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Design Optimization Studies and Life Estimation for Typical Aircraft Brake Housing

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ABSTRACT: The Aircraft Brake housing is one of the critical system which encompasses a large number of fluctuating load (Fatigue). The Braking action due to which a torque generates and transmitts to wheel and brake assembly to make the Aircraft stop is an important component to study. In this paper the Desing and FEA analysis of Brake housing system are carried out to study the life estimation. The modeling and analysis are done using CATIA V5 and ANSYS 15 respectively. Aircraft Brake Housing Design for Static Load Requirements, Maximum brake operated pressure requirement, Proof pressure requirement and Burst pressure requirement and Dynamic Analysis Maximum operating pressure for 5000 cycles and Design landing for 100000 cycles and High Cycle Fatigue Estimation Based on SN Method and Goodman Assessment are studied thoroughly in this research. Analysis results are correlated to meet the TSO-C135 requirements to satisfy the FAA guidelines.

KEYWORDS: Brake housing, Fatigue, FEA, CATIA V5, ANSYS 15, TSO-C135, FAA.

I. INTRODUCTION

Aircraft brake housing system exclusively located at the main wheel. An aircraft braking system is given in Figure 1. As shown, the brake is composed of a stack of rotating brake discs(rotors) which engage the wheel, and stationary brake discs (stators), which engage the torque tube. The torquetube is attached to the brake housing that links to the landing gear through a torque take-out rod. Duringoperation, the brake is activated by the fluid pressure, which compresses the heat stack: the rotors are squeezed together by fluidic pistons and the brake produces torque by virtue of which aircraft stops.



Fig.1 Aircraft Brake System

Besides the primary task of stopping the aircraft, brakes are used to control speed while taxiing, to steer the aircraft through differential action, and to hold the aircraft stationery when parked and during engine run-up. In Aircraft Braking System, Brake Housing is the critical component, which is under various loads under various operating conditions. Current aircraft brake housing is cast aluminium encloses the piston and cylinder and forms a pressure



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vessel for the brake fluid. The fastener bolts tied between torque plate and brake housing transfers the high torque load from the torque pin which in-turn connects to strut and landing gear assembly. These tie bolts are utilized for attaching areas of abrake housing get together, String length that must be adequate to completely draw in the nut including the loading element and there must be a suitable unthreaded bearing territory to convey the obliged load. At whatever point a most extreme vitality Rejected Take Off has happened the trademark heat create can be very intense and the parts are to be examined for airworthiness and redesigned according to the techniques set up by the TSO prerequisites.

II. LITERATURE REVIEW

Components Maintenance Manual External design Wheels and Brakes (Cleveland Wheels and Brakes) [1] It tells about Brake assemblies in detail. Brake assembly and the qualification tested with respect to the Technical Standard Order and specific aircraft requirements to properly and safely declare aircraft under different conditions. The unauthorised substitution of the components can accord the brake effectiveness which is a violation of the qualification basis and is prohibited.

Mark P. Dyko, N. Eidom, [2] the aircraft brake housing and assembly of torque tube for a vehicle such as an aircraft is presented. The interfacing between torque tube and brake housing also torque tube is accommodated by a thermal composite material insulator that is located brake housing of adjacent.

Jean Jacques Sinou et al., **[3]** examined about Friction induced vibrations which are a major concern in a wide variety of mechanical systems. That is especially in the case of aircraft braking systems where the problem of unstable vibrations in disk brakes are studied. They observed that the stability analysis indicates that system instability can occur with a constant friction coefficient. A perfect correlation between the numerical model and the experimental tests is obtained for the frequency of instability and the deformation shape of the unstable mode. Generally they observed that the aircraft brake system is stable at low values of brake friction coefficient and unstable at high values.

S. Vats et al [4] Studied different types of Aircraft braking which includes the aircraft disc brakes in the landing gear, thrust reversers. The study emphasized the fail safe technology against the conventional method.

III. METHODOLOGY

MODELING

The 3D CAD model of Aircraft Brake Housing and Tie-Bolts are developed using CATIA V5 software separately, later assembled for tie bolt strength analysis. The modeled Brake housing and assembly of Brake housing with Tie-Bolts are imported to ANSYS Workbench, where analysis is carried out for various loads and various conditions.



Fig.2 CAD model of Brake Housing

MATERIAL PROPERTIES

Aluminum 2014-T651 is one of the most popular of the 2000 series aluminum alloys. It is commonly extruded and casted. It is easily machined in certain tempers; having high hardness, difficult to weld and mainly this alloy are used for cycling frames and components. Al 2014-T651 material is used in aircraft brake housing system design and the material properties of Aluminum in the Table 1.



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Vol. 6, Issue 7, July 2017 Table 1. Material Properties of Al-2014-T651

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DESCRIPTION	VALUE
Young's Modulus (E)	73000 MPa
Poisson's ratio (v)	0.33
Density (p)	$2.8 \times 10^{-6} \text{kg/mm}^3$
Yield Strength (σ_y)	414MPa
Ultimate Strength (σ_u)	483MPa
Mass of Aircraft Brake Housing Component	6.7 kg
Volume of Aircraft Brake Housing Component	$2.4 \text{x} 10^6 \text{ mm}^3$

MESHING

The CAD models are imported to ANSYS 16.0 Work bench where the meshing and analysis is carried out. Here carefully, the critical regions are selected for fine mesh such as Passage Hole, Lug Region, Critical fillet Region, Piston Area and Rib region. 2nd order tetrahedral high quality element has 3 translational degrees of freedom per node for a total of 30 degrees of freedom per individual element.

The tetrahedral are known as the simplex which means that the any 3D volume regardless the shape can be meshed. These are the only kind of elements that can be used with adaptive refinement. The SOLID 187 element is defined by 10 nodes having 3 Degree of freedom at each node. It has the quadratic displacement behavior and it suits well to the modeling of the irregular meshes. This element has plasticity, hyper elasticity, creep, stress stiffening, larger deflection and large strain capabilities.

Tie Bolts has been modeled with Hex dominant mesh. Fine mesh is considered at the critical regions. Total numbers of nodes and elements are tabulated in Table 2.

Analysis	Total Number of Elements	Total Number of Nodes		
Static Structural and Fatigue	349151	564615		

Table 2. Details of Meshing

IV. EXPERIMENTAL RESULTS

The obtained stress values for three different pressure conditions are summarized as below

1) Factor of Safety (FOS) = <u>Material Yield Strength</u> Working Stress

2) Margin of Safety (MOS) = Factor of Safety -1



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Fig. 3 Maximum pressure at (a) Lug region (b) Passage hole (c) Inside Cylinder

The Table 3 and 4 shows the results of maximum operating and Proof Pressure Condition and Table 5 and Table 6 shows the results of Burst pressure condition.

Tuble 5 Results of Fluxing and 11001 11 essure condition						
Load	Description	Maximum Stress(MPa)				Material Yield Strength(MPa)
Case		Lug Passage Inside Critical				
		Region	Hole	Cylinder	fillets	
1	Maximum operating	291.95	126.88	112.12	144.78	414
	Pressure					
2	Proof Pressure	43.16	176.18	143.41	119.10	414

Table 3 Results of Maximum operating and Proof Pressure condition

Table 4 Results of Maximum operating and Proof Pressure condition

Load Case	Description	Margin of Safety (FOS-1)			
		Lug	Passage	Inside	Critical
		Region	Hole	Cynnaer	Fillets
1	Maximum operating	0.3	2.0	2.4	1.6
	Flessule				
2	Proof Pressure	7.8	1.2	1.6	2.2

Working Stress

Table 5 Results of Burst Pressure condition

Load Case	Description	Maximum Stress(MPa)			Material Ultimate Strength(MPa)	
		Lug	Passage	Inside	Critical	
		Region	Hole	Cylinder	fillets	
1	Burst	57.55	234.91	191.22	158.80	483
	Pressure					



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Fig.4 Total deformation



Fig,5 Burst Pressure

Table 6 Results of Burst Pressure condition

Load Case	Description	Margin of Safety (FOS-1)			
		Lug Region	Passage Hole	Inside Cylinder	Critical fillets
1	Burst Pressure	6.6	0.9	1.3	1.7

FATIGUE LIFE ESTIMATION

The Table 7 shows the Fatigue life requirements for the Design Landing pressure and maximum operating pressure

Table 7 Fatigue Life Requirements

Load Case	Brake Pressure Cycle	Required Number of cycles
Design Landing Pressure	12.41 MPa	100000
Maximum Operating Pressure	21.37 MPa	5000



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MAXIMUM OPERATING PRESSURE

Piston end load of 27.27 kN is applied on the end face with respect to local coordinate system in negative X – direction and brake pressure of 21.37 Mpa.



Fig.6 (a) Maximum Piston End load (b) Design Landing Pressure

FATIGUE CALCULATIONS

At Passage Hole:

- i. $\sigma_{max} = 117.45$ MPa.
- ii. $\sigma_{min} = 0$ MPa. (Because of Repetitive loading)

iii.
$$\sigma_a = \frac{\Delta \sigma}{2} = \frac{\sigma \max - \sigma \min}{2} = 58.73 \text{MPa.}$$

- iv. $\sigma_m = \frac{\sigma \max + \sigma \min}{2} = 58.73 \text{MPa.}$
- v. Corrected Alternating Stress (σ_{ac}) to make $\sigma_m = 0$.

$$\sigma_{ac} = \sigma_a / (1 - \sigma_m / \sigma_u) = 58.73 / (1 - 58.73 / 435) = 67.9$$
 MPa.

vi. Fatigue Strength Margin = Endurance Factor of Saftey-1

$$= \frac{Endurance Stengt h}{FE stess} -1$$

$$=\frac{193}{67.9} - 1 = 1.8$$

Since Fatigue Strength Margin > 1, Hence Design is safe.

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- vii. Actual number of cycles at 67.9 MPa for Maximum Stress Location: >1e6 Cycles
- viii. Fatigue Damage at Passage Hole =Required Cycles / Actual Cycles

$$= (5000) / (3e10) \approx 0$$

Since Fatigue Damage < 1, Hence Design is safe.

ix. The Fatigue Damage effect is extremely weak and negligible on aircraft brake system for1e5 cycles.

Aircraft brake housing passage hole fillet region is having a corrected alternating stress of 67.9 MPa and it is less than the material endurance strength of 193 MPa and there by having an infinite design life of more than 1e6cycles.



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Fig. 7 (a) SN Curve (b) Infinite Design Life Curve

V. CONCLUSION

It is concluded that aircraft brake housing design provides the best solution with regards to acceptable maximum operating, proof and burst pressure design margins as per the TSO-C135 minimum performance standards. The following analysis for the aircraft brake housing proves the design substantiation as per the TSO-C135 guidelines. Results shows that aircraft brake housing and tie bolt are safe under all brake operating pressure conditions.

1) Structural analysis of the aircraft brake housing shows the maximum displacement is observed at lug top edge region and the maximum von-Mises stress is observed in passage hole region. All observed stress values are within the safe limits for the aluminum 2014 - T651 material.

2) Aircraft brake housing is having infinite fatigue life of more than 1e6 cycles. It satisfies the design requirements of 1e5 cycles for design landing pressure and 5000 cycles for maximum operating pressure conditions.

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