

Table 1: Variable Load Spectrum for typical aircraft

Sl no	G range	Cycles
1	0.5g to 0.75g	57000
2	0.75g to 1g	28000
3	1g to 1.25g	24000
4	1.25g to 1.5g	18000
5	0 to 1.5 g	50
6	-0.5 g to 1.5g	100

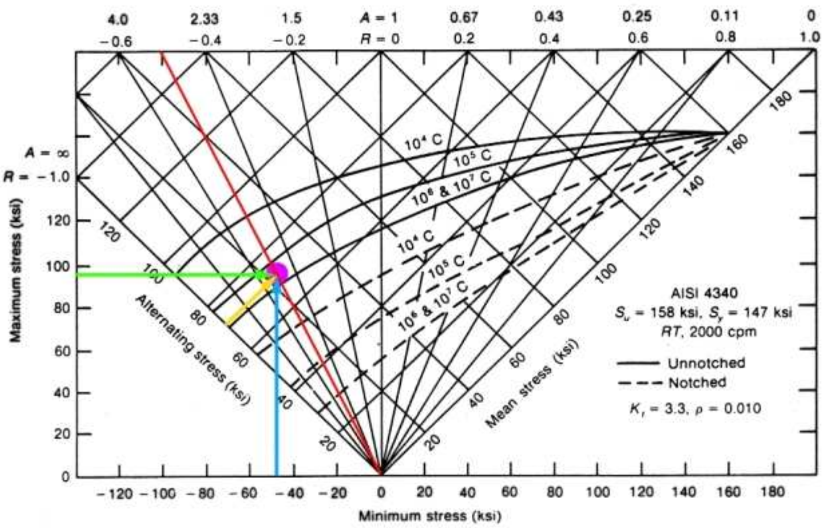

Fig 10: Graph for No of Cycles To Failure

Table 2: Range \, stress ratio and cycles

Sl no	Range	Stress ratio(R)	Stress amp(ksi)	Cycles
1	0.5g to 0.75g	0.6682	5.27	infinite
2	0.75g to 1g	0.75	5.36	Infinite
3	1g to 1.25g	0.8	5.27	Infinite
4	1.25g to 1.5 g	0.83	5.27	infinite
5	0 to 1.5 g	0	31.80	$2.5*10^4$
6	-0.5g to 1.5g	-0.33	42.43	13750

Range: 0 to 1.5g

Ni/Nf = 50/25000 = 0.002

Range: -0.5g to 1.5 g

Ni/Nf = 100/13750 = 0.007

Total damage accumulated is 0.002+0.007 = 0.009

Total damage accumulated is 0.009 which is less than 1. Hence the structure is safe i.e. structure does not fail due to fatigue with in service life.

4. CONCLUSIONS

Stress analysis of the Landing gear well beams is carried out and maximum stress is identified near rivet location at fixed end which is found out to be lower than yield strength of the material. Normally the fatigue crack initiates in a structure where there is maximum tensile stress is located. The fatigue calculation is carried out for the prediction of the structural life of landing gear well beams. Since the damage accumulated is less than the critical damage in the well beams structure is safe from fatigue considerations. Life of the particular region in landing gear well beams structure is predicted to become critical and found out to be 111110 flying hours or 111.11 blocks, hence advised to conduct the maintenance without fail during this period. Fatigue crack growth analysis can be carried out in the other parts of the landing gear well beams structure. In the future work damage tolerance evaluation and structural testing of the landing gear well beams structure can be carried out for the complete validation of all theoretical calculations. As well as beam structure optimization can also be carried out to meet the appropriate factor of safety of landing gear beam section

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