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Design of Small Passenger Aircraft Front Spar Using Strengths of Material and FEM Approach

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Abstract:- **Structural safety with the minimum weight is the requirement in the aircraft design and development process. A small size passenger aircraft wing front spar design is considered in the current study. Spars are the principal structural members of wing, they correspond to the longerons of fuselage, they run parallel to the lateral axis of the aircraft from the fuselage toward the tip of the wing. The research work includes a parametric study of the wing front spar by varying the sections and material used for the front spar. This current project outlines the wing front spar considered as a beam with several stations, and the design is carried out for the external Bending Moment at each station. A finite element approach is used to verify the calculated stresses developed at each station for a given bending moment Linear static analysis is used for the stress analysis.**

***Keywords*- Spar, Stress analysis, Wing, structural integrity Aircraft, FEA.**

INTRODUCTION

An aircraft is a complex structure,but a very efficient man-made flying machine. Aircrafts are generally built-up from the basic components of wings, fuselage, tail units and control surfaces. Each component has one Or more specific functions and must be designed to Ensure that it can carry out these functionssafel .Any small failure of any of these components may lead to a catastrophic disaster causing huge destruction of lives and property. When designing an aircraft,it's all aboutfinding the optimal proportion of the weight of the vehicle and payload. It needs to be strong and stiff enough to withstand the exceptional circumstances in which it has to operate. Durability is an important factor. Also, if a part fails, it doesn't necessarily result in failure of the whole aircraft. It is still possible for the aircraft to glide over to a safe landing place only0if the aerodynamic shape is retained-structural integrity is achieved.

The basic functions of an aircraft's structure are to transmit and resist the applied loads; to provide an aerodynamic shape and to protect passengers, payload systems, etc., from the environmental conditions encountered in flight. These requirements, in most aircraft, result in thin shell structures where the outer surface or skin of the shell is usually supported by longitudinal stiffening members and transverse frames to enable it to resist bending, compressive and torsional loads Without buckling. Such structures are known as semi monocoque, while thin shells which rely entirely on their skins for their capacity to resist loads are referred to as monocoque.

Aircraft Component
Wings:

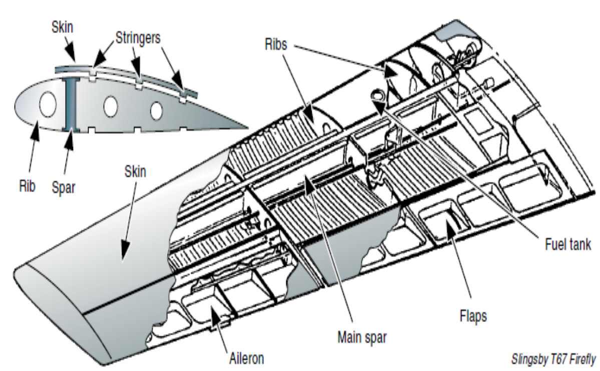

Figure 1: Wing

The wings are designed to cope with the flight loads of lift and drag. They also may support other external devices such as engines (on multi-engine airplanes) and flaps. Wings generally have one or more internal spars which are attached to the fuselage and extend to the wingtips. The spars carry the major loads,which are upward bending because of the lift, and downward bending because of wing-mounted engines and fuel. The wings in most airplanes also contain fuel tanks installed between the curved upper and lower surfaces. This is an efficient use of the space available,and the weight of the fuel in the tanks also provides A downward force on the wing structure that reduces. The upward bending effect of the lift forces.

2. LITERATURE SURVEY

Pascal Casari, Bernard Stervinou, Peter Davies, Dominique Choqueuse[1]. An aircraft wing spar made of carbon fiber and epoxy resin was made using different industrial techniques regarded as a reference, this process It is also the most expensive, and this justifies the development of alternative low-cost methods. RI: liquid injection resin, this is a promising technique because it requires little equipment to obtain an acceptable quality, two different pressures examined. RFI: Resin Film Infusion It aims to combine both the advantages of using the same resin as that used for prepreg and low cost production facilities. This study is an important database for the evaluation of the mechanical properties obtained from different industrial processes. A total tensile, bending, impact and damage test was conducted. Some peculiarities observed, as the result of waviness defect of one side of the laminate which affects the flexural strength, particularly for processes of dry fabrics. Impregnated a benchmark for all mechanical properties, but remains expensive this justifies the creation of alternative techniques that require lighter and facilities shorter lay-up durations as LRI process. For the RFI process, it appears that the conditions for good construction not optimized.

Polagangu James, D. Murali Krishna, Gaddikeri Kotreshand Byji Varughese[2] Inter side spar of the wing of atransport aircraft is subjected to various types of cargo. One of the loads posed stability problem in Inters par ribs of the wing is brazier load, which occurs due to bending of the wing. This paper describes the finite element analysis of spar between ribs of the wing at the local level against brazier load.

This study has taken place at the wing metal transformation in the composite wing. The objective of this study is to reduced weight penalty to the maximum extent possible by removing material where possible. This paper is limited to discuss the linear buckling analysis of the ribs during brazier load. The bending factor of the ribs under examination reported in terms of square root times the eigenvalue obtained from the finite element analysis, representing the non-linear effect of the bending moment loading brazier. This study has contributed to reconfigure / redesigning Interspar ribs of the wing. This has led to significant savings 285 Kg weight represents 15.77% of the total mass reductions spar between ribs.

3.AIRCRAFT SPECIFICATIONS:

The following are the specifications for the selected aircraft. i.e., BEECHCRAFT KING AIR B200GT

General characteristics:

Crew: 1–2
Capacity: 13 passengers
Length: 13340mm
Wingspan: 16610mm
Height: 4570mm
Wing area: 2.815 X 107mm2
Empty weight: 3,520 kg
Max. Take-off weight: 5,670 kg
Power plant: 2 × Pratt & Whitney Canada PT6A-42 turboprops, 635kW each

Performance:

Maximum speed: 545 km/h at 7,620m = 151.388 m/s
Cruise speed: 536 km/h at 7,620 m (max cruise)
Stall speed: 139 km/h
Range: 3,338 km with maximum fuel and 45 minutes' reserve
Service ceiling: 10,700 m
Rate of climb: 12.5 m/s
Wing loading: 0.0002016443kg/mm²
Power/mass: 220 W/kg

Table 1: Wing specifications

Wing span	16610	mm
Root chord (C_r)	2529.796	mm
Tip chord (C_t)	1026.43	mm
Aspect ratio (AR)	9.783	
Taper ratio (TR)	0.406	
full length of the wing (b)	8304.991	mm

Material Properties

The materials used for the analysis are Al7075 and Al2024-T351. Their material properties are as given below.

Aluminium alloy Al7075-T6

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Table.2: Mechanical properties of 7075-T6 Aluminium alloy

Young's modulus	71700 N/mm^2
Poisson's ratio	0.33
Density	2.81 X 10^{-6} kg/mm^3
Tensile yield strength	503 N/mm^2
Tensile ultimate strength	572 N/mm^2

Aluminium alloy Al2024-T351

Table 3: Material Properties in Al 2024-T351

Properties	Material
Young's modulus	73100 N/mm^2
Poisson's ratio	0.3
Density	2.78 X 10^{-6} kg/mm^3
Tensile yield strength	345 N/mm^2
Tensile ultimate strength	483 N/mm^2

4.RESULTS AND DISCUSSION

4.1 Stress plot for Al2024-T351

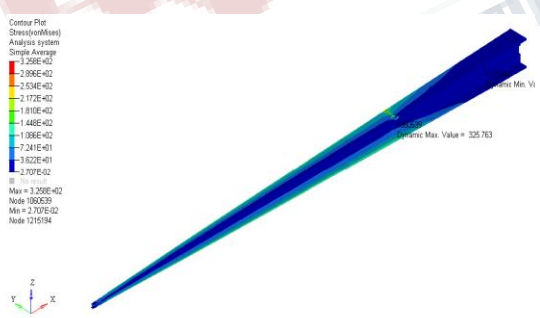

Figure 4.1: Stress Plot for I-Section for Al2024-T351

Figure 4.1 represents the stress plots for the front spar using I-Section and Al2024-T351 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

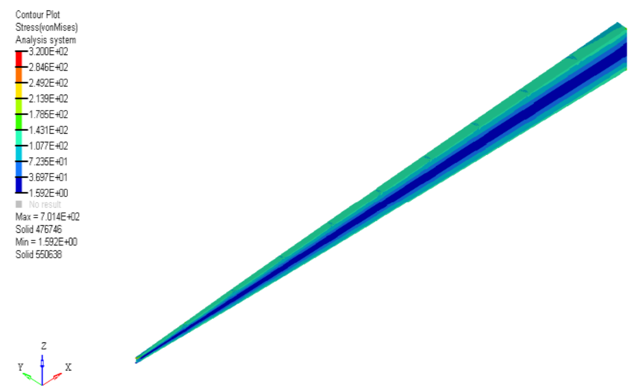

Figure 4.2: Stress Plot for C-Section for Al2024-T351

Figure 4.2 represents the stress plots for the front spar using C-Section and Al2024-T351 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

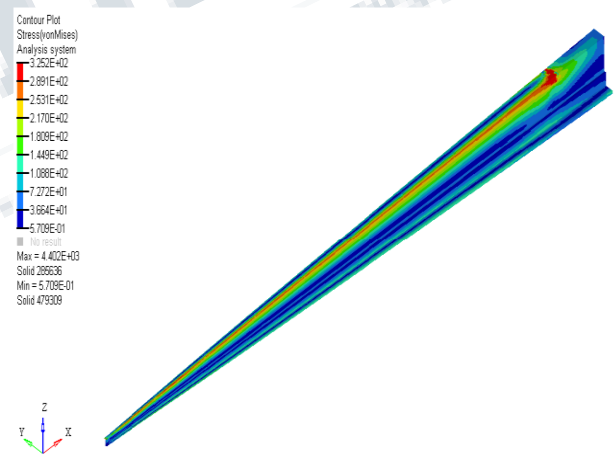

Figure 4.3: Stress Plot for Z-Section for Al2024-T351

Figure 4.3 represents the stress plots for the front spar using Z-Section and Al2024-T351 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

4.2 Stress plot for Al7075-T6

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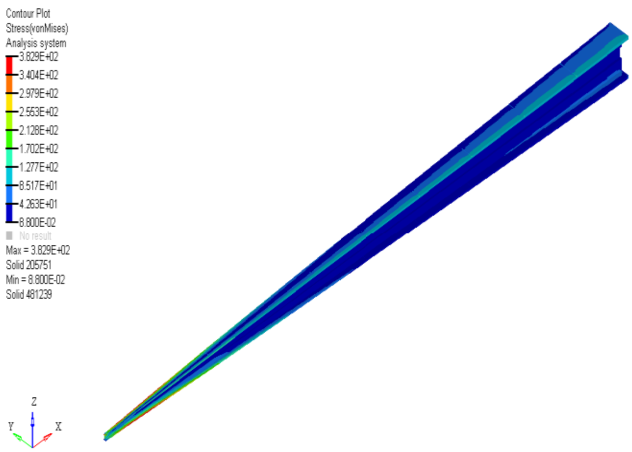

Figure 4.4: Stress Plot for I-Section for Al7075-T6

Figure 4.4 represents the stress plots for the front spar using I-Section and Al7075-T6 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

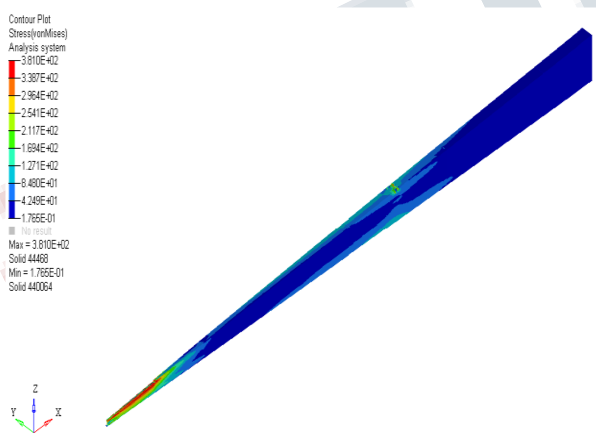

Figure 4.5: Stress Plot for C-Section for Al7075-T6

Figure 4.5 represents the stress plots for the front spar using C-Section and Al7075-T6 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

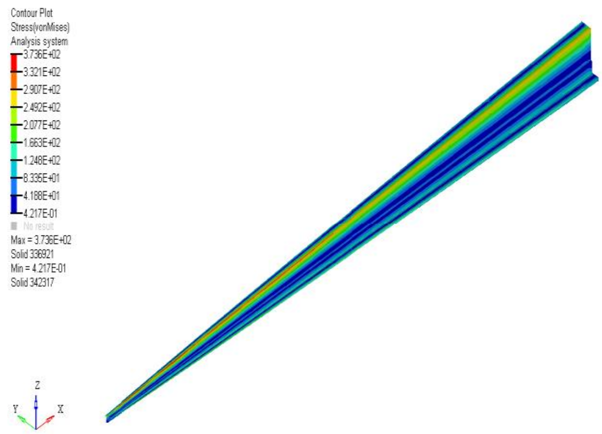

Figure 4.6: Stress Plot for Z-Section for Al7075-T6

Figure 4.6 represents the stress plots for the front spar using Z-Section and Al7075-T6 as material. Although the maximum stress value is seen to match the calculated stress value, the minimum stress value is seen on the web of the sections and the overall stress distribution is lower in value except for a few regions on the model.

CONCLUSION:

Based on the FEM results, the following conclusions can be drawn.

•The percentage of error in value between the SOM generated and FEM generated results are in close proximity to each other and can be used to validate the obtained FEM results.

•The results show that the load carrying capacity of all the three selected sections for each material is same for the given dimensions and loads.

•Although the load carrying capacity of the models are same, the load distribution is observed to be less severe in case of I-Sections for both the materials.

•The C-Sections and the Z-Sections follow a similar path with decreasing severity of load distribution in the given respective order.

Hence, it can be concluded that the I-Section is more suitable in load distribution as compared to the C-Section and Z-Section and the other two sections follow respectively.

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