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TOPOLOGY OPTIMIZATION OF WING RIBS IN CESSNA CITATION

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***Abstract*—Structural design optimization is currently a valid design methodology which is applied in advanced engineering. The main important parameter in aircraft design is to reduce the weight and thus by achieving better performance. In wing most of the weight is contributed by the ribs which gives the basic shape to the wing. In this paper the structural optimization of the rib is performed by Computer Aided Optimization. By this optimization the weight of the wing gets reduced even with the better performance.**

***Keywords*— Topology optimization, Finite element analysis, Stress estimation, Material reduction.**

1. INTRODUCTION

Optimization is a process of selecting or converging onto a final solution amongst a number of possible options, such that a certain requirement or a set of requirements is best satisfied i.e. you want a design in which some quantifiable property is minimized or maximized (e.g., strength, weight, strength-to-weight ratio).

The optimization technique involves number of design iteration, which can be minimized to get the best Results. when designing an aircraft it is necessary to find optimal proportion of the vehicle weight and payload. The main components of a business aircraft are Fuselage, Engines, Wings, Spoilers, and Control Surfaces such as Flaps and Slats, Elevators, Stabilators and Rudder. Design processes follows with ribs in the wing.

The application of optimization technology is becoming widespread throughout the aviation industry, exploiting the potential to design lighter aircraft. This paper deals with the Cessna citation , a business aircraft.

Normally there are three types of optimization:
1. Cross sectional optimization
2. Topology optimization
3. Geometric optimization
In our project we are going to do the optimization through Topology methodology

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1.1 TOPOLOGY OPTIMIZATION

The objective of topology optimization is to determine holes and connectivity's of the structure by adding and removing material in the extended domain which is a large fixed domain that must contain the whole structure to be determined. Thus, a material model must be defined to allow the material to assume intermediate property values by defining a function of a continuous parameter.

2. COMPONENTS FOR OPTIMIZE

2.1 RIBS

Ribs are often added to increase strength in many types of parts. The major advantage of ribs is that they can add strength without increasing the typical wall thickness. This practice results in a part design that is lighter and uses less valuable material, but has the strength required.

The ribs need to support the wing-panels, achieve the desired aerodynamic shape and keep it, provide points for conducting large forces, add strength, prevent buckling, and separate the individual fuel tanks within the wing.

2.2 SPARS

The spar is the main structural member of the wing. This spars carries flight loads and the weight of the wings while on the ground. Other structural and forming members such as ribs may be attached to the spar or spars, with stressed skin construction also sharing the loads where it is used. The wing ma have one spar or no spar at all.However, where a single spar carries the majority of the forces on it, it is known as the main spar.

2.3 SKIN

The skin of an aircraft is the outer surface which covers the wings and fuselage. Light aircraft have airframes primarily of all aluminium semi-monocoque construction, however, a some light planes have tubular truss load carrying construction with fabric or aluminium skin, or both. The skin needs moderately high yield strength and hardness to minimize ground damage Although design strength requirements are relatively low. The skin is the main part which increases the weight of the wing.

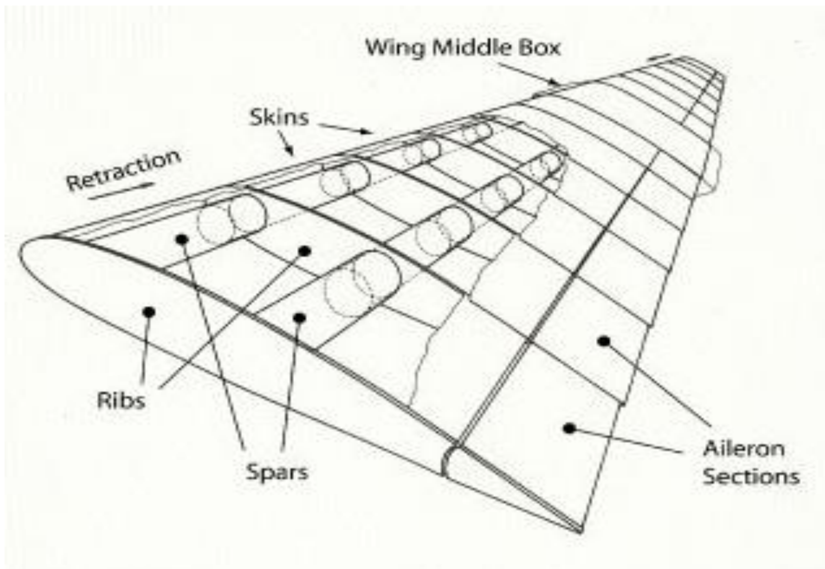

Fig.1 AIRCRAFT WING

3. DESIGN OF WING RIBS

Ribs give the shape to the wing section, support the skin (prevent buckling) and act to prevent the fuel surging around as the aircraft maneuvers.

They serve as attachment points for the control surfaces, flaps, under carriage and engines. They transmit the air load from the wing covering to the spars. The ribs orientation is based on providing maximum bending stiffness. Calculations of NACA 4-digit Series Airfoil for Point Creation in Table:

The NACA 4-digit series is defined by four digits, e.g. NACA 4412: m=4%, p=4/10, t=12%.

x	y	z
1	0.0013	0
0.95	0.0147	0

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0.9	0.0271	0
0.8	0.0489	0
0.7	0.0669	0
0.6	0.0814	0
0.5	0.0919	0
0.4	0.098	0
0.3	0.0976	0
0.25	0.0941	0
0.2	0.088	0
0.15	0.0789	0
0.1	0.0659	0
0.075	0.0576	0
0.05	0.0473	0
0.025	0.0339	0
0.0125	0.0244	0
0	0	0
0.0125	-0.014	0
0.025	-0.02	0
0.05	-0.025	0
0.075	-0.027	0

0.1	-0.029	0
0.15	-0.029	0
0.2	-0.027	0
0.25	-0.025	0
0.3	-0.023	0
0.4	-0.018	0
0.5	-0.014	0
0.6	-0.01	0
0.7	-0.007	0
0.8	-0.004	0
0.9	-0.002	0
0.95	-0.002	0
1	-0.001	0

Fig.2 NACA 4-digits series 4412 airfoil contour points

3.1 MODELLING OF WING RIB

The generic aircraft wing model is composed of both the surface and the solid model For wing panels, wing spars and wing ribs. Each Wing panel, wing spar and wing ribs also have Individual parameters that define the geometry and Shape of each element, furthermore there are also Global parameters which control the number of Wing panels, spars and ribs as well as the mesh Characteristics. Whenever, a new wing panel, a Wing spar or a wing rib is added into the model, a Join which already exists in the model is updated with the new geometry. These joins are connected To each individual surface mesh for wing panels, Wing spars and wing ribs.

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A. Modelling steps using solid works software

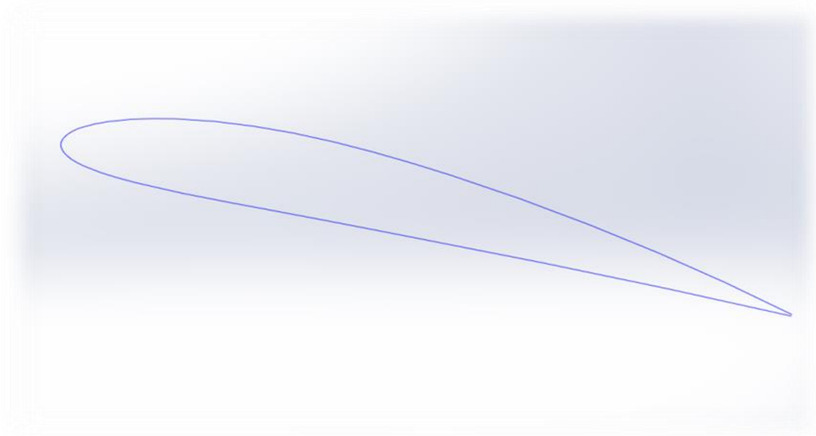

Fig.3 2D drawing using solidworks

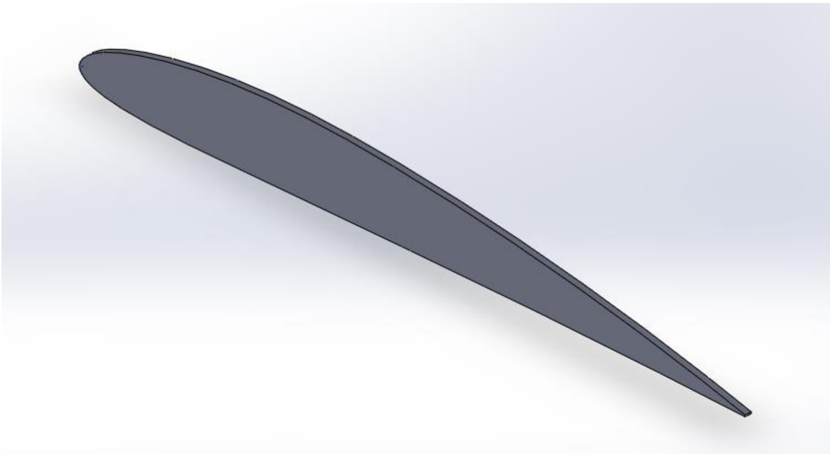

Fig.4 3D model developed in solidworks

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4. ANALYSIS

Aerodynamic pressure is applied on the wing profile and checking the displacement, stresses for the wing rib. After this aim and challenge is to reduce the weight of the component Altair Optistruct is used for topology optimization. Above procedure is shows complete steps to solve the aerodynamic analysis using Radioss software. After seeing base run analysis results, optistruct is used for seeing weight reduction model. Using analysis page constraints, forces and moments are applied to the component. For topology optimization we need to do organizing the elements like shown in above figure.

4.1 ASSUMPTIONS OF FEA

- Material properties were isotropic and homogeneous.
- Analysis of both wing ribs was linear static.
- Steady state analysis was carried out.
- Wing rib from both sides was fixed in this analysis.

The meshing is very important for the analysis of any structural object or body. Meshing is the process of discretization of a body into smaller pieces for accuracy of the results. The web or group of nodes and elements is known as mesh

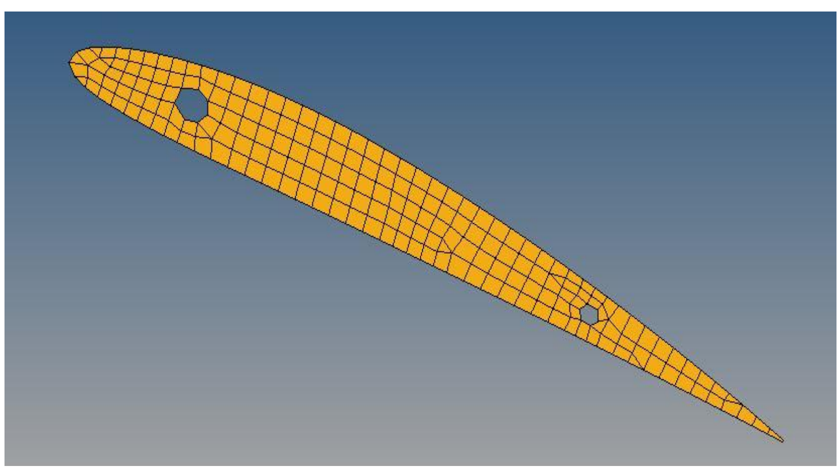

Fig. 5 meshing of wing rib

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Material properties

Al 7075 material is used for the both wing ribs which is very common for aircraft structural parts. In the following table.6 its mechanical and physical properties are shown:

s.no	Physical and mechanical properties	values
1	Young's modulus	71700 N/mm
2	Poisson ratio	0.33
3	Density	2.81 e-9 t/mm3

Boundary conditions

1. Aerodynamic load or pressure

2. Direction of applied pressure is downward y-axis on upper flange

3. All six degrees of freedom are constraint.

4.2 TOPOLOGY OPTIMISATION

We need to move the mesh to non design area for which model should not change at that location. For that purpose design and non design area is created and solved the Optistruct software. Tool page-Count-select FE entities- and click on displayed, It shows nodes and elements.

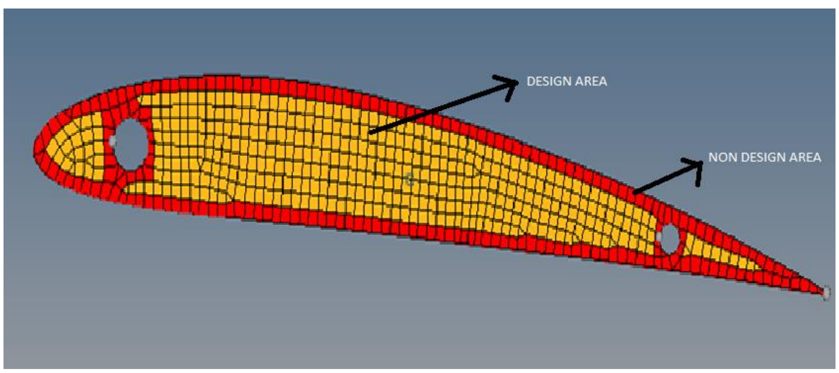

Fig .7 wing rib before topology optimisation

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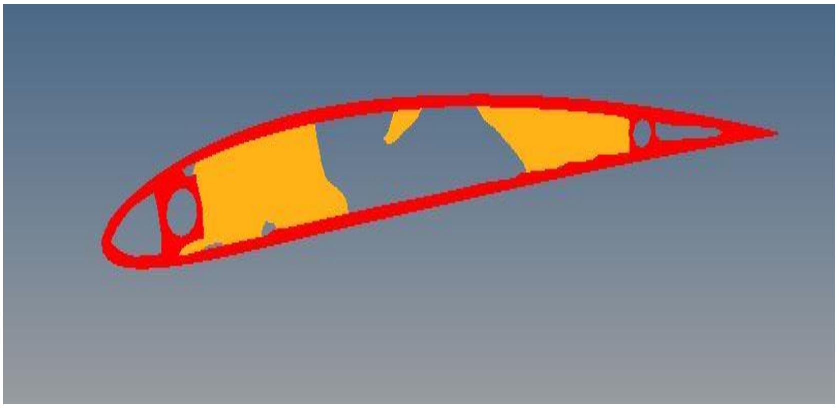

Fig.8 wing rib after topology optimisation

5. RESULT AND DISCUSSION

A. Displacement

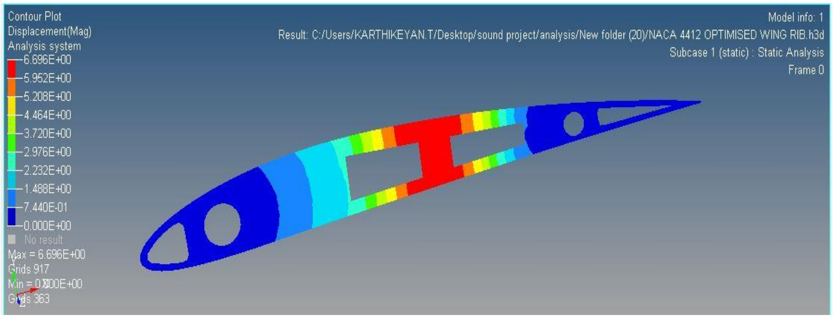

Fig.8 Displacement for optimized model is 6.06mm

B. Stress

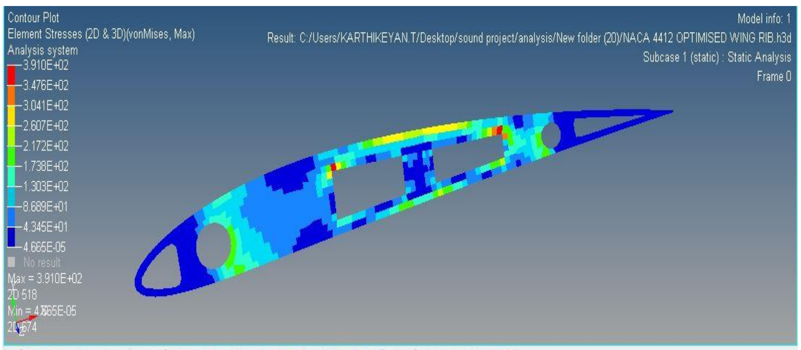

Fig.9 Stress for optimized model is 390 MPa

COMPARISON FOR TWO MODELS

Contents	Model	Optimized Model
Weight	21.8 kg	15 kg
Displacement	3.34 mm	6.0 mm
Stress	299 Mpa	390 Mpa

The above table shows the comparison of stress, displacements and mass of two models, which is below the yield point value of Aluminium 7075- material. The value of stress in optimized model is 390 Mpa

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