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ESTIMATION OF AIRCRAFT WING RIB WEIGHT REDUCTION BY DIFFERENT CONFIGURATIONS

S. AMRUTHA, K. RANI, N. PRAVALIKA, G.K. HEMALATHA SK. SALMAN BEEBI & DR.J. KRISHNA
Department of Mechanical Engineering, RISE krishnasai prakasam group of institutions, Vallur, Ongole.
Assistant prof and Associate prof Department of Mechanical Engineering, RISE krishnasai prakasam group of institutions, Vallur, Ongole

ABSTRACT

Aircraft wing is that complicated structure found over the aircraft due to its complicated behavior towards the various loads and maneuvering. Stress concentration in an elastic body may be caused mainly by two mechanisms
i.e. concentrated loads or forces acting on a body and geometrical discontinuities of a body such as holes or abrupt change of its surface geometry. In this project wing rib without cutout and wing rib with different cutouts are taken into consideration. In this project equivalent stresses and deformation for various cutouts such as circular, elliptical, triangular, and rectangular and without cut section are estimated using CATIA as designing software and ANSYS for analysis. The materials used for the project are aluminum 7075 and carbon epoxy. Therefore, after the comparison of stress and deformation in various configurations, the best suitable configuration with the best material among above two mentioned.

1. INTRODUCTION

Wing rib:

They help distribute the aerodynamic forces (such as lift) acting on the wing during flight. This is crucial A wing rib is a structural component of an aircraft wing, typically made of lightweight materials such as aluminum, carbon fiber, or wood. Wing ribs provide shape and support to the wing, maintaining its aerodynamic profile and ensuring stable flight. Wing ribs support the wing's skin and help maintain the air foil shape by giving the wing its contour. They are strategically placed along the length of the wing, running from the root (near the fuselage) to the tipfor maintaining the structural integrity of the wing. The ribs help maintain the correct aerodynamic profile of the wing. Each rib corresponds to a specific section of the air foil, ensuring that the air foil's shape is maintained from root to tip. Since they are typically made from lightweight materials and often feature internal cutouts or spars, wing ribs help reduce the overall weight of the aircraft without sacrificing strength. performance and safety.

APPLICATIONS:

Commercial Aviation: Wing ribs are used in commercial aircraft, such as Boeing and Airbus planes.

General Aviation: Wing ribs are used in general aviation aircraft, such as Cessna and Piper planes.

Military Aviation: Wing ribs are used in military aircraft, such as fighter jets and transport planes.

2. LITERATURE REVIEW

Guguloth Kavya & B.C. Raghukumar Reddy: Demonstrated 3D modeling of an aircraft wing enhanced by adding ribs and spars. They performed static structural analysis using three materials—S Glass, Kevlar 49, and Boron Fiber. Among these, **S Glass showed superior structural performance**, indicating its suitability for wing applications.

N. Maheswaran:
Focused on optimizing wing spar beams for a six-seater aircraft. The study emphasized the **strength-to-weight ratio** in airframe structures and utilized **strength of materials** principles for achieving efficient design.

Rahul Sharma & Garima Garg: Analyzed stress and displacement on wing ribs with and without 1mm cutouts under 0.01 MPa air pressure using CATIA V5 and MSC NASTRAN-PATRAN. Their study revealed that cutouts reduce weight and cost, albeit possibly affecting structural strength.

Bindu H.C. & Muhammad Muhsin Ali H. Investigated **buckling strength** and weight reduction strategies for ribs. They used FEM tools to perform buckling and linear static analyses, highlighting **stress concentrations around cutouts** as critical design considerations.

S. Bairavi & Suresh Balaji: Concluded that cutouts in wing ribs lead to stress concentration, potentially reducing mechanical strength and increasing the risk of structural failure.

I.K. Gujral: Studied rib design to support bending and compressive loads and maintain wing shape. The study involved linear static and buckling analysis using FEM tools, with optimized design parameters implemented in CATIA.

Kannan T. & Mr. Veer Anjaneyulu
Conducted design and analysis of wing ribs using various composite materials. FEM was used to evaluate stress tensors and critical displacements under different loads and fiber orientations. Their classical approach emphasized selecting optimal design parameters and comparing performance for different fiber configurations.

J.A. Newlin & Geo. W. Trayer
Tested multiple wing rib designs, showing that well-balanced and carefully manufactured ribs, regardless of size, yield high strength-to-weight performance. Efficient designs significantly reduced weight with minimal strength compromise.

I.K. Gujral Punjab Rib Maintaining the shape of wing and also support the bending and compressive loads which act on the wing. the objective is to increase the critical buckling strength and reduce the weight of the ribs.

3. METHODOLOGY OF STUDY

DESIGN SPECIFICATIONS

Nose block	463mm
Tail block	107,85mm
circle	56mm
ellipse	47mm
rectangle	29mm

TYPE OF ANALYSIS AND FORMULAS

Bending Stressin Wing Rib
$\sigma = My/I$

Shear Stressin Wing Rib
$\tau = VQ/It$

Load Transfer from Skin to Rib
$q = V \cdot I/A$

Rib Weight Estimation
$W_{rib} = \rho \times A \times L$

AIRCRAFT SPECIFICATIONS	
All up weight of wings	= 2000 Kg
Load factor	= 3 g condition
Factor of safety	= 1.5
Design limit load	= 6000 Kg
Design ultimate load	= 9000 Kg
Lift load on wings	= 4800 Kg
Load on each wing	= 2400Kg
Load on spar	= 1800Kg General Performance characteristics:
Cruise speed:	905 Km/hr
Max speed:	950 km/hr
Range:	9070 km
Max wing loading:	7975.5 N/m2
Minimum thrust/weight	0.287

4.MATERIAL DATA OR TYPES OF MATERIALS

1. WING RIB WITH ELLIPSE HOLE

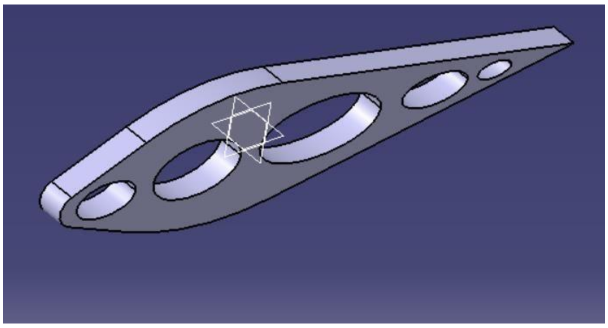

Fig. 4.1 Wing rib ellipse holes

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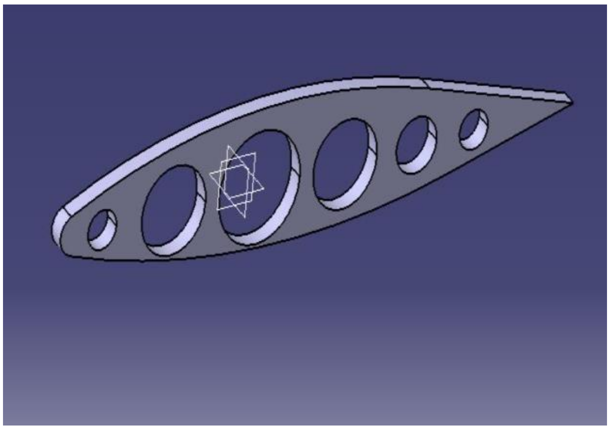
4.2. WING RIB WITH CIRCLE



4.3 WING RIB RECTANGLE HOLES

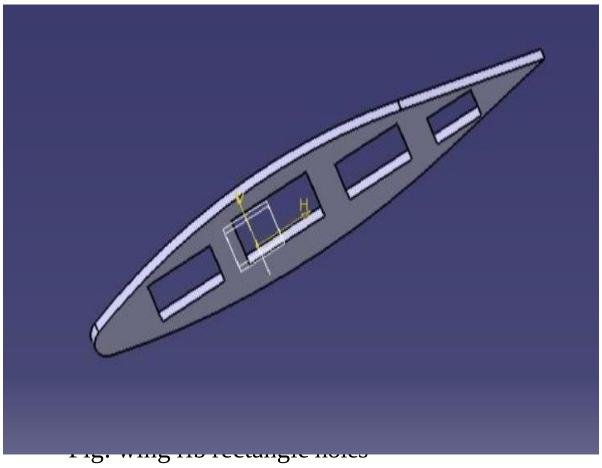


Fig: wing rib rectangle holes

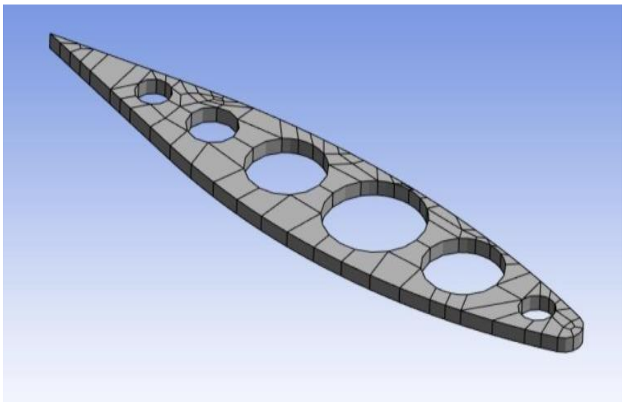


Fig: meshing component

Statistics	
Nodes	902
Elements	91
Mesh Metric	None

5. STATIC STRUCTURAL ALUMINUM 7075

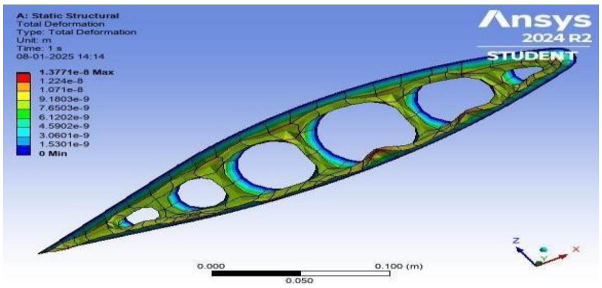


Fig: Total deformation of wing rib circle holes

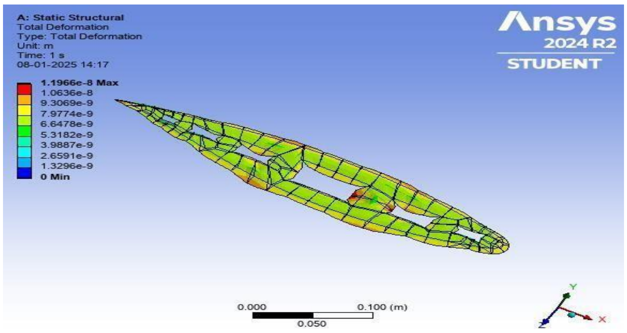


Fig: Total deformation of wing rib rectangle

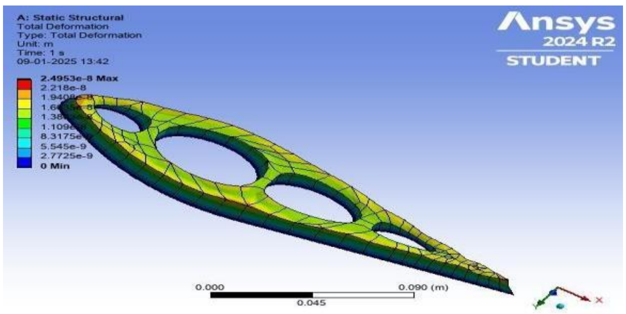


Fig: Total deformation of wing rib ellipse

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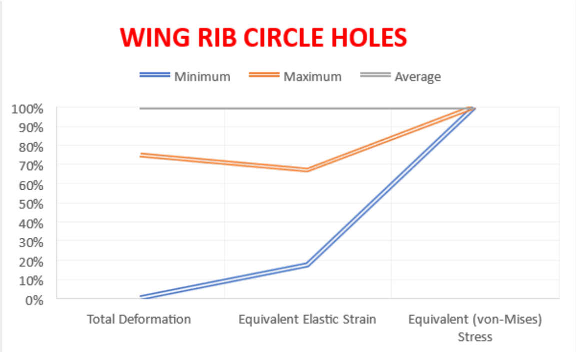
6. Results and Discussions

STATIC STRUCTURAL

ALUMINIUM 7075

WING RIB CIRCLE HOLES

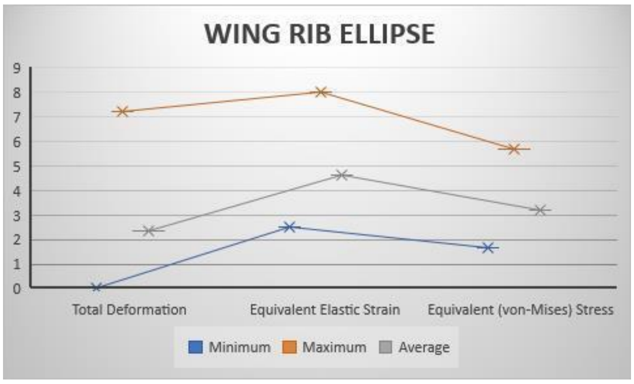
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	1.3401e-006 m/m	94739 Pa
Maximum	4.0045e-008 m	3.8407e-006 m/m	2.7216e+005 Pa
Average	1.3507e-008 m	2.5655e-006 m/m	1.7487e+005 Pa



WING RIB RECTANGLE

WING RIB ELLIPSE

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	2.5356e-006 m/m	1.6727e+005 Pa
Maximum	7.2471e-008 m	8.005e-006 m/m	5.6835e+005 Pa
Average	2.3507e-008 m	4.6339e-006 m/m	3.1941e+005 Pa



STEEL

WING RIB CIRCLE HOLES

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	5.257e-007 m/m	1.0482e+005 Pa
Maximum	1.3771e-008 m	1.3222e-006 m/m	2.6399e+005 Pa
Average	4.8417e-009 m	9.0536e-007 m/m	1.7525e+005 Pa

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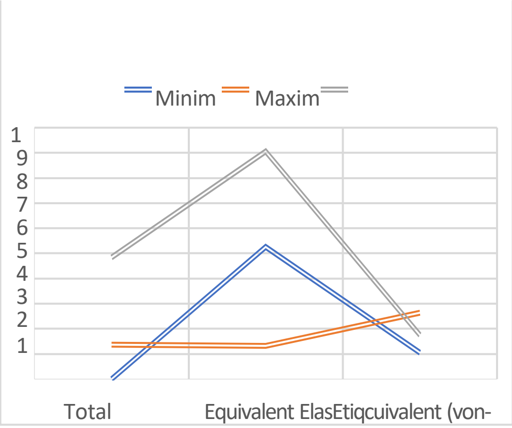
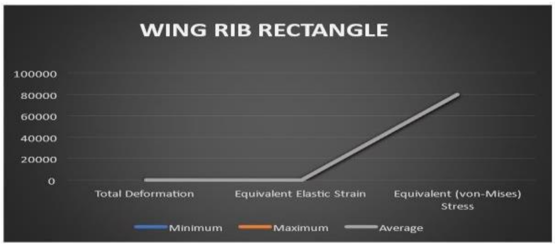
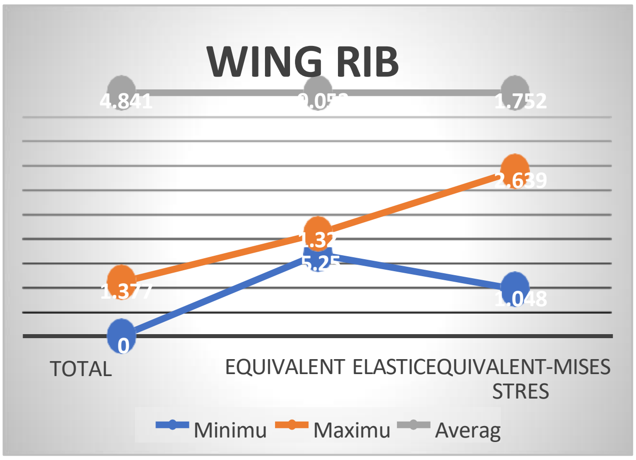


WING RIB RECTANGLE



Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	4.5263e-007 m/m	89475 Pa
Maximum	1.1966e-008 m	1.1053e-006 m/m	2.2097e+005 Pa
Average	4.0922e-009 m	7.58e-007 m/m	1.4566e+005 Pa

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	1.1382e-006 m/m	79799 Pa
Maximum	3.4662e-008 m	3.2136e-006 m/m	2.2805e+005 Pa
Average	1.1371e-008 m	2.1453e-006 m/m	1.4483e+005 Pa



WING RIB ELLIPSE

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	5.257e-007 m/m	1.0482e+005 Pa
Maximum	1.3771e-008 m	1.3222e-006 m/m	2.6399e+005 Pa
Average	4.8417e-009 m	9.0536e-007 m/m	1.7525e+005 Pa

CONCLUSIONS

From the above project it was found that inserting the circular hole in the plate enhance the strength of the wing rib. Inserting holes in the rib found out to be effective with weight reduction compared to the initial geometry and other configurations with cut sections. The maximum stress occurs around the holes and it is to be considered as the critical region in the later stages. And also, materials used for aircraft wings are mostly metallic alloys. In this project, the materials used are Al 7075 T6 and carbon epoxy. Strength/Weight Ratio = ultimate strength/Density Al 7075-T6: = (572*10^6 N/mm^2)
/ (2804) = 203994.289 N-m/kg Carbon Epoxy: = (597*10^6 N/mm^2) / (1600) = 373125.000 N-m/kg
from the above data it is concluded that carbon epoxy has more strength to weight ratio compared to that of Aluminium 7075-T6. So instead of metallic alloys like Al 7075-T6 we can also use carbon epoxy. 10.

FUTURE SCOPE

In the present thesis, the load considered for analysis is only air pressure. But more loads will be acted on spars like upward bending loads resulting from the wing lift force that supports the fuselage in flight, fuel carried in the wings, and wing-mounted engines if used,

drag loads dependent on airspeed and inertia, rolling inertia loads and Chord wise twisting loads due to aerodynamic effects at high air-speeds often associated with washout, and control reversal can be done using ailerons. The effect of these forces on the wing can substantially change the results, so the present work can be extended by applying the above forces also. Try using different materials which can reduce the weight. The number of cut sections, distance and other configurations can be modified. Meanwhile the von-Mises stress in the component keeps on increasing as the numbers of cutouts are increased.

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