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Design and modal analysis of bulkhead for a trainer aircraft

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Abstract-A new method of bulkhead model is done by CATIA V5. The method of creating a model helps to determine the internal forces, deflections, and stress distribution along the bulkhead using finite element software packages MSC NASTRAN, and the shear flow distribution in the adjacent skin. Several bulkheads next to each other can be analyzed simultaneously if the study of interaction becomes necessary. The results of this method compare favorably with the results of a three-dimensional finite element stress analysis and test measurements. The method can be used with any existing two-dimensional finite element computer program containing just a beam element, and it does not require large computer storage.

Defective bulkhead of a jet trainer aircraft was selected and is modified in such a manner that the defect can be minimized. For this purpose the defective bulkhead was imported to CATIA, and then is redesigned to meet the requirement.

After redesigned the model, it has been imported to MSC PATRAN in order to perform preprocessing and post processing. The Problem is solved using MSC NASTRAN and the criteria for static strength requirements and frequency of free vibration due to its self excitations are satisfied.

I. INTRODUCTION

A. Structural Stress

The primary factors to consider in aircraft structures are strength, weight, and reliability. These factors determine the requirements to be met by any material used to construct or repair the aircraft.

Airframes must be strong and light in weight. An aircraft built so heavy that it couldn't support more than a few hundred pounds of additional weight would be useless. All materials used to construct an aircraft must be reliable. Reliability minimizes the possibility of dangerous and unexpected failures .Many forces and structural stresses act on an aircraft when it is flying and when it is static. When it is static, the force of gravity produces weight, which is supported by the landing gear. The landing gear absorbs the forces imposed on the aircraft fuselage during takeoffs and landings .During flight, any maneuver that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage.

Stresses on the wings, fuselage, and landing gear of aircraft are tension, compression, shear, bending, and torsion. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage (tail section) absorbs the same stresses and transmits them to the fuselage. These stresses are known as loads, and the study of loads is called a stress analysis.

B. Types of Structural Stress

The five basic structural stresses to which aircraft are subject are:

1) *Tension*
2) *Compression*
3) *Torsion*
4) *Shear*
5) *Bending*

While there are many other ways to describe the actual stresses which an aircraft undergoes in normal (or abnormal) operation, they are special arrangements of these basic ones.

II. BULKHEAD

Basically, the purpose of aircraft structure is to transmit and resists all loads applied to it. The fuselage structures of general aviation aircraft today can usually be divided into the truss, monocoque, or the semi-monocoque types. Truss or framework types of construction have wood, steel tube, aluminum tube, or other cross sectional shapes which may be bolted, welded, bonded, pinned, or riveted into a rigid assembly.

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The use of new materials in the construction of civil aircraft is now becoming common place. To continue these trend composite materials will be used for wing skins, control surfaces, bulkheads and access panels. Advanced metallic materials will be used in high load areas (landing gear, flap mechanisms, engine and wing attachment structures)[2]. As proposed in the VT study, micro-perforated titanium, wing-leading-edge skins will be used for the boundary layer suction structure[1]. A conventional, aluminium alloy, fuselage pressure shell will be proposed as this is well proven and adds confidence to the aircraft structural framework. Filament wound composite structures may offer mass reductions for the pressure cabin but this technology is still unproven in airliner manufacture, so it will not be used on our aircraft.

Both the monocoque and semi-monocoque fuselage structures use their covering or skin as an integral structural or load carrying member. Monocoque (single shell) structure is a thin walled tube or shell which may have rings, bulkheads or formers installed within. It can carry loads effectively, particularly when the tubes are of small diameter[3]. The stresses in the monocoque fuselage are transmitted primarily by the strength of the skin. As its diameter increases to form the internal cavity necessary for a fuselage, the weight-to-strength ratio becomes more efficient, and longitudinal stiffeners or stringers are added to it.

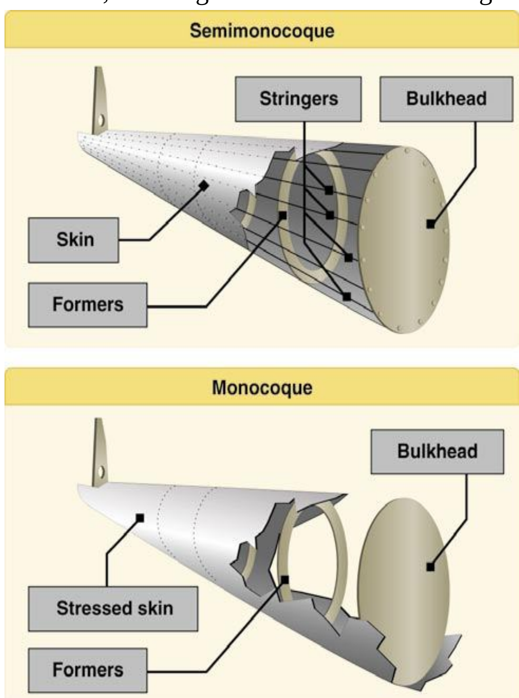

Fig 1: Types of fuselage structures

III. CONSTRUCTION MATERIALS

Fuselages must be constructed of materials that are both light and strong. Early aircraft were made of wood. Lightweight metal alloys with strength greater than wood were developed and used on later aircraft .Materials currently used in fuselage construction are metallic materials.

A. *Metallic Materials*

The most common metals used in aircraft fuselage construction are aluminum, steel and their alloys[5].

1) *Alloys:* An alloy is composed of two or more metals. The metal present in the alloy in the largest amount is called the base metal. All other metals added to the base metal are called alloying elements. Adding the alloying elements may result in a change in the properties of the base metal. For example, pure aluminum is relatively soft and weak. However, adding small amounts of copper, manganese, and magnesium will increase aluminum's strength many times. Heat treatment can increase or decrease an alloy's strength and hardness. Alloys are important to the aircraft industry.
2) *Aluminum:* Aluminum alloys are widely used in aircraft fuselage construction. Aluminum alloys are valuable because they have a high strength-to-weight ratio. Aluminum alloys are corrosion resistant and comparatively easy to fabricate. The outstanding

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characteristic of aluminum is its lightweight. Aluminium alloys are mainly used for bulkhead constructions.

3) *Steel Alloys:* Alloy steels used in fuselage construction have greater strength, more so than other fields of engineering would require. These materials must withstand the forces that occur on today's modern aircraft. These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum. High tensile steels withstand stress of 50 to 150 tons per square inch without failing. Such steels are made into tubes, rods, and wires, commonly these are made to use in longerons[4]. Another type of steel used extensively is stainless steel. Stainless steel resists corrosion and is particularly valuable for use in or near water.

B. *Nonmetallic Materials*

In addition to metals, various types of plastic materials are found in aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and carbon-fiber materials.

1) *Transparent Plastic:* Transparent plastic is used in canopies, windshields, and other transparent enclosures. You need to handle transparent plastic surfaces carefully because they are relatively soft and scratch easily. At approximately 225°F, transparent plastic becomes soft and pliable[2].
2) *Reinforced Plastic:* Reinforced plastic is used in the construction of radomes, wingtips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mildew and rot[6]. Because it is easy to fabricate, it is equally suitable for other parts of the aircraft. Reinforced plastic is a sandwich-type material (fig.4-4). It is made up of two outer facings and a center layer.

IV. BULKHEAD MODELLING

A. *Two Dimensional Structure Of Bulkhead*

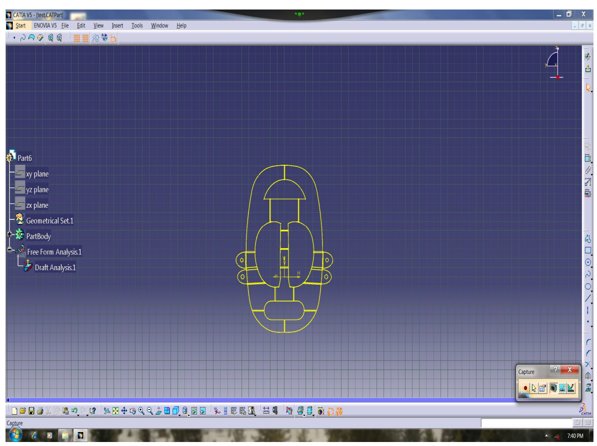

Fig 2: Two dimensional structure of bulkhead

B. *Three Dimensional Structure Of Bulkhead*

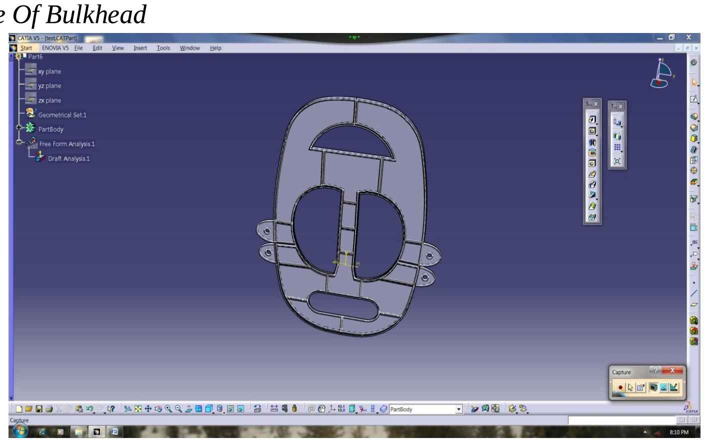

Fig 3: Three dimensional structure of bulkhead

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Total thickness of the bulkhead is 40mm. Pocketing is done on both the sides of the bulkhead with 14mm. After pocketing the bulkhead will be having a thickness of 12mm. Specified passages were made as per to meet requirement. There three passages are air duct, fuel tank, hydraulic and pneumatic systems .The lug thickness is 30mm. 15 stringers of variable thickness [12, 10, 20] are provided for structural support. The holes lugs are 5mm diameter.

V. ANALYSIS OF BULK HEAD

A. Modal Analysis

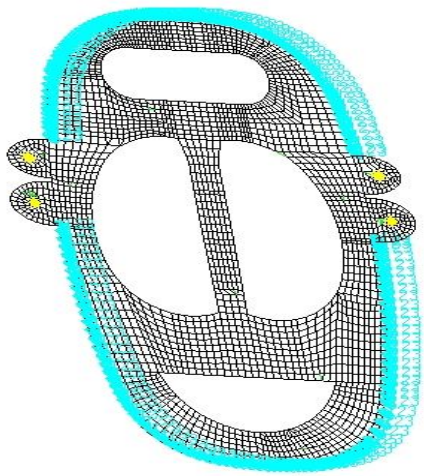
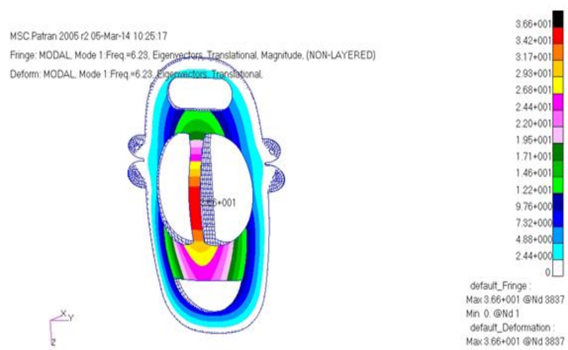
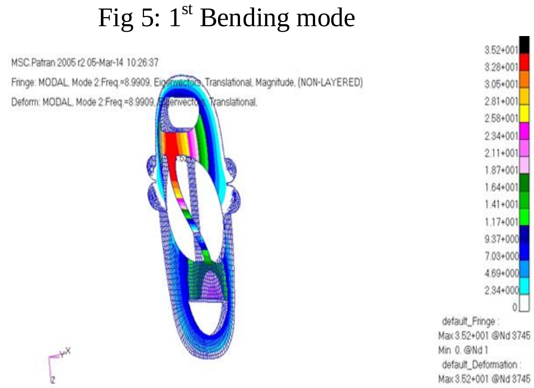


Fig 4: Bulkhead with 2mm thickness



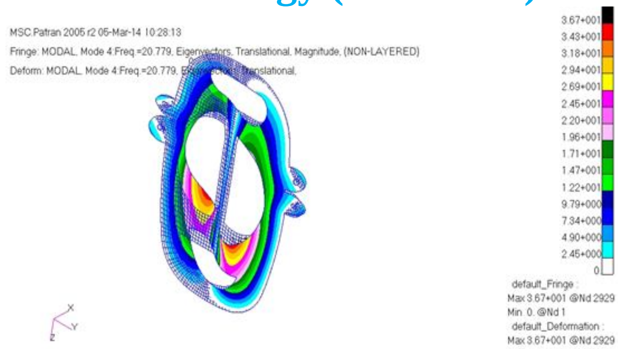
Frequency = 6.23 Hz

Fig 5: 1st Bending mode



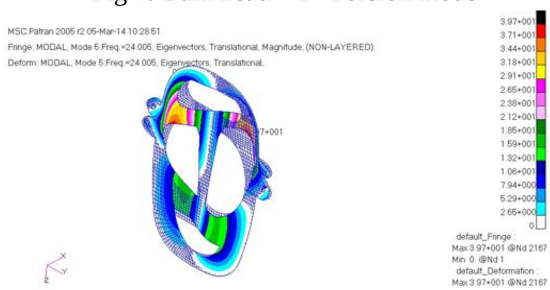
Frequency = 8.99 Hz

Fig 6: 2nd Bending mode



Frequency = 20.779 Hz

Fig 7: Bulk head – 1st Torsion mode



Frequency = 24.006 Hz

Fig 8: Bulk head – 2nd Torsion mode

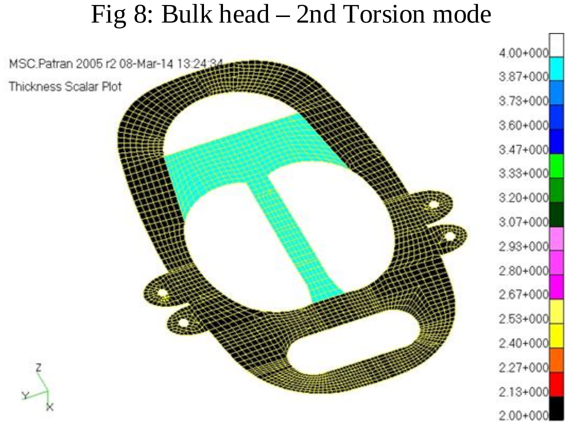
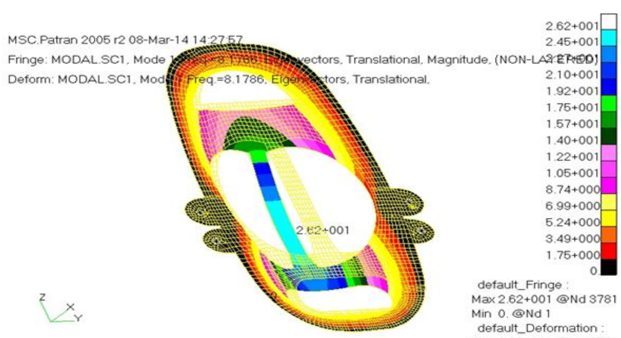


Fig 9: Bulkhead with 4mm thickness



Frequency = 8.1786 Hz

Fig 10: 1st mode bendin

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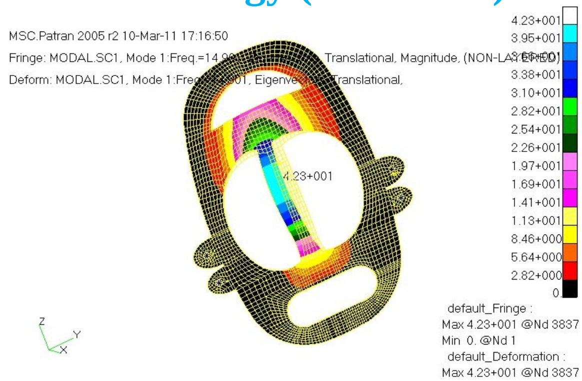


Frequency = 14.901 Hz

Fig11: 1st mode bending (6mm and 2mm thickness)

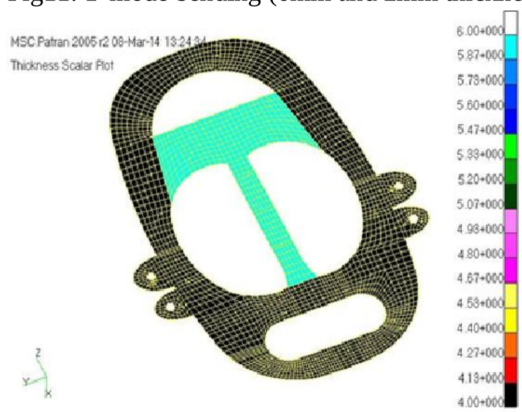
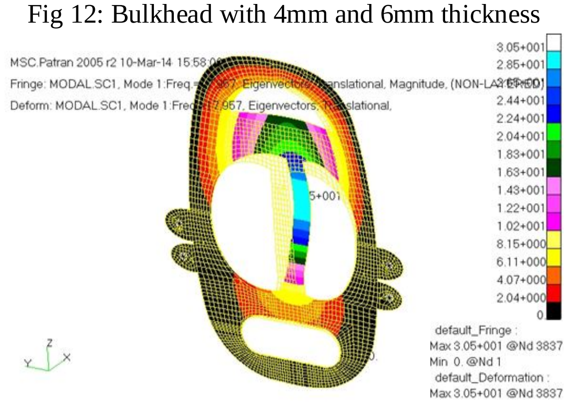


Fig 12: Bulkhead with 4mm and 6mm thickness



Frequency = 17.067 Hz

Fig: 1st Bending Mode

VI. CONCLUSION

For a jet trainer aircraft the Natural frequency value is 15 Hz. The result in modal analysis shows that the required frequency of 15 Hz [7] and above is achieved for the bulkhead with the combination of 6mm and 4mm thickness of bulkhead.

The combination of 6mm and 2mm thickness bulkhead with added stiffeners also give good result but with less mass difference the case4 gives the best value to be achieved.

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