Structural Analysis of Rear Pressure Bulkhead of Typical Transport Aircraft

Ashish Rawat, Suraj Sharma, Amir Shaikh, Nithin Kumar K. C., Shwetank Avikal

Abstract: In this study, many researchers studied flat bulkhead, but Dome-shaped bulkhead is more preferable as it withstands pressure loads. We modeled a rear pressure bulkhead of a typical transport aircraft using CATIA V5 modeling software. Finite element analyses were carried out by the rear pressure bulkhead subjected to the boundary conditions (Fuselage is fixed and attached to the aircraft honeycomb structure and 0.1Mpa pressure is applied to the bulkhead). From the FEA of the rear pressure bulkhead, we obtained Von-Misses stresses and the deformations were obtained. The maximum displacement of 5.46mm was observed on the dome. The maximum normal stress at the circumferential direction was about 306Mpa.

Keywords: Transport Aircraft, Pressure Bulkhead, Stress analysis, Fuselage, composites

I. INTRODUCTION

Aircraft are mostly used for transportation of goods and public. An aircraft structure is made up of four basic sections namely fuselage, wings, horizontal stabilizers and empennage and structural materials, and frame design [1]. A fuselage is the long tubular structure which is the main part of the aircraft where all the passengers are kept and the luggage compartment is accommodated. The fuselage is the single unit but divided into different segments as the cockpit, luggage room, and passenger area [2].

A fuselage is the main body section, tubular in design which holds crew, passengers, and cargo and holds all the pieces of an aircraft together as a frame. A fuselage can be of different types according to the requirement or purpose. The fuselage structure is the assembly of the main body and front and rear bulkhead [4].

A bulkhead is a part of the fuselage structure riveted at the front end and rear end. The rear end bulkhead is a thin sheet dome or hemispherical shaped component structured and supported with stiffeners for better sustainability against the perpendicular pressure load. As the thin dome shape only cannot withstand high pressures, stiffeners are welded across the sheet to give it the rigidity against the perpendicular pressure load [5].

The atmospheric pressure of 760 mm Hg is human comfort pressure.

On increasing the altitude, the atmospheric pressure decreases. So constant pressure is maintained inside the fuselage for human comfort. For this, the fuselage must be airtight [6]. Also at high altitude, the pressure difference in the fuselage and the surrounding is so high that the aircraft structure should be strong enough to withstand this. But considering the aviation and the fuel economy, the aircraft should be light. So an optimized structure is made which is lighter and strong enough to bear the high pressure at that altitude [7]. The air inside the fuselage is circulated inside it only and not with the outside. Thus circulated air exerts the pressure on the rear bulkhead the most [8-9]. In this study, we are analyzing the pressure bulkhead to understand its behavior for the given boundary conditions.

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Ashish Rawat, Department of Mechanical Engineering, Graphic Era Deemed to be University, Dehradun, India.

Suraj Sharma, Department of Mechanical Engineering, Graphic Era Deemed to be University, Dehradun, India.

Amir Shaikh, Department of Mechanical Engineering, Graphic Era Deemed to be University, Dehradun, India.

Nithin Kumar K.C., Department of Mechanical Engineering, Graphic Era Deemed to be University, Dehradun, India. E-mail: kcnkumar@ymail.com

Shwetank Avikal, Department of Mechanical Engineering, Graphic Era Hill University, Dehradun, India.

II. MATERIALS AND METHOD

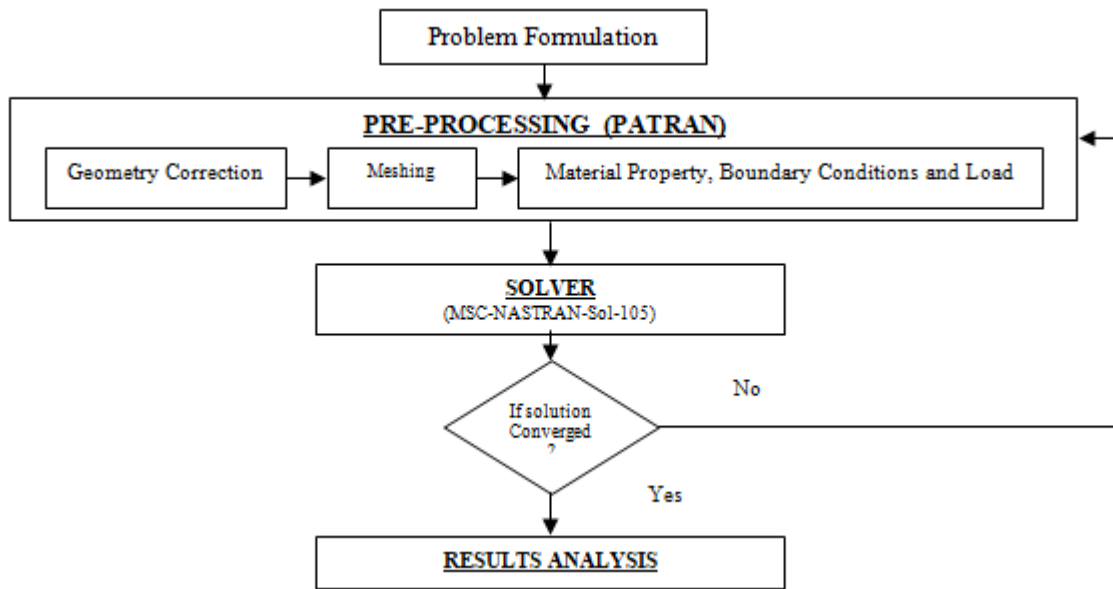The Fig.1. Shows the methodology followed in this study

Fig. 1 Methodology

1.1. Materials Properties

The UD carbon prepreg material was used in the fabrication of Pressure bulkhead. The basic material properties used in this analysis are shown in Table 1. The stacking sequence is [45/-45/0/90] $_s$ and Laminate thickness is 3mm [10].

Table 1: Material properties of UD Carbon Fiber Composite

E_{11} (GPa)	E_{22} (GPa)	G_{12} (GPa)	γ_{12}	ρ (g/cm3)
130	10	3	0.33	2.78

Aluminum alloys are widely used in aerospace, automobile industries because of their low weight and high strength. These alloys are correction resistance and easy to fabricate. The Al-2024-T3 alloys are widely used in aerospace. In this study, Al 2024-T3 is considered for Fuselage and stiffeners in the analysis and its material properties are young's modulus 72 GPa, Poisson's ratio is 0.33 and density is 2.78 g/cm^3 [11-12].

1.2. Boundary Conditions

The analysis is of the rear pressure bulkhead for multiple loads where the pressure is crucial for the bulkhead. Therefore the result discussed in this paper details the pressure cause on it. Here the analysis of pressure load on the bulkhead is by applying ultimate pressure of 0.1MPa (14 psi) normal to the inner surface of rear pressure bulkhead using PLOAD4 option of NASTRAN. All the linear DOF at nodes are constrained to forward end in the analysis of the fuselage skin [3].

1.3. Three-dimensional modeling and Meshing

The pre-processing and the post-processing of the finite element model were executed using MSC-Patran and solved in MSC/NASTRAN. The members like bulkhead contour and fuselage skin were modeled using the CATIA P3 V5-6R2016 (Fig.2) and the structural members like stringers were meshed using the CQUAD4 and CTRIA3 with PSHELL property in MSC-Nastran. Here all the composite parts were treated as 2D orthographic layered shell structural elements. These were modeled with the PCOMP property in MSC-Nastran [3]. The meshed model of the rear bulkhead with fuselage skin is shown in Fig. 3.
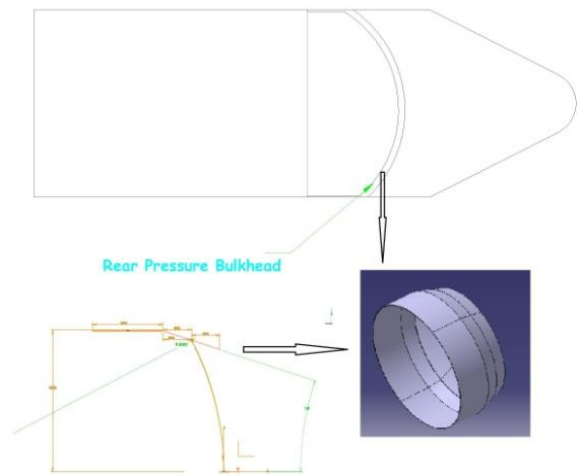

Fig.2 Cad Model

Fig.3 Meshed Model

III. RESULTS AND DISCUSSIONS

The rear pressure bulkhead is subjected to the boundary conditions (Fuselage is fixed and 0.1Mpa pressure is applied to the bulkhead). From the finite element analysis of the rear pressure bulkhead, the Von-Misses stresses and the deformations were obtained. The displacement contours are shown in Fig. 4 and 5. The maximum displacement was observed on the dome with 5.46mm. The maximum normal stress at the circumferential direction was nearly about -306Mpa.
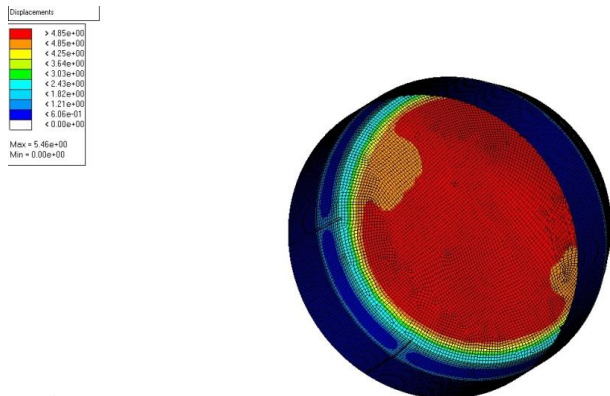

Fig. 4Displacement

The deformation is more in the center of the pressure bulkhead as compared to the circumferential direction. The Minimum 0.6mm and maximum of 5.46mm deformation are observed (Fig. 4).
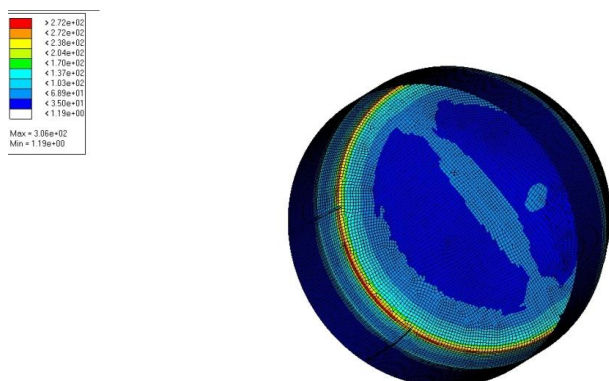

Fig. 5Maximum normal stresses

The stress distribution is more in the circumferential direction of the pressure bulkhead as compared to the center. The Minimum 1.19Mpa and maximum of 306Mpa stress are observed (Fig. 5).

IV. CONCLUSIONS AND FUTURE WORK

The static stress analysis of rear pressure bulkhead was carried out meeting all the boundary conditions. The following conclusions were made.

➢ The unstiffened pressure bulkhead will not withstand the given pressure load unless the bulkhead is stiffened.
➢ Many researchers studied flat bulkhead, but Dome-shaped bulkhead is more preferable as it withstands pressure loads.
➢ The maximum displacement of 5.46mmwas observed on the dome. The maximum normal stress at the circumferential direction was nearly about 306Mpa. This study gives the importance of usage of stiffeners because as the thickness increases the weight of the bulkhead increases.

The same work will be carried out by performing weight optimization using Yamada-Sun failure criteria for strength and buckling effect will be studied along with this.

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