S J C INSTITUTE OF TECHNOLOGY

Department of Aeronautical Engineering

CERTIFICATE

This is to certify that the project work entitled **"ADAPTIVE MODELLING AND STRUCTURAL OPTIMIZATION OF WINGBOX"** carried out by **Mr. BASAVARAJU B N** [1SJ17AE010], **Mr. C H LOKESH** [1SJ17AE012], **Mr. JASON JEEVAN C J** [1SJ17AE017] and **Mr. NIKHIL M** [1SJ17AE030], are the bonafide students of S J C Institute of Technology, in partial fulfillment for the award of degree of **Bachelor of Engineering** in **Aeronautical Engineering** of the **Visvesvaraya Technological University, Belagavi** during the year **2020-2021**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated and deposited to departmental library. The project report has beenapproved as it satisfied academic requirements in respect of project work prescribed for the Bachelor of Engineering.

6/8/2021 (V Rajan) 6/8/21

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Structural and Optimizations have been gaining more attention in recent years for their contributions in the design enhancement, especially in the early stages of product development. Structural weight has always been important in the aircraft manufacturing industry. When a modern fully-loaded subsonic aircraft takes off, only 20% of its total weight is payload. Of the remaining 80%, roughly half is aircraft empty weight and the other half is fuel weight. Hence, any saving in structural weight can lead to a corresponding increase in payload. Ultimately, for a given payload, saving in aircraft weight means reduced fuel requirements. Therefore, it is not surprising that the aircraft manufacturers are prepared to invest heavily in weight reduction. Hence, the main aim of an aircraft design engineer is to design a stable wing structure in the most economical manner having adequate strength and stability.

A parametric wing box model is required, which is suitable for the global optimization of the internal wing structure. It is important that the model should be adaptive to an external aerodynamic wing shape (e.g. obtained from aerodynamic optimization). A wing structure consisting of spars, ribs, skins and stringers is optimized considering two design constraints: (i) maximum stress, and (ii) instability (panel or column buckling) while the objective function is the weight of the wing. The wing carries an elliptically distributed load along the span. Positions of ribs as well as dimensions and thickness properties of certain parts of the structure are the design variables. Results indicate that significant improvement in terms of objective function has been achieved through the optimization procedures.

Wing ribs are planar structures capable of carrying in-plane loads and are placed along the wing span. Besides serving as load redistributors, ribs also hold the skin-stringer to the desired contour shape. Ribs reduce the effective buckling length of the stringers (or the skin-stringer system) and that increases their compressive load capability. It is noted that the rib is supported by span wise spars. The cover skin of the wing together with the spar webs forms an efficient torsion member

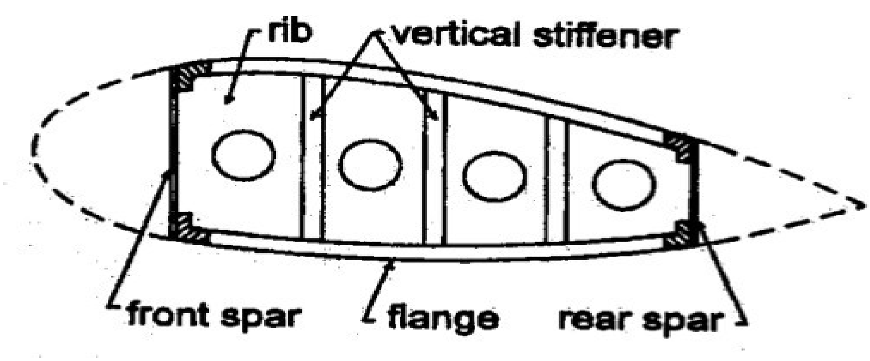


Fig 1.1. Ribs Structural Components.

2.0 STRUCTURAL COMPONENTS

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 spar 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 loadswhere it is used. The wing may 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, 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.

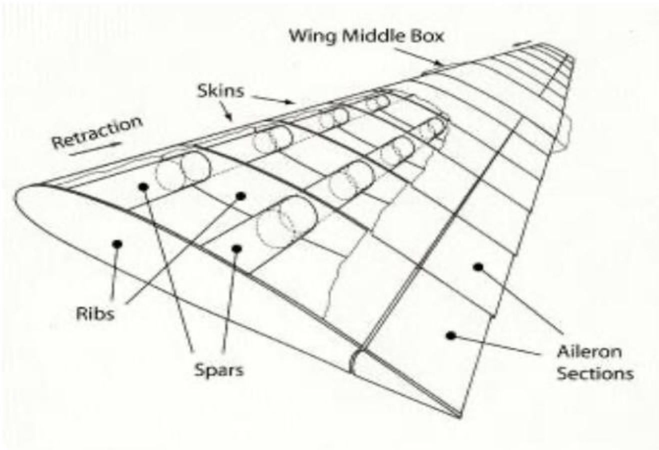


Fig1.2. Wing Structural components.

3.0 TOPOLOGY OPTIMIZATION.

The objective of topology optimization is to determine holes and connectivity 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.

In the least-weight and performance design of aircraft and aerospace structures, sizing and shape optimizations are two traditional techniques and have been widely employed. Topology optimization has been developed remarkably over the last several decades in both theoretical studies and practical applications. By redistributing the material layout and accordingly the load carrying paths, topology optimization has been recognized as one of the most promising techniques in the design of aircraft and aerospace structures. Meanwhile, plenty of technical difficulties highlighted in the rapid development of aeronautics and

aerospace structural engineering promote the progress of topology optimization theories in turn. Literature surveys have summarized recent advances and applications of topology optimization. These notable achievements continue to motivate further studies on the applications of topology optimization in designing complicated engineering structures. Generally speaking, topology optimization intends to find an optimal structural configuration within a given design domain for specified objectives, constraints, loads and boundary conditions. To achieve this, each component of an aircraft needs to be optimized, in particular with respect to weight. Different disciplines such as aerodynamics, structural analysis and dynamic analysis should be considered in order to find optimal designs. High computational costs lead to the need of computationally efficient simplified models, which can be used at the preliminary design stages for the global exploration of possible designs, while providing sufficient accuracy.

Fig 1.3. Leading edge topology Optimization Shape.

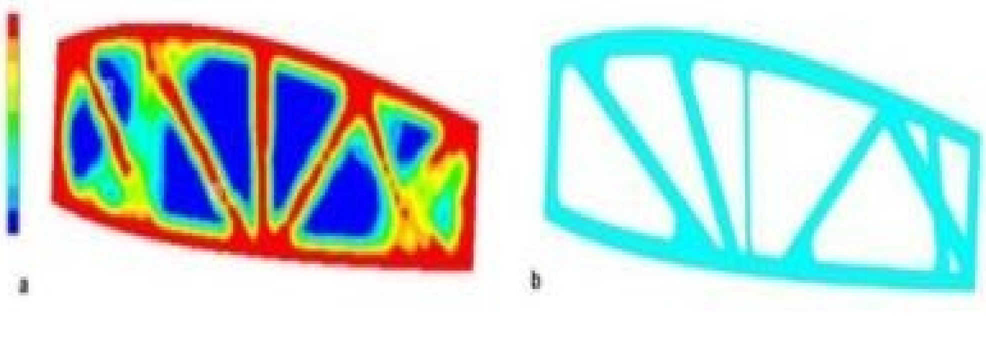
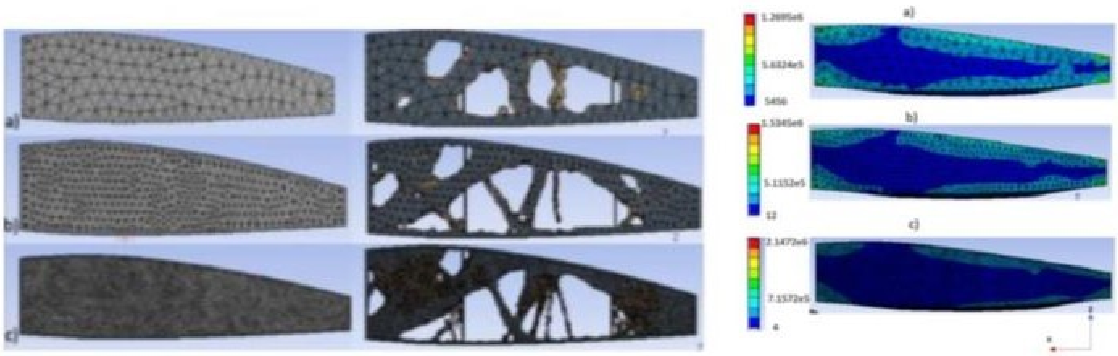


Fig 1.4. Rib Optimization.



- The redundant structural surfaces where the stress values were low or negligible, have been removed and only those regions where the structural load is concentrated.

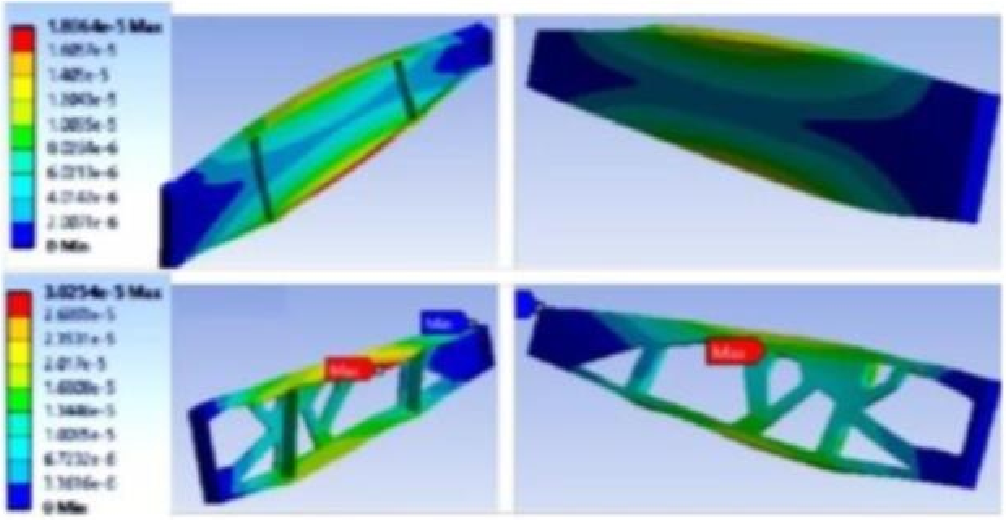


Fig 1.5. Structural optimization and load distribution.

4.0 OBJECTIVES.

The following are the main objectives of the present work.

- To design the wing box of Airbus A320-100 by using reference images and NACAcoordinates.
- CFD analysis of the Airbus A320-100 wing skin for obtaining aerodynamic load inANSYS Fluent.
- Structural optimization of the designed conventional wing box using Autodesk Fusion 360.
- Stress Analysis of the optimized wing box using Fusion 360.
- Comparison of the optimized wing box with the conventional wing box for weight reduction.

CHAPTER 2

LITERATURE REVIEW

In this section literature available on design and concept on aircraft wing box andits optimization has been reviewed. In order to achieve economic feasibility, fuel efficiency and cost reductions, careful optimization of each aircraft component is one of the main goals in the aerospace industry. Wing optimization has gained high attention in the recent engineering optimization literature. A large number of papers focus on the optimization of theexternal aerodynamic wing shape.

Wing box adaptive parametric modelling and its application to structural optimization has been analyzed. The external wing shape is defined here with a set of parameterized NACA airfoils although the wing box components can adapt to any closed wingskin surface. The implemented parametric model allows easy variation of different internal structural components of the wing box, e.g., number and location of ribs/spars/stringers, their shape, thicknesses etc. The flexibility of the model allows the use of numerical optimization for automatized design improvement, considering structural design goals. This paper presentsa flexible and fast parameterized wing box model to find the optimal design of internal components. Additionally, a two-level optimization approach is proposed, including global wing box layout optimization and sub-components shape optimization.

Shaik Shama Sultana, Y.N.V.Santosh Kumar and Shaik AzmatullahRahaman.

This paper investigated the light features of Tejas Aircraft. It includes design of supersonic delta wing with customized airfoil according to the aircraft performance requirements, and integrates technologies such as relaxed static stability, fly-by-wire flight control system, multi-mode radar, integrated digital avionics system, composite material structures, and a flat rated engine. The delta wing structure is designed using CATIA software, which includes payloads such as drop tanks and missiles. Meshing is done in hyper mesh and static analyses of the delta wing payloads by including weights in different cases are analyzed. The delta wing design according to the dimensions given is drafted in the software CATIAwhere the delta wing is sketched and made in 3D. The model is imported to Hypermesh for meshing and later saved to Ansys for analysis.

Saravanan. G, Arul Johnson. A and Pandiarajan. P.

This paper investigated the maximum stress concentrated part of the splice joint of an aircraft bottom wing skin due to tensile loading and its fatigue life estimation.Splicing is normally used to retain a clean aerodynamic surface of the outer skin for most of the aircraft structure. This research considered the aircraft wing box with a bottom skin splice joint for stress analysis. The wing box comprised two spar beams, three ribs, stiffeners covered with skin plate. The stress analysis of thejoint is carried out to compute the stresses at rivet holes due to By-pass load, bearing load and secondary bending. A finite element analysis is carried out to evaluate the stresses. Analyses were performed by MSC PATRAN and NASTRAN software. The analysis revealed that the rivet hole regions experience the maximum stress. The moststress concentrated part was identified by local analysis of the splice joint.

Mohamad Fotouhi, Amir-MusaAbazari, Abduraouf Mohmoud Ajaj, Roya Akrami, Sakineh Fotouhi, HafizTauqeer Ali.

This paper examined the current state of topology optimization technology and investigated how topology optimization can be utilized in the aerospace industry. The objective is to minimize the overall weight of an aircraft and increase fuelefficiency, thereby reducing the operating cost and greenhouse gas emissions. Simulation is performed using Ansys Workbench. The geometry was created in AnsysSpace Claim and the meshing and FEA analysis were performed within a static structural solver. A mesh sensitivity analysis was performed for three different mesh sizes namely, coarse, medium and fine, to demonstrate the effect of mesh resolution intopology optimization. The optimization was performed with an objective to minimize themass of the rib with a target of a maximum of 50% of its original mass. The optimization provided a weight reduction of approximately 39.5%. However, the geometry obtainedfrom this simulation was very complex and difficult to manufacture.

Inmodern aircrafts wing ribs are cut to provide space for fuel tanks and other equipment to pass through it. Hence it reduces the weight of the wing and also drag acting on the wing. In this project wing rib with different cut-outs and without cut- out are consideredfor static structural analysis for particular pressure force. The problem is to find whetherthe wing rib with cut section or without cut section provides more strength against the pressure force. The main objective of this work was considering the different criteria of wing rib in order to find out which criterion gives the most accurate strengthpredictions and to compare the same with different materials.

Optimized design and analysis for the development of aircraft droop noseribs. This paper presented the development of a parameterized automated generic model for the structural design of an aircraft wing. Furthermore, in order to perform finite element analysis on the aircraft wing geometry, the process of finite element mesh generation is automated. Work illustrated how topology, sizing and shape optimizationtools can be used in the design of aircraft components. The technology was successfully used in an industrial environment with short industrial time scales and hason a single application proved to be able to provide efficient stress and stability component designs. Initial studies have shown that care should be taken in the modelling of the load and boundary conditions of the components. For aircraft component design it is also important to be aware of the impact of changing loading situations. The truss type designs obtained using the topology optimization are highly specialized designs optimized for certain loading situations. Load definitions generally change as the design of an aircraft matures, and this could seriously affect the optimalityof the structure. It could therefore prove important to carefully select applications for topology optimization and only use the technology on structures with well-defined loading conditions.

Anna L. Arsenyeva and Fabian Duddeck.

The research presented in this paper is focused on the development of an adaptive geometric model for the wingbox for structural optimization. The external wing shape is defined here with a set of parameterized NACA airfoils although the wingbox components can adapt to any closed wing skin surface. This paper presented a flexible and fast parameterized wingbox model to find the optimal design of internal components. Additionally, a two-level optimization approach was proposed, including global wingbox layout optimization and sub-components shape optimization. Special stiffener-based parameterization for the ribs shape optimization, as well as an automatic sub-modeling and load extraction procedure for different wing box components, were implemented within this work. The implemented parametric model allowed easy variation of different internal structural components of the wingbox, e.g., number and location of ribs/spars/stringers, their shape, thicknesses etc. The flexibility of the model allows the use of numerical optimization for automatized design improvement, considering structural design goals. To illustrate the potential of the parametric modeling, an efficient two-level optimization process is proposed, aimed to find the optimal global layout of the wingbox at the first level and to refine subcomponents design (e.g. ribs) at the second level.

Lars Krog, Alastair Tucker & Gerrit Rollema.

The present paper considered the use of the compliance formulated topology optimization method and detailed sizing/shape optimization methods to the design of aircraft components but also discussed the difficulties in obtaining correct loading and boundary conditions for finite element-based analysis/optimization of components that are integral parts of a larger structure. This paper studied the use of Altair's finite element-based topology, sizing and shape optimization tools for design of aircraft components. Aircraft components are often stability designs and topology optimization methods still completely lack the ability to deal with buckling criteria. The present work therefore used the traditional compliance-based topology optimization method to suggest an optimal design configuration, which is engineered to provide the design with some stability. Finally, a detailed sizing/shape optimization was performed including both stability and stress constraints. How topology, sizing and shape optimization tools may be used in the design of aircraft components have also been illustrated in this paper.

CHAPTER 3

SOFTWARES USED

3.1 Autodesk Fusion360.

Fusion 360 is a cloud-based CAD/CAE/CAM tool for collaborative product development. Fusion 360 enables exploration and iteration on product ideas and collaboration within distributed product development team. Fusion 360 combines organic shapes modelling, mechanical design and manufacturing in one comprehensive package. Fusion 360 helps students and educators prepare for the future of design. It is a CAD, CAM and CAE tool of its kind, connecting your entire product development process into one cloud-based platform. The Autodesk Simulation family of products delivers a comprehensive set of finite element analysis and simulation software tools that are easy to integrate into each phase of the product development process. From mechanical stress, vibration and motion to computational fluid dynamics, plastic injection molding and Multiphysics, finite element analysis and simulation software from Autodesk provides a fast, accurate and innovative approach to solving your most challenging design problems

Fig 3.1. Fusion360

3.2 ANSYS Fluent.

Ansys FLUENT software contains the broad physical modelling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Special models that give the software the ability to model in-cylinder combustion, aeroacoustics, turbomachinery, and multiphase systems have served to broaden its reach.

Ansys FLUENT software as an integral part of their design and optimizationphases of product development. Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability. User-definedfunctions allow the implementation of new user models and the extensive customization of existing ones. Ansys FLUENT's interactive solver set-up, solution, and post-processing makeit easy to pause a calculation, examine results with integrated post-processing, change any setting, and then continue the calculation within a single application. Case and data files can also be read into Ansys CFD-Post for further analysis with advanced post-processing tools andto compare results from different cases side-by-side.

Fig 3.2. ANSYS Fluent

3.3 CATIA.

CATIA (computer-aided three-dimensional interactive application) is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), PLM and 3D, developed by the French company Dassault Systems. Since it supports multiple stages of product development from conceptualization, design and engineering to manufacturing, it is considered a CAx-software and is sometimes referred to as a 3D Product Lifecycle Management software suite.

Like mostof its competition it facilitates collaborative engineering through an integrated cloud service and have support to be used across disciplines including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

Fig 3.3. CATIA

CHAPTER 4

PROBLEM IDENTIFICATION AND METHODOLOGY

4.1 Problem Identification

Aggressive weight targets and shortened development time-scales in the civil aircraft industry naturally calls for an integration of advanced computer aided optimization methods into the overall component design process.

- Optimization of wing box ribs from conventional wing box to reduce weight.
- Studying the effects of loads acting on the wing box after Shape Optimization of ribs.
- Displacement field of wing box under its own weight.
- Stress distribution on the wing box under its own weight.
- Displacement field of the wing box under the loading due to level flight cruisecondition.
- Stress distribution of the wing box under the loading due to level flight cruise condition.

4.2 Methodology.

A wing of Airbus A320-100 aircraft wing which is having a wing span of 1665 cm from root to wing tip is considered for the design of the wingbox. The Airbus A320 family is low-wing cantilever monoplanes with a conventional empennage with a singlevertical stabilizer and rudder and wing has a sweep of 25 degrees.

The A320 wing is shorter and much lighter compared to the A321's, but the plan ofthe wing remains the same. A modified plan wing with double-slotted inner flap, a lengthened,and a much more substantial version of A320, the A321 is built to prevent a deterioration of high and low speed performance. Comparatively, a wing component will experience stress, bending, torsional, and deformation.

Hence, to study the three dimensional of the wing structures, this project establishesan extended wing box model. Additionally, the construction and configuration of the A320 wing box for these studies are about the same as the real one. This project is concerned with only the structural optimization of win box. Other chief constraints of the lifting surface are

In Airbus A320-100 NACA 23015 aerofoil is used which has a high lift characteristic in subsonic speed, and thus it is very suitable for the transport aircraft of A320-100.

- The first digit, when multiplied by 3/2, yields the design lift coefficient (Cl) in tenths.
- The next two digits, when divided by 2, give the position of the maximum camber (p)in tenths of chord.
- The final two digits again indicate the maximum thickness (t) in percentage of chord.

The Airbus A320-100 consists of 27 ribs from wing root to wing tip each rib is of 20 cm thickness. With root chord length of 7.05m and wing tip chord length of 1.05m.

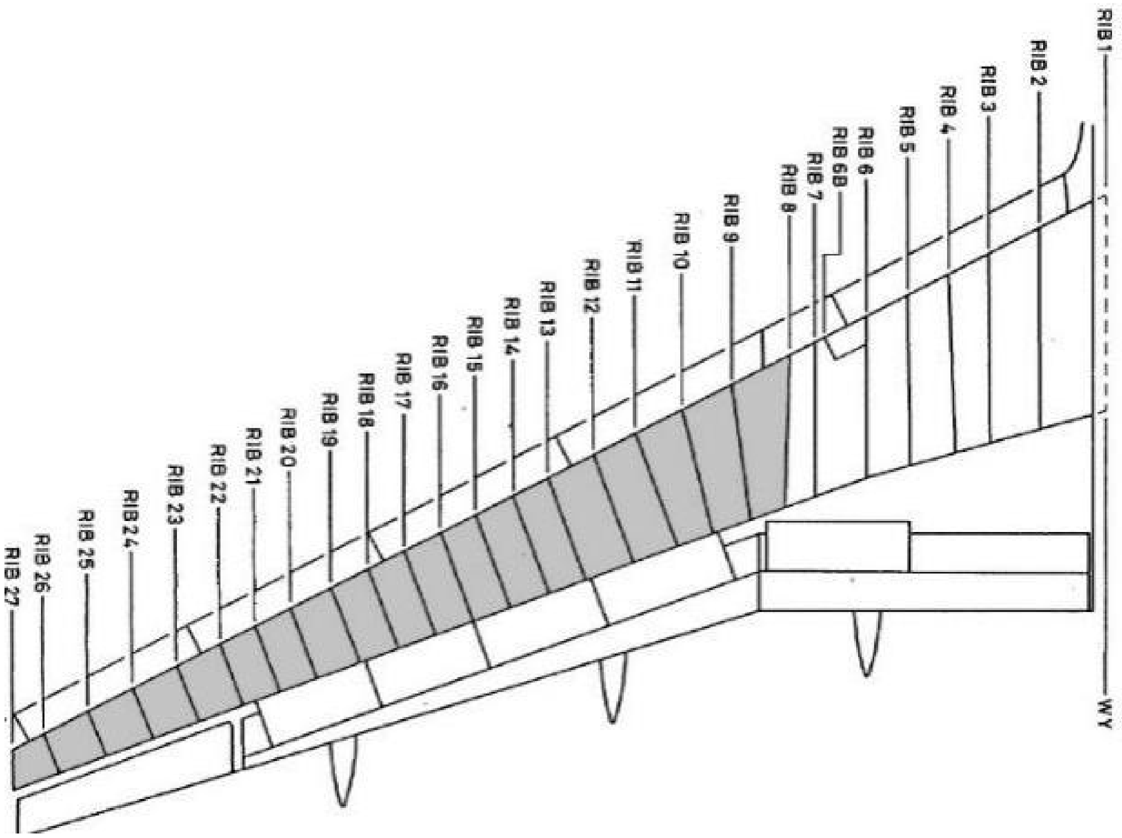


Fig 4.1. The Wing model of Airbus A320 consists of ribs and spars.

Material used is Aluminium 7075. The wing box is designed using CAD, CAEsoftware Autodesk Fusion 360. Aluminium 7075 properties

Table 4.1. Al 7075 Properties.

Density	2.81E-06 mm^3
Youngs' Modulus	71.7 GPa
Poisson's Ratio	0.33
Yield Strength	145 MPa
Ultimate Tensile Strength	276 MPa
Thermal Conductivity	0.173 W/mm (C)
Thermal Expansion Coefficient	2.34E-05/C
Specific Heat	960 J/Kg C

4.2.1 Design of Wing box.

The wing box of airbus A320 was designed using Autodesk Fusion 360, with the help of reference image of different views of A320. This reference images were then constrained to the actual dimensions of the Airbus A320. The length of the wing from the center of fuselage to wing tip is 1705cm and length of the aircraft is 3757cm from nose to tail of the aircraft. The height of the aircraft is 1176cm from the ground to the vertical tail tip.

Below images show the top view, front view and side view with constrains of A320.

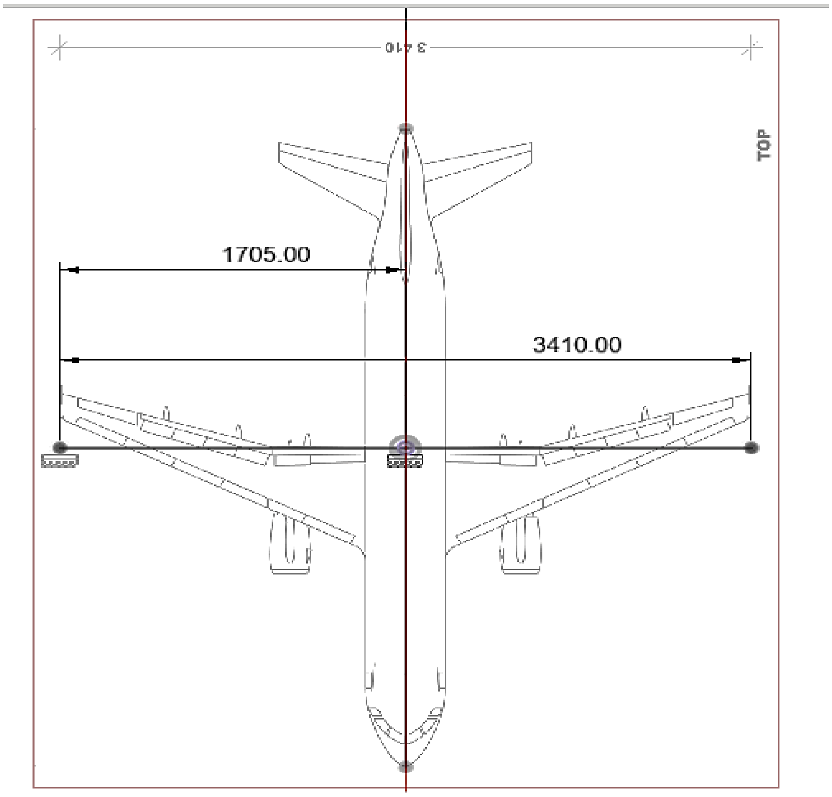


Fig 4.2. Top view of the aircraft.

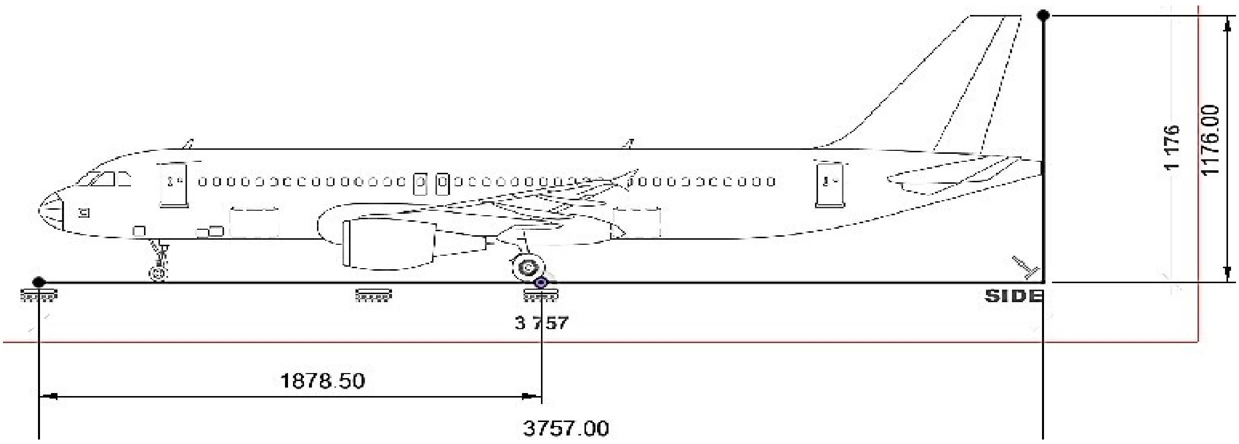


Fig 4.3. Side view of the aircraft.

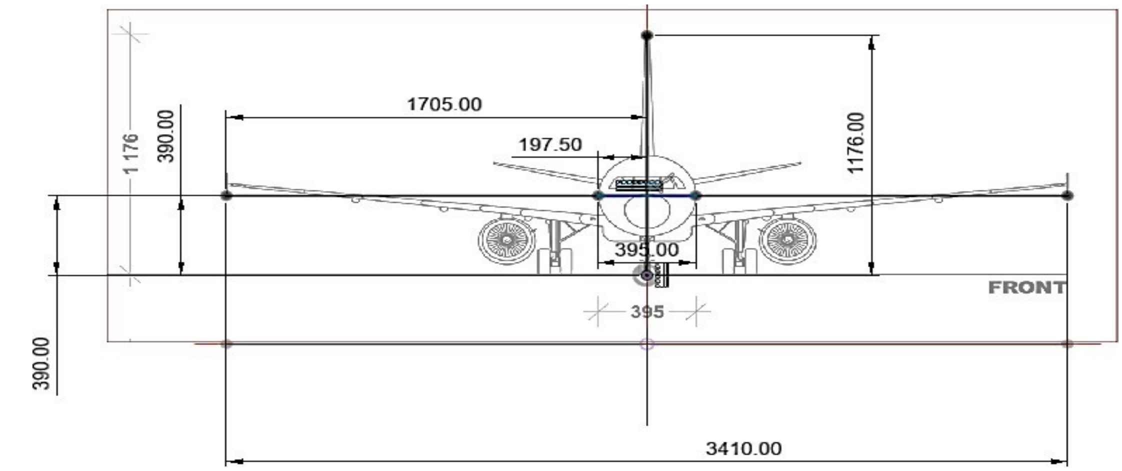


Fig 4.4. Front View of the aircraft.

These reference images views are then combined and arranged in isometric view for designing of wing box.

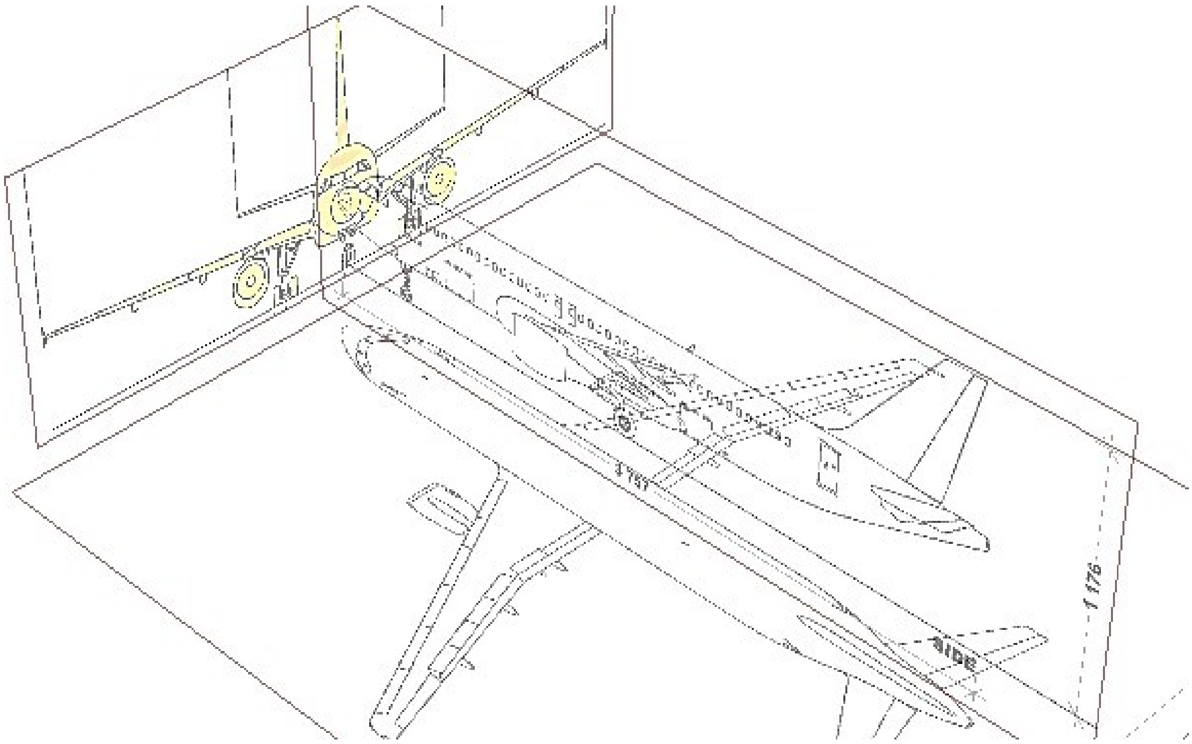


Fig 4.5. Isometric view of reference images.

For positioning of the ribs on to the reference image. (The Wing model of Airbus A320 which consists of ribs and spars.) is used as a reference image and is positioned on the top view.

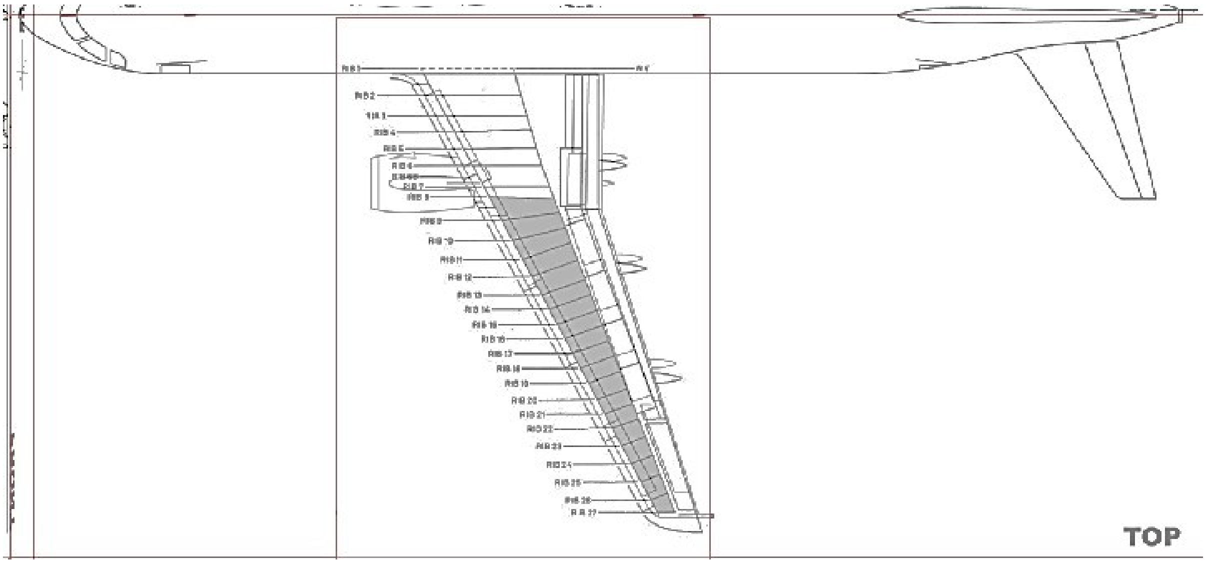


Fig 4.6. Placing reference ribs position on the reference images.

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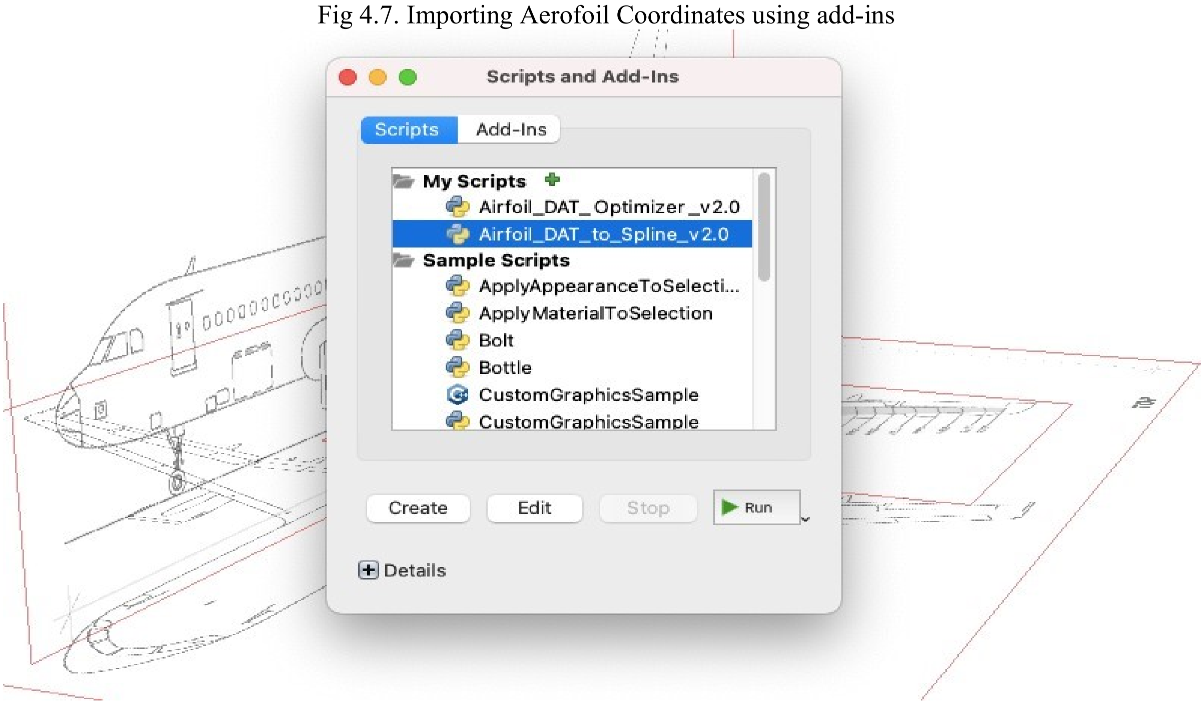
The aerofoils used in A320 is NACA 23015, the aerofoil coordinates are obtained from the aerofoil tools and then imported to Autodesk Fusion 360.

Fig 4.7. Importing Aerofoil Coordinates using add-ins



After importing the coordinates to the Fusion 360, three planes are constructed at wing root, wing mid-section and near wing tip for importing the coordinates at this plane for wing skin lofting.

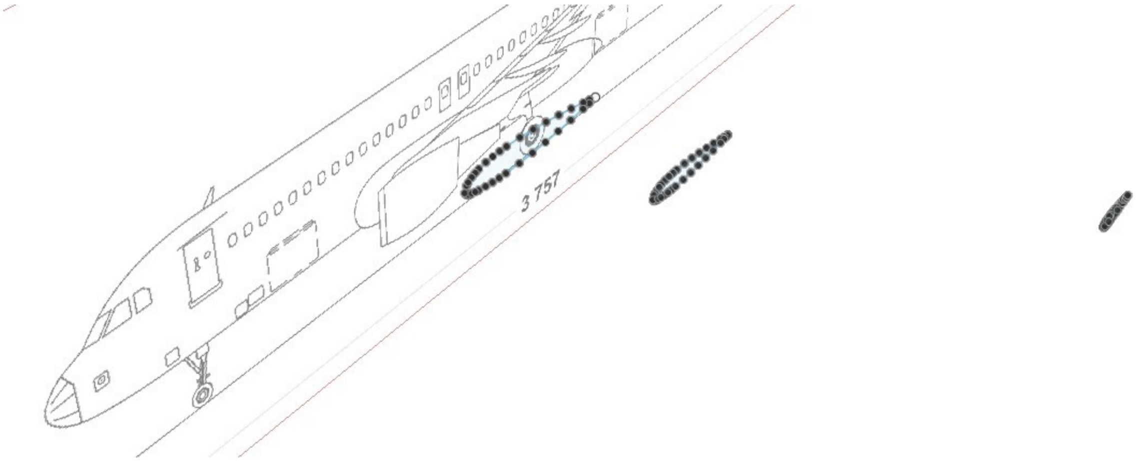


Fig 4.8. Imported aerofoil coordinate at constructed planes

Spars are then sketched using the reference image by sketching on the top view of the reference image.

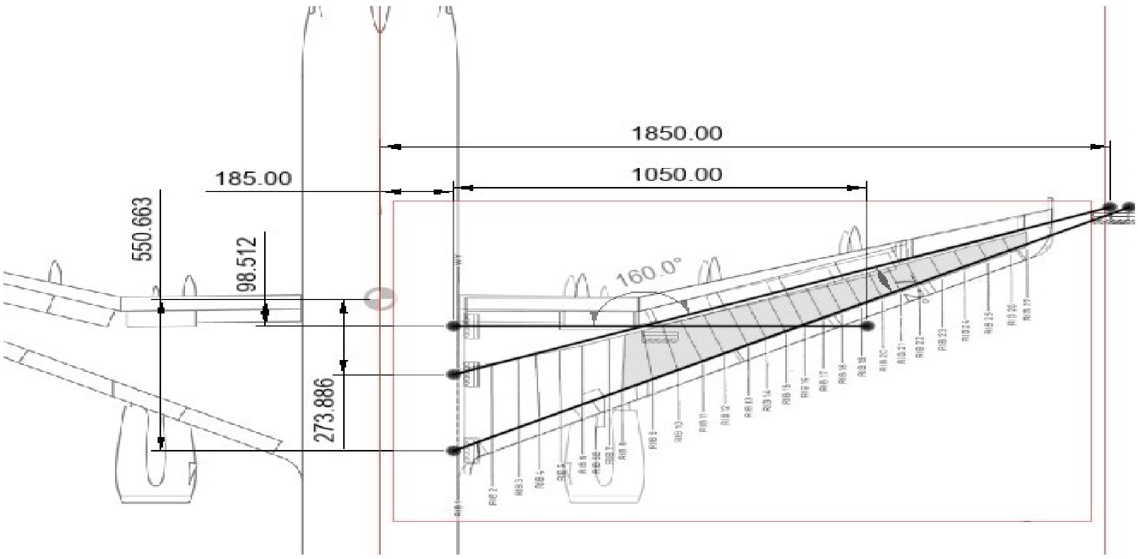


Fig 4.9. Sketching Spars.

The spars of the wing are generated by wing the sketch for creating spars at each spar station.

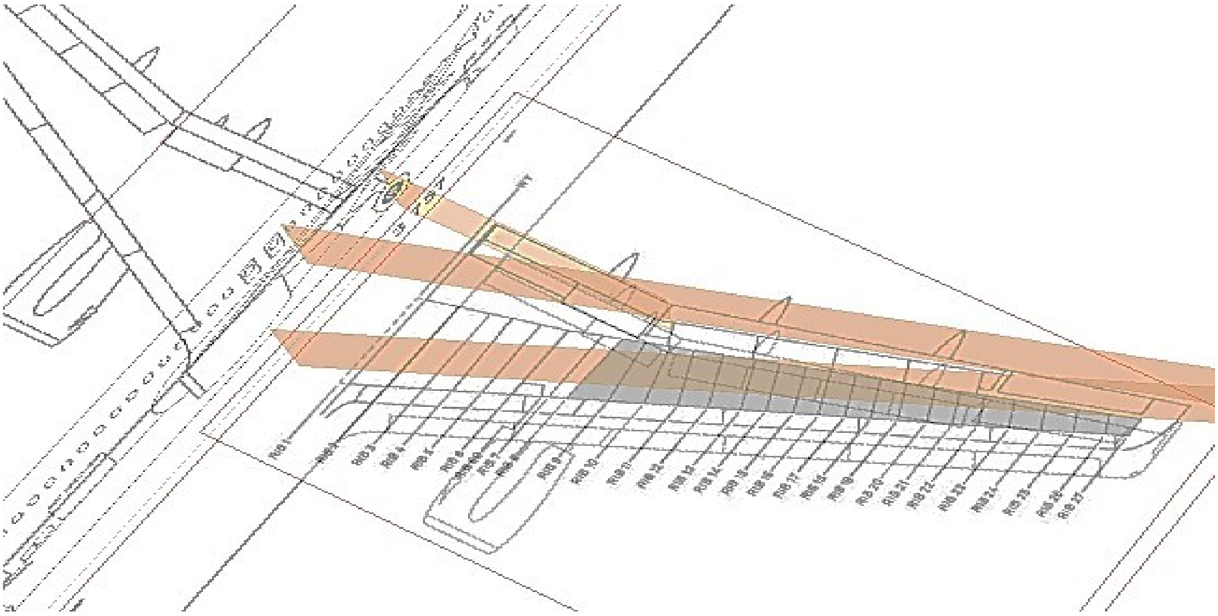


Fig 4.10. Creating construction Planes.

Using the above construction planes sketches are created and surface patch is done.

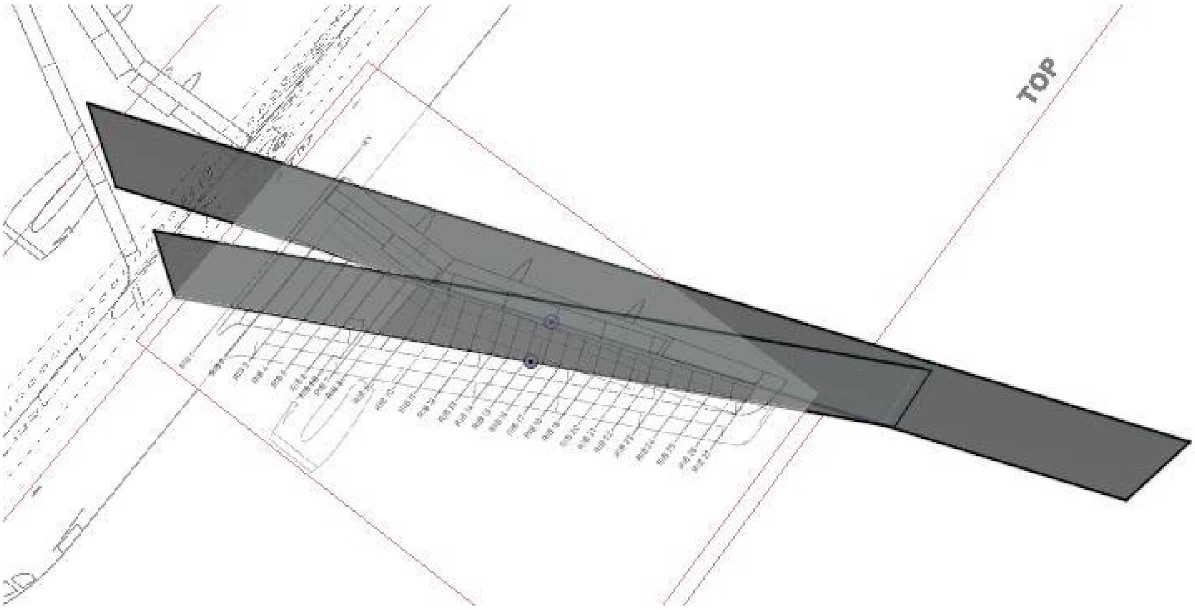


Fig 4.11. Surface patch for constructing spars.

Ribs are then sketched using the reference image by sketching on the top view of the reference image at the corresponding stages.

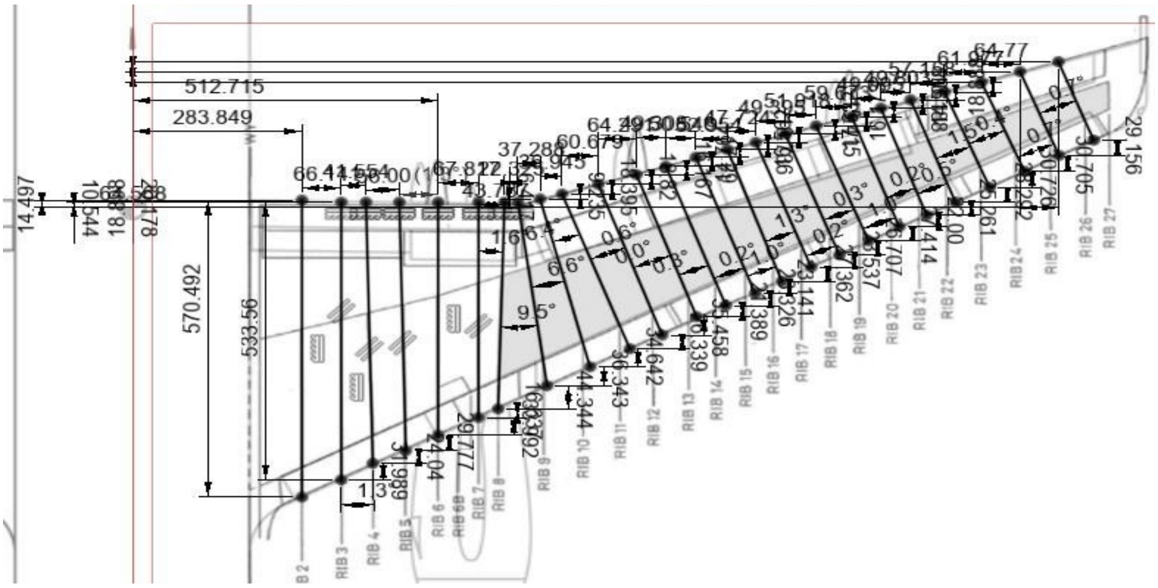


Fig 4.12. Sketching Ribs.

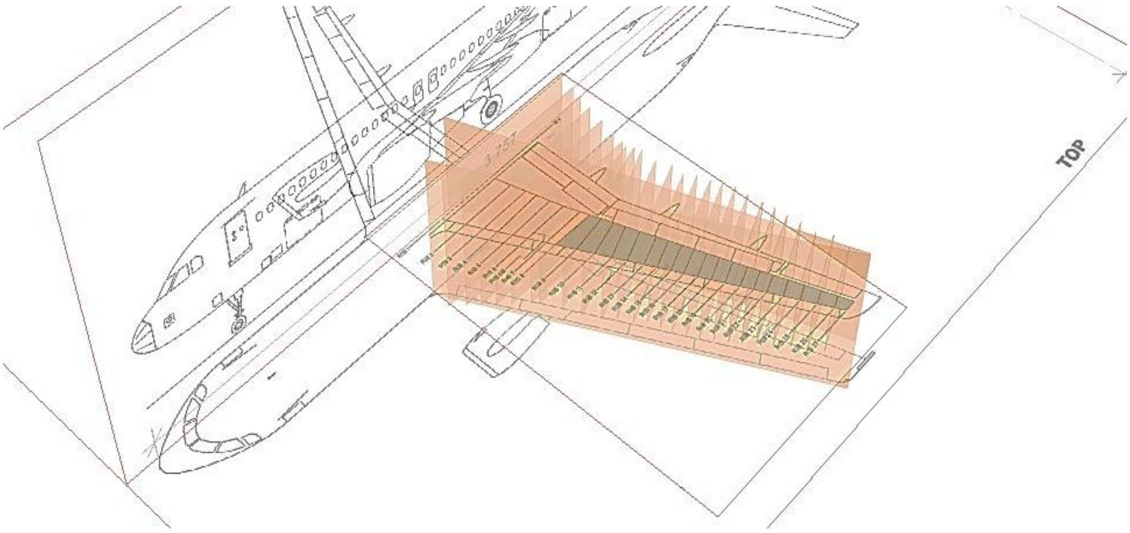


Fig 4.13. Creating construction Planes for Ribs.

Using the above construction planes sketches are created and surface patch is done for ribs construction.

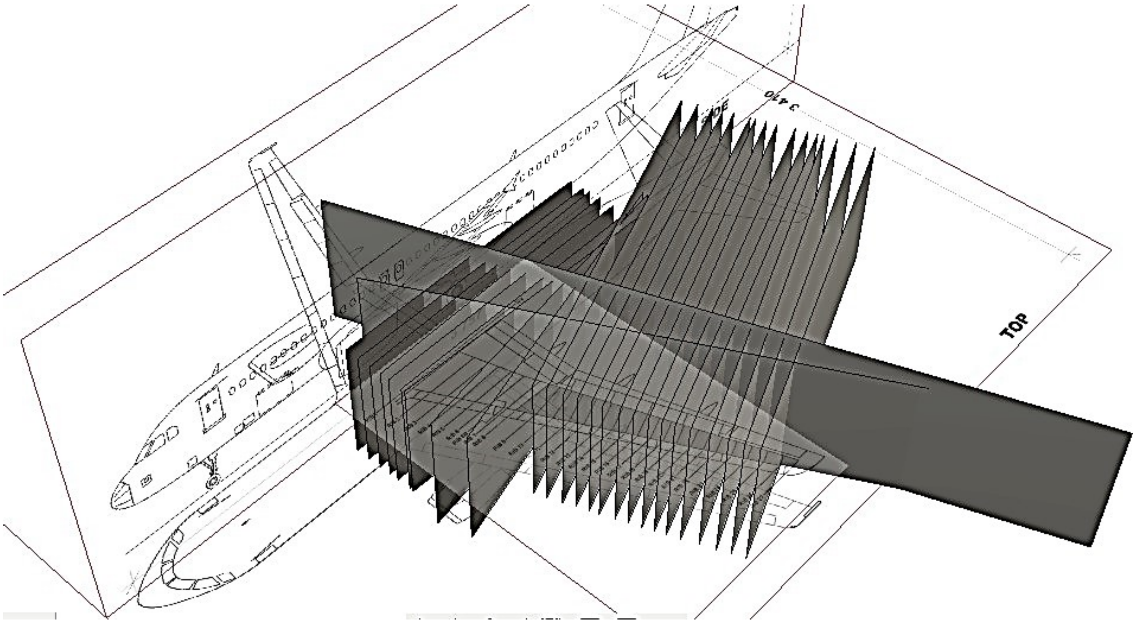


Fig 4.14. Surface patch for constructing ribs.

Lofting the wing skin using the imported NACA 23015 coordinates.

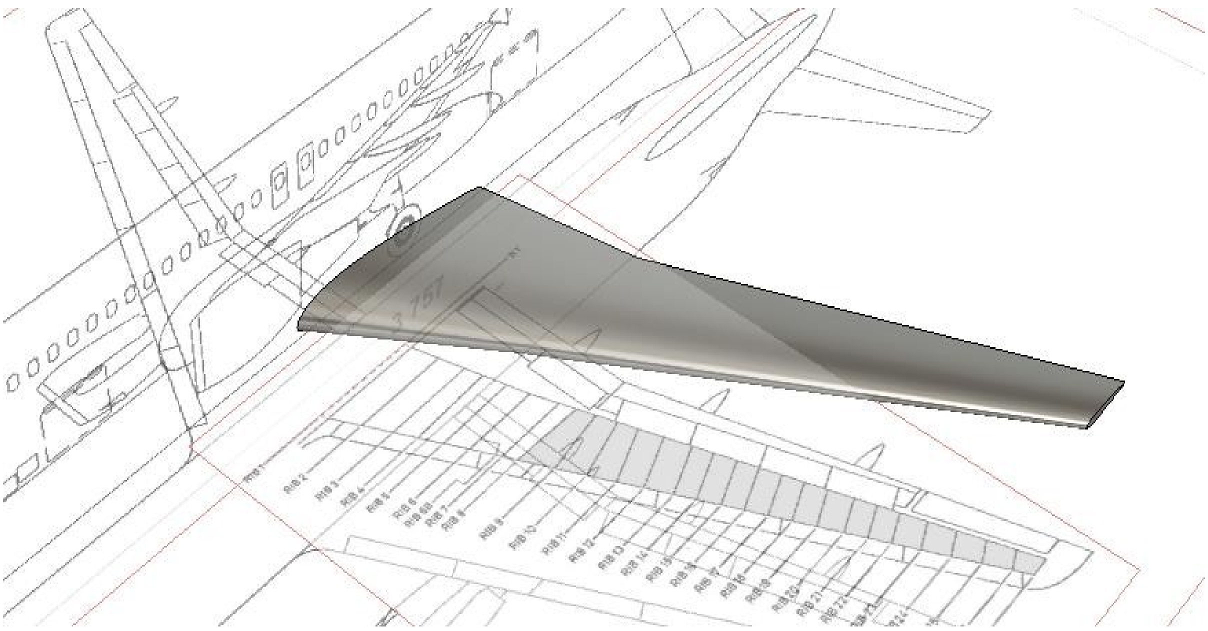


Fig 4.15. Wing skin lofting.

Using the surface patches of ribs and spars with the wing skin loft boolean operationis carried out to delete the unwanted surfaces to obtain ribs and spars inside the wing skin.

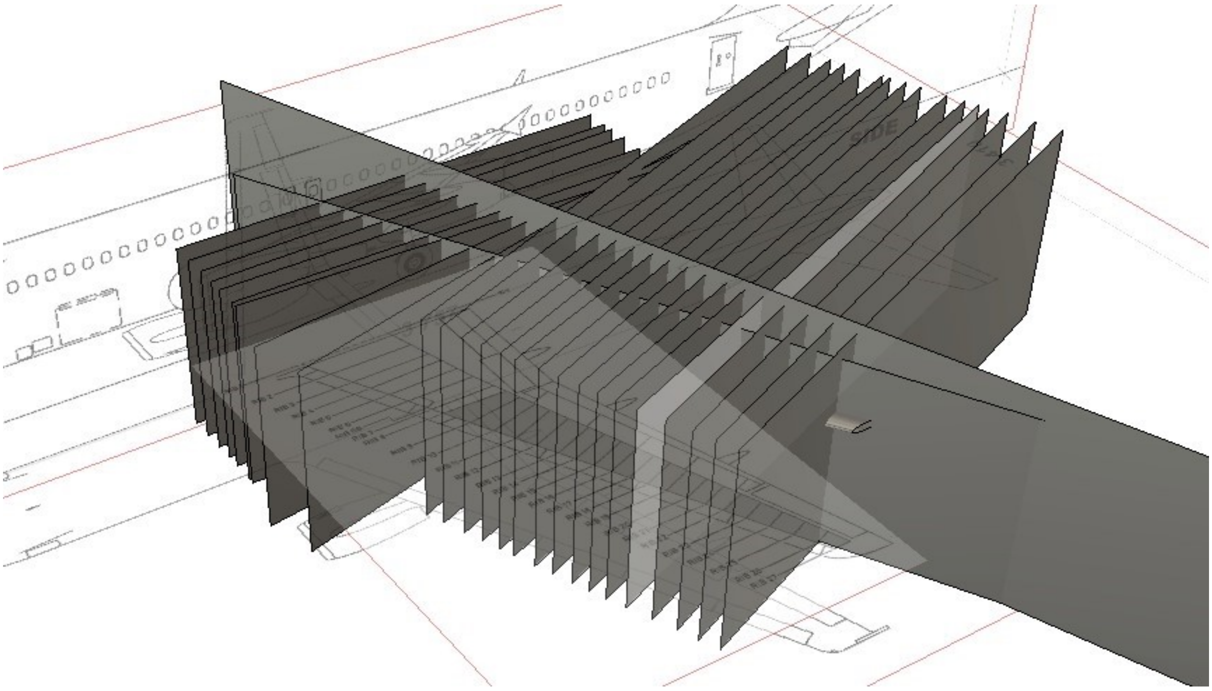


Fig 4.16. Boolean operation.

After boolean operation the ribs and spars are constructed according to thecorresponding stations.

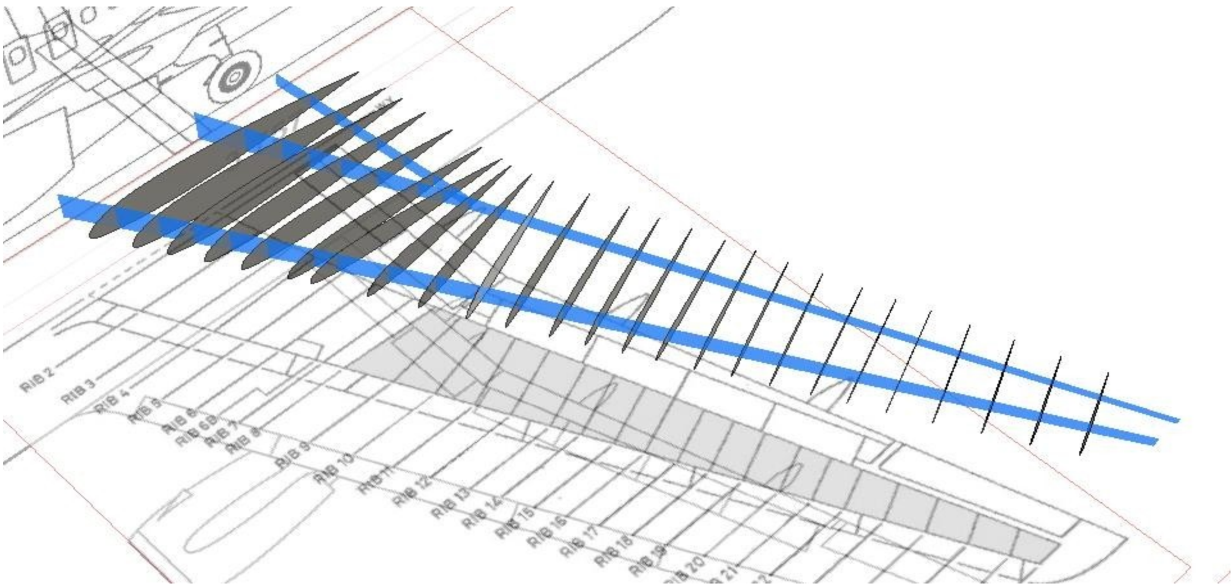


Fig 4.17. Ribs and Spars at the corresponding stations.

After performing boolean operation, hexagonal cut outs are created on the ribs near leading edge and trailing edge. The ribs and Spars are extruded.

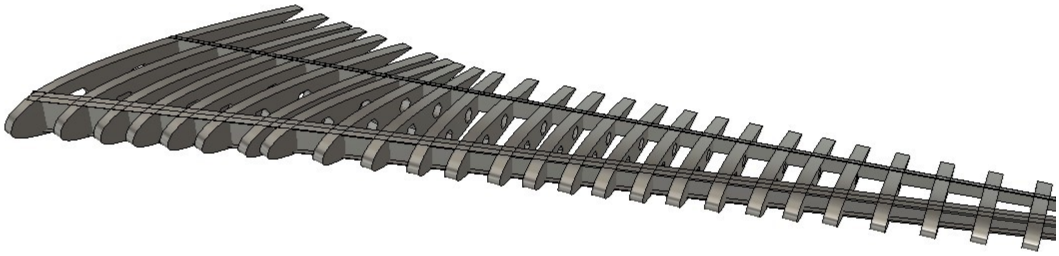


Fig 4.18. Giving thickness to ribs and spars.

The skin of the wing is given a thickness of 1.3cm. Below image shows the final wing design.

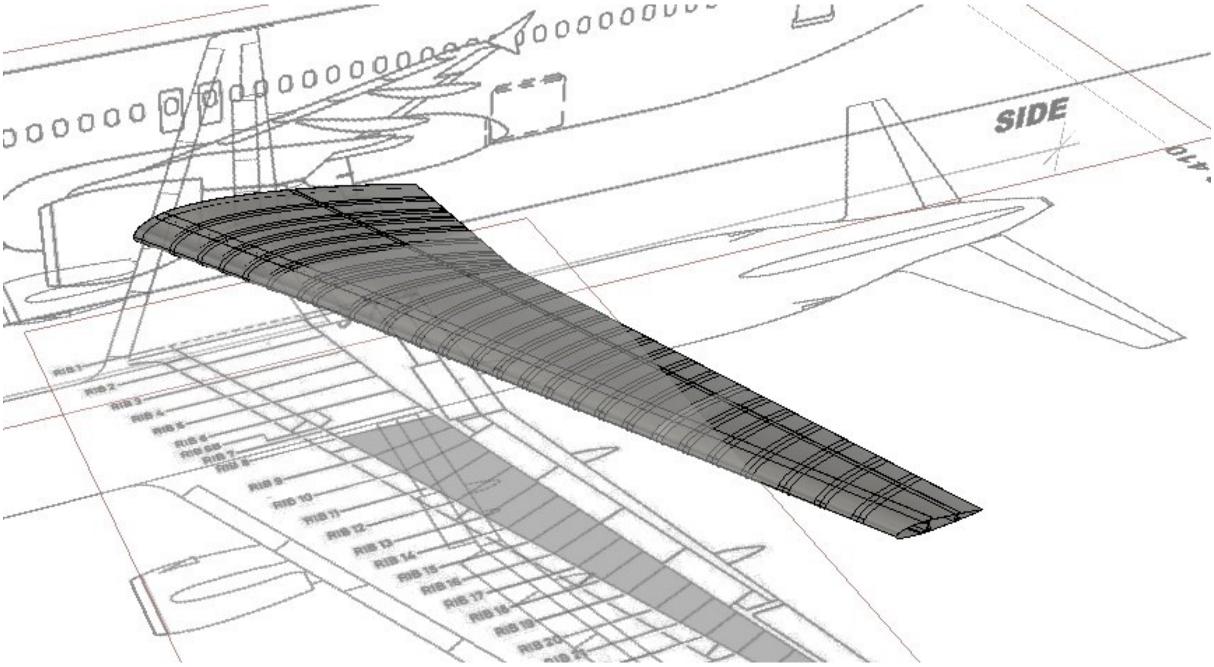


Fig 4.19. Final Wing Design.

Table 4.2. Airbus A320-100 Wing Specification.

Parameter	Values
Wing Span	33.91m
Root Airfoil	NACA 23015
Tip Airfoil	NACA 23015
Root Chord Length	7.05m
Tip Chord Length	1.50m
Skin Thickness	1.3m
Rib Thickness	20m
Front Spar	I Section
Rear Spar	C Section

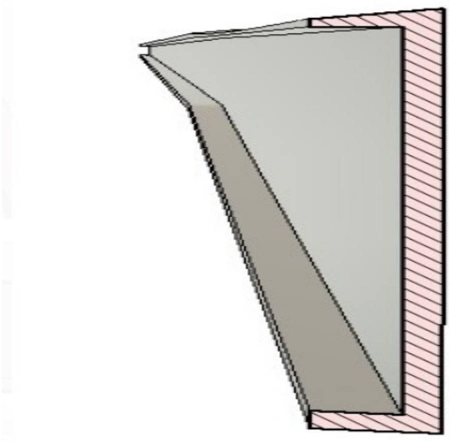
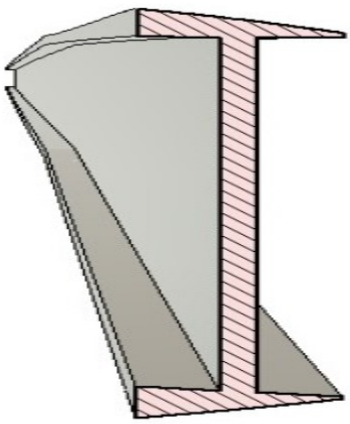


Fig 4.20. Rear Spar C Section.

Fig 4.21. Front Spar I Section.



4.2.2 CFD OF WING SKIN ANALYSIS

The wing skin is imported to ANSYS Fluent to conduct fluid flow analysis for obtaining the pressure loads acting on the wing at Mach number 0.8395. The flow domain is sketched at a distance 10 times of the wing span.

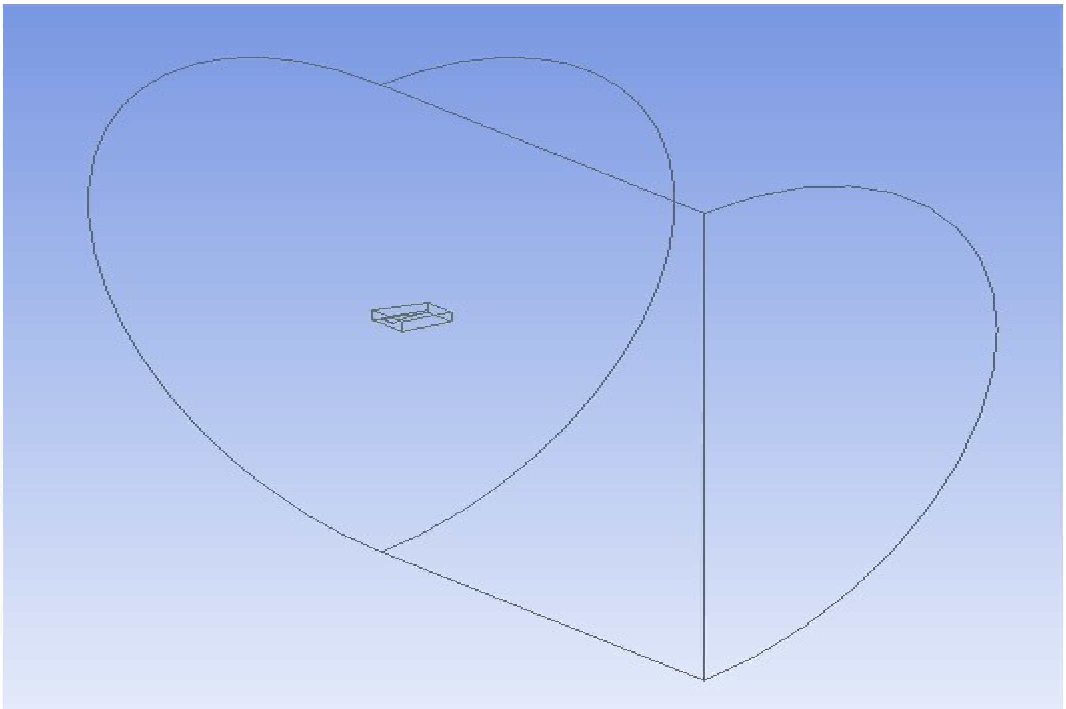


Fig 4.20. Wing skin with flow domain.

Boundary Conditions

The boundary condition considered for fluid flow analysis of the wing is Mach number of 0.8395 which is at transonic region at Reynolds number 11.72E6 at angle of attack of 3.06 degree

Table 4.3 Boundary Conditions

Boundary Name	Boundary Type	Condition
Near Side	Symmetry	Symmetrical w.r.t boundary
Wing Surface	Wall	V = 0
Inlet, Far Side and Outlet	Pressure far field	p=45.8290 psi T=460R M=0.8395 Alpha=3.06 degrees

Meshing

Wing skin is then meshed in ANSYS Mechanical using tetrahedron and prism element mesh.

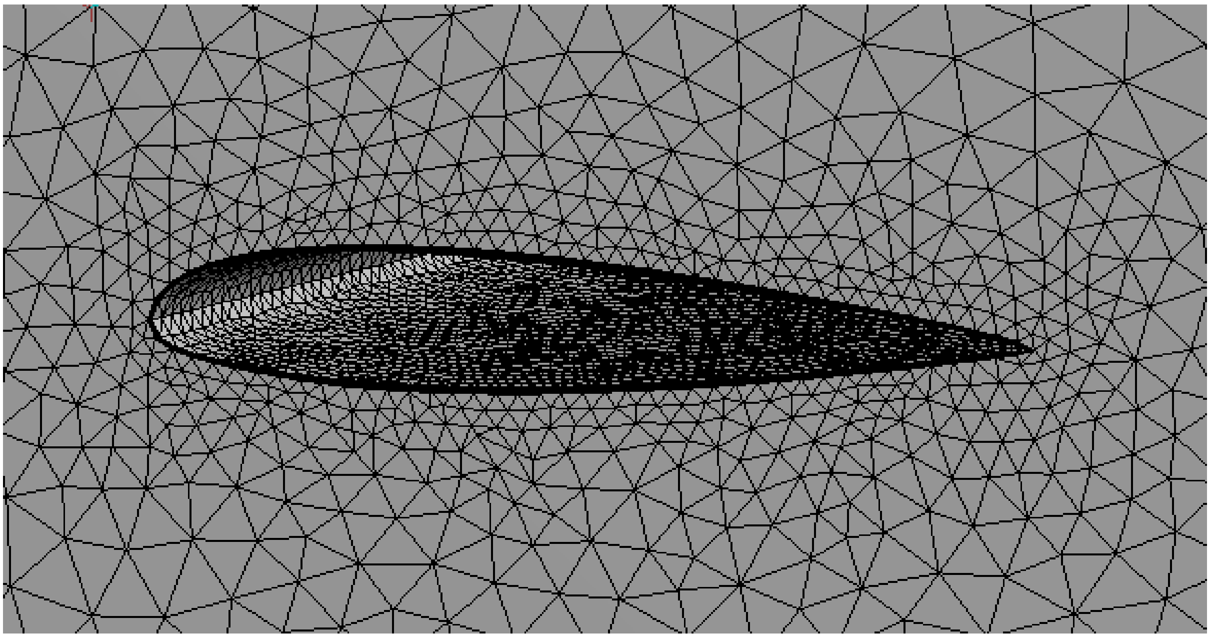


Fig 4.21. Meshing of wing skin.

Table.4.4. Meshing details

No. of Nodes	300099
No. of Elements	80707
Type of mesh element	Tetrahedron, Prism

4.2.3 STATIC STRUCTURAL ANALYSIS OF CONVENTIONAL WING BOX

The static structural analysis of the wing box is carried out in Autodesk Fusion 360. For static analysis the wing leading edge and trailing edge are excluded. Therefore, only the wing box is considered for the further analysis.

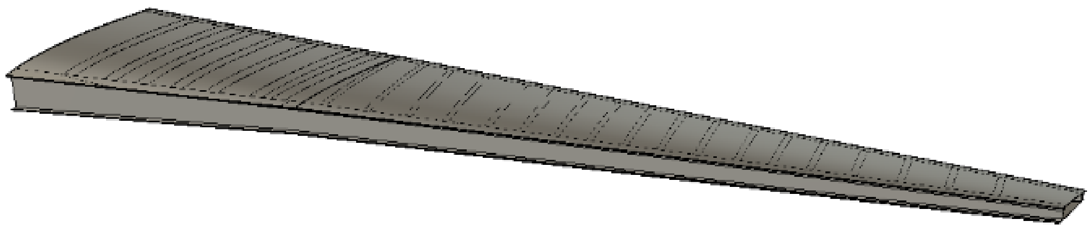


Fig 4.23. Wingbox for Static Analysis

Then the above wing box is checked for any interference between wing skin and ribs or between ribs and spars vice versa and material Aluminium 7075 is assigned.

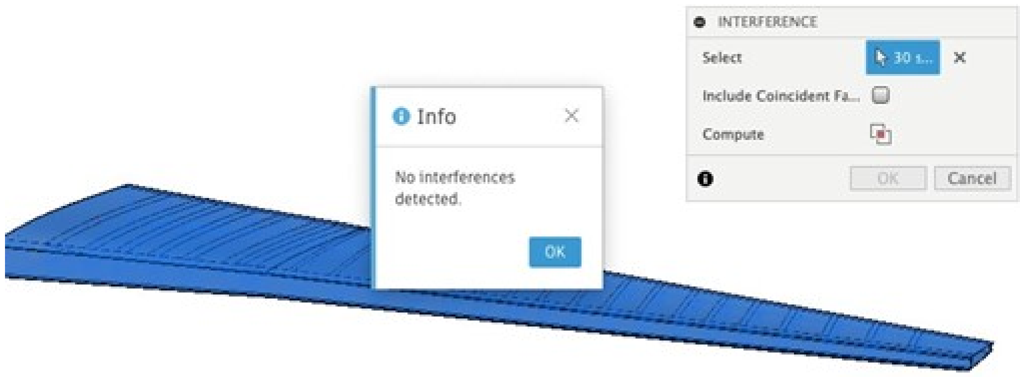


Fig 4.24. Checking for interference.

As discussed earlier the material used for the wing box is Aluminium 7075. This material is assigned to the wing skin and ribs and spars.

After checking for interference and assigning the materials the corresponding boundary condition for static analysis is applied to the wing box.

The wing box is then meshed by using local mesh control to refine the mesh. The mesh element used is tetra mesh element. Number nodes are 1113894 and number of elements are 546061.

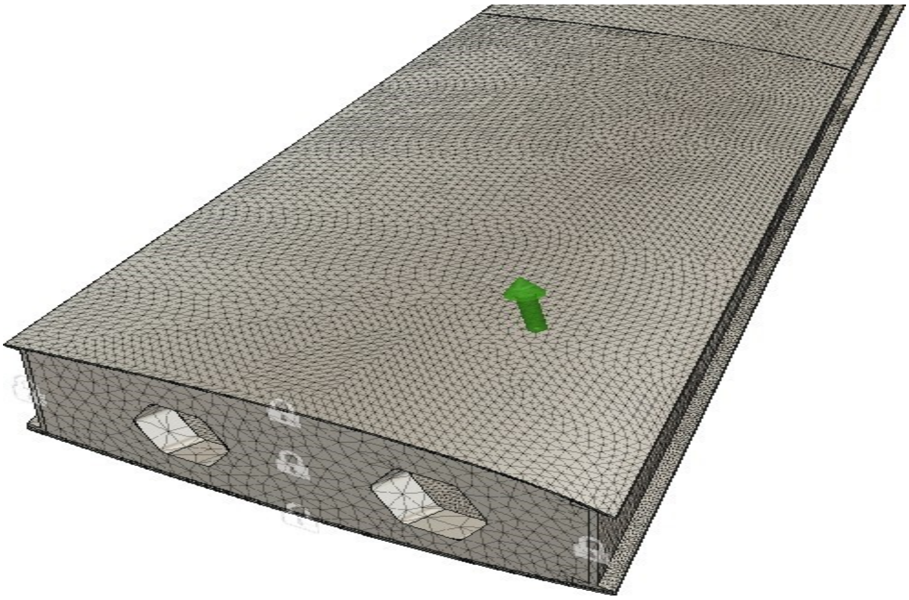


Fig 4.25. Meshed wing box.

Table.4.4. Meshing details

No. of elements	1113894
No of nodes	546061
Type of mesh element	Tetra

CHAPTER 5

RESULTS AND DISCUSSION

5.1 STATIC ANALYSIS OF CONVENTIONAL WING BOX

After meshing the wing and post processing the wing is then analyzed in post processing in ANSYS post processing. From the result it is concluded that the pressure on the surface of the wing is 0.4Mpa, therefore this pressure loads is considered for further simulation for static analysis.

After meshing the wing box is then taken to post processing using Fusion 360. The results are then obtained after post processing.

The loading condition considered are engine load, gravity load and pressure load acting on the wing. Airbus A320 uses CFM56-5B4 engine which is having a weight of 2381.36kg. This load is distributed to the wing rib at the station of Rib 7, Rib 8 and Rib 9. The pressureload is obtained from the CFD analysis which is of 0.4Mpa is considered. The constant gravityload of 9.81m/s is considered with wing root is fixed.

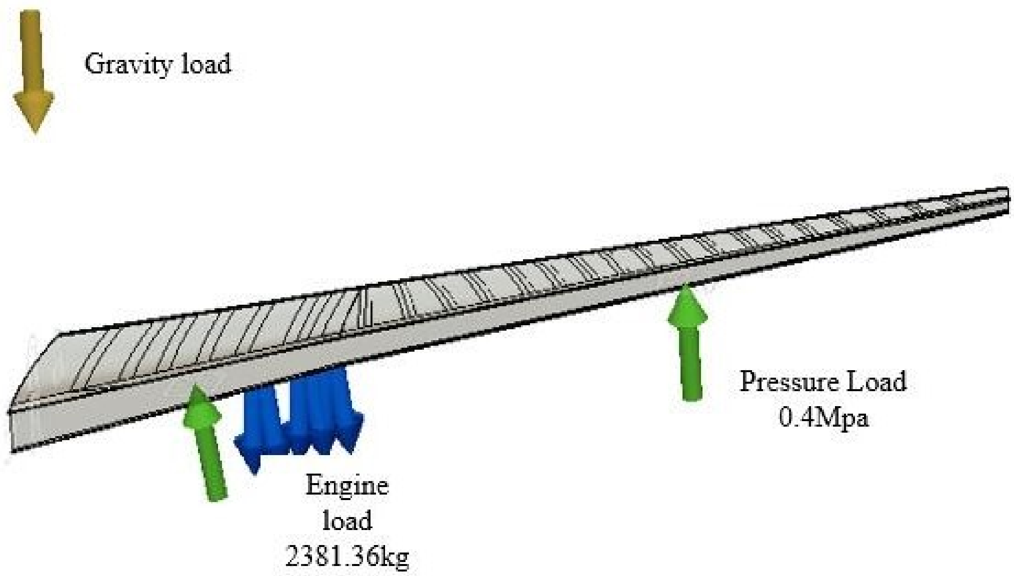


Fig 5.1. Wing box loading conditions.

The Maximum displacement obtained is 1279mm at the wing tip and minimum displacement at the wing root which is 0.3257mm.

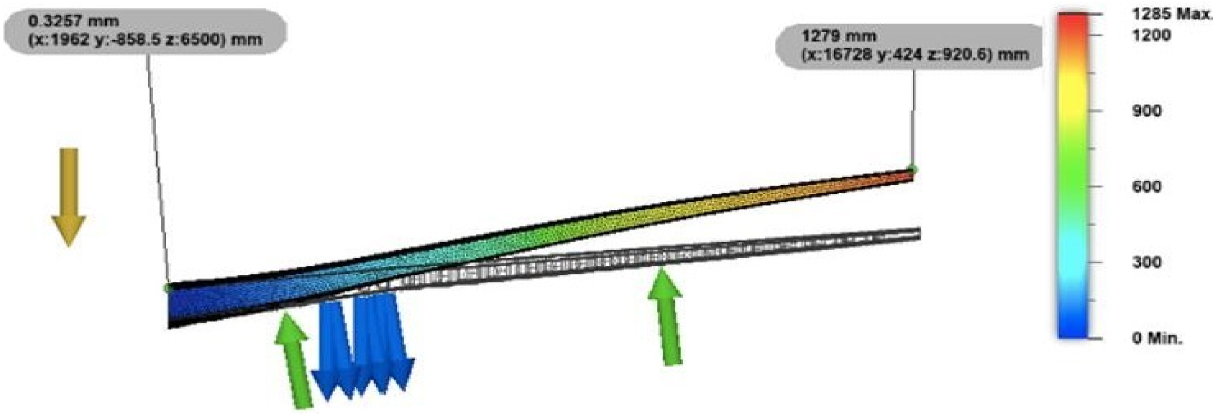


Fig 5.2. Displacement Result.

The stress is obtained with maximum stress of 1242Mpa at the wing root and 2.291Mpa at the wing tip.

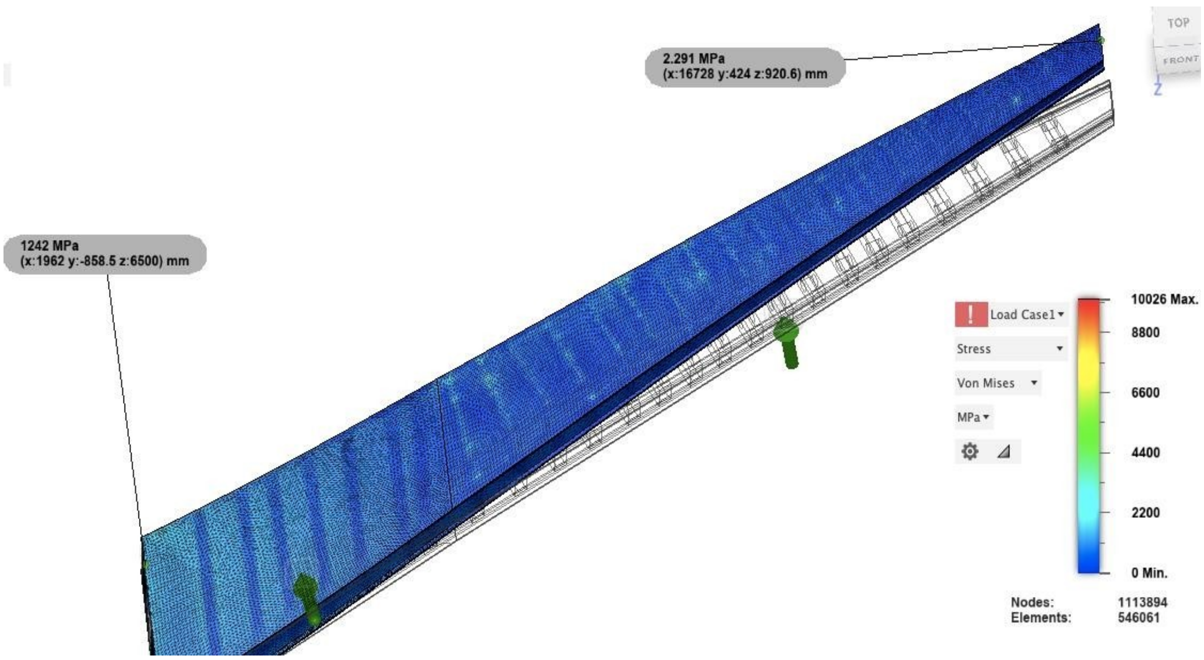


Fig 5.3. Stress Result.

Reaction force is obtained with maximum reaction force acting at the wing root is 9.61e7N

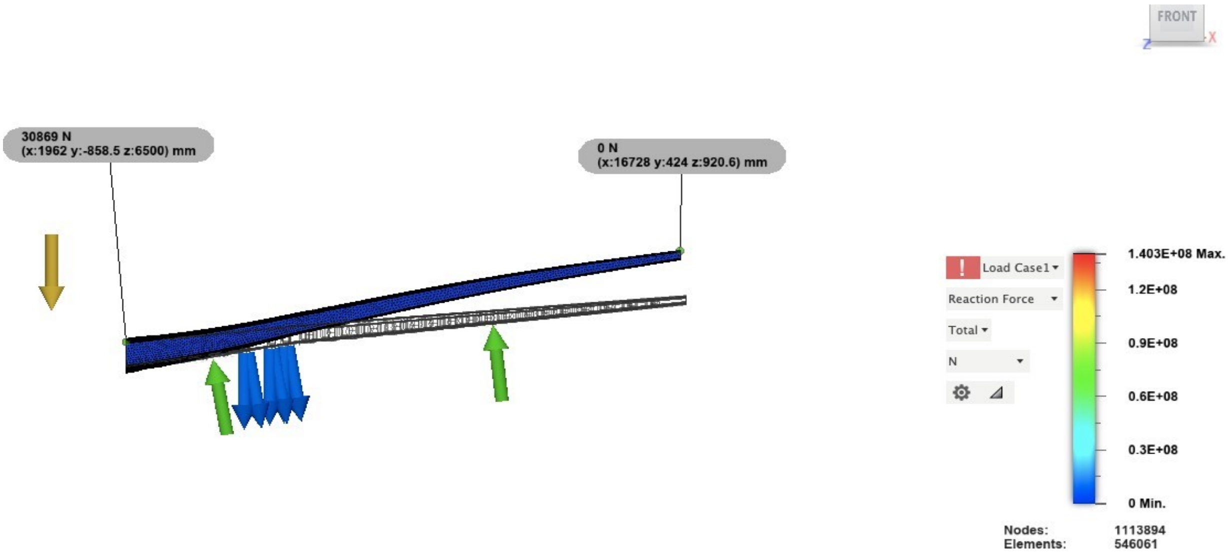


Fig 5.4. Reaction Force Result.

Static structural analysis for the conventional wing box is done. Therefore, these results are then taken for the optimization, by giving the mass target and the material are removed on the on the rib where the von-mises stresses are less.

5.2 STRUCTURAL OPTIMIZATION OF WING BOX

The load condition which was given above are applied again for the structural optimization. The optimization was done using Fusion360. The Load conditions are gravity load, pressure load of 0.4Mpa and engine load. Thematerial assigned is Aluminum 7075.

The wing box is then meshed using local mesh control, type of element used is tetra and hexa element. Number nodes are 1113894 and number of elements are 546061. Applying the loading condition to the wing box for optimization. The wing skinand spars are constrained for optimization which means during the analysis the material is notremoved in the spars and skin, therefore the optimization is carried out only on the rib.

During the optimization different mass target was given to the wing box to remove certain amount of material from the ribs. A mass target of 70%, 75%, 80%, 85% and 90% was given to check for the optimization results. But the mass target of 70% and 75% showed an error that the material can't be removed for this mass target.

The optimization for 90% mass target, the amount of material removed from the ribs was very less and was not feasible. Therefore, the optimization for 85% was carried out for two different wing box one with the ribs containing hexagonal cut-out and other wing box without the hexagonal cut-out.

5.2.1 85% Mass Target Result.

Structural optimization for wing box with hexagonal cut-out for 85% target, materials are removed near the leading edge of the ribs. The approx. mass removed is 10124.439kg therefore the mass ratio is 87.34%

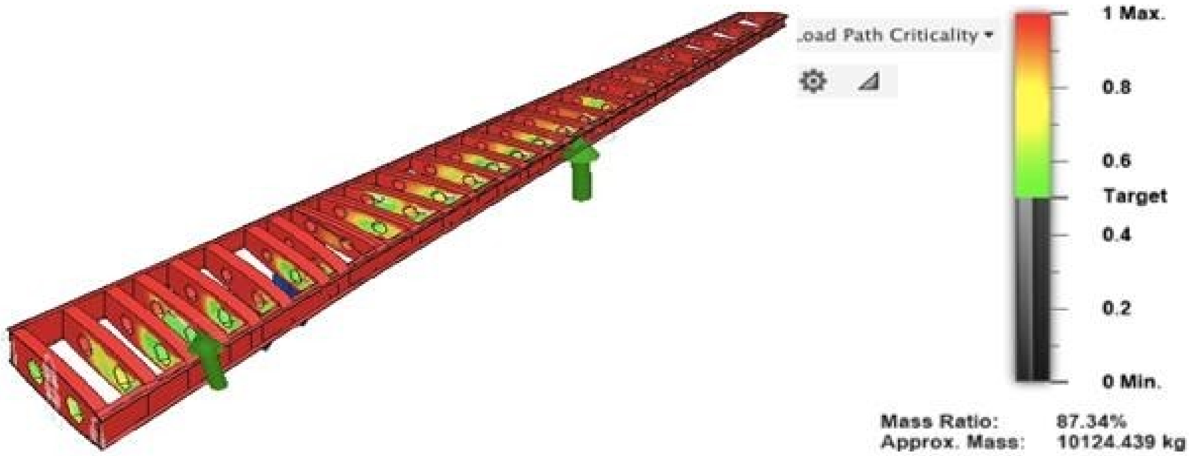


Fig 5.5. Optimized wing box for 85% mass target with cut-out.

Structural optimization of wing box without cut-outs for 85% mass target, the resultswere similar to that of the wing box with cut outs. Therefore, for further analysis of the wing box with hexagonal cut outs is considered

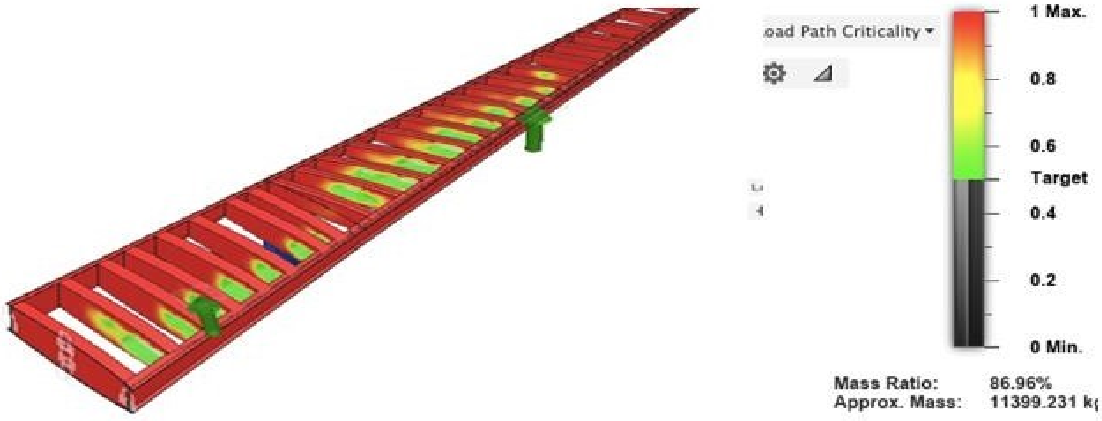


Fig 5.6. Optimized wing box for 85% mass target without cut-outs.

5.3 TRUSS MEMBERS FOR STRUCTURAL INTEGRITY

Wing box is the optimized for 85% mass target and the truss members are added to the area where the material is removed. The truss members are added for the purpose of structural integrity. This structural truss member is added to all the ribs where the material is removed towards the leading edge of the rib.

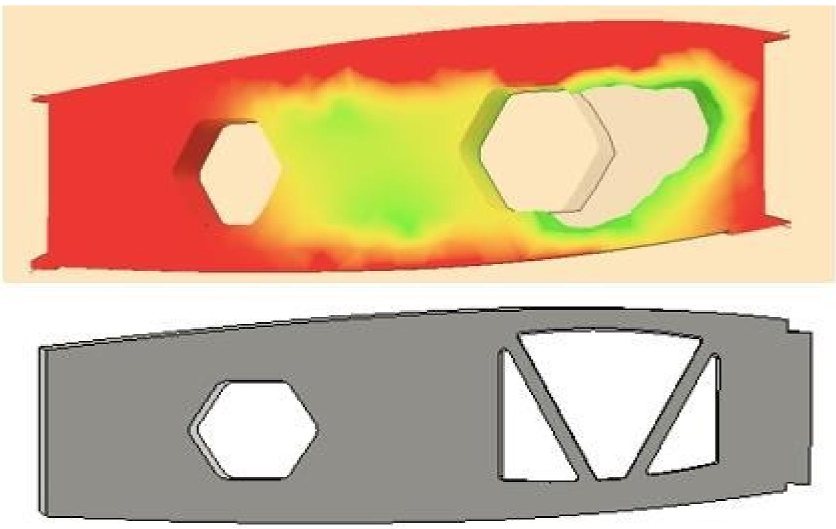


Fig 5.7 Optimized rib 2 and truss member added for rib 2

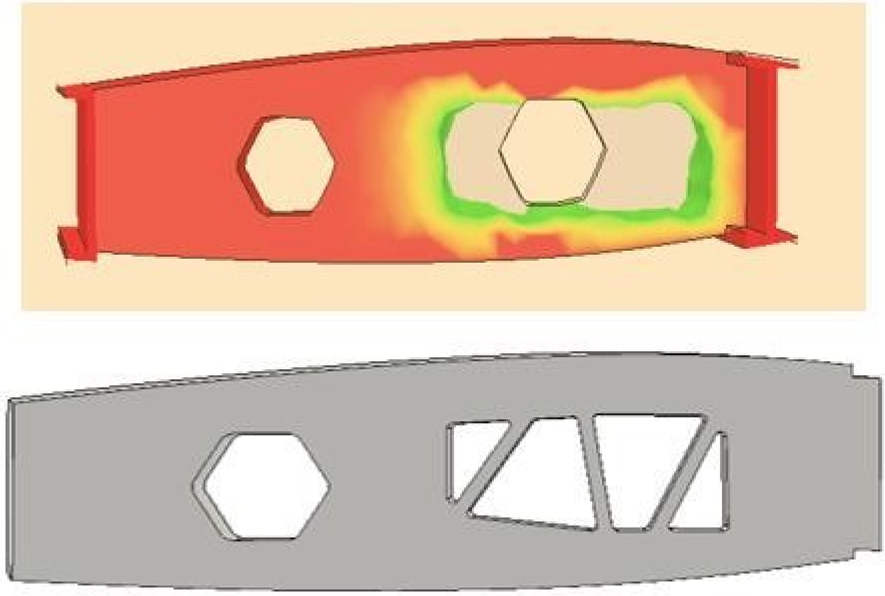


Fig 5.8. Optimized rib 4 and truss member added for rib 4

The truss member is added to rest of the ribs to maintain of structural integrity of the wing.

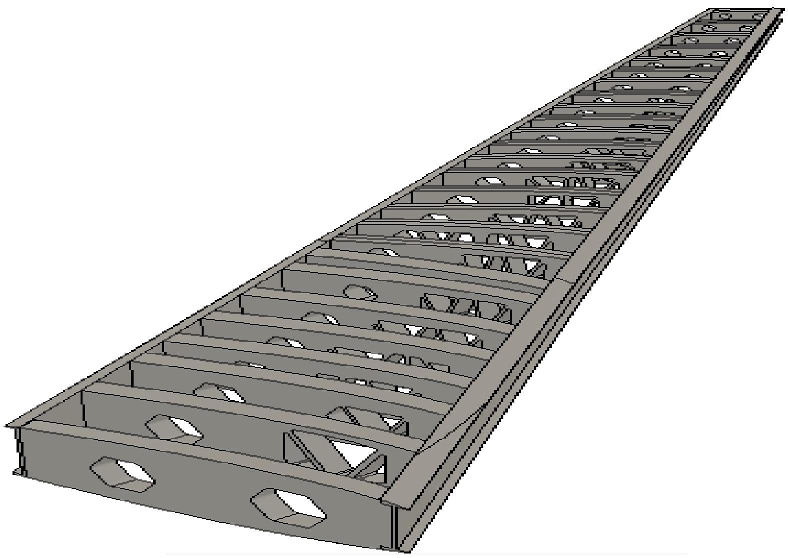


Fig 5.9. Wing box with added truss member.

5.4 STATIC ANALYSIS OF OPTIMIZED WING BOX

Static structural analysis for optimized wing box with added truss member is performed using Fusion360. The load conditions are gravity load, Engine load and pressure load. The material assigned isAluminium 7075. Below are results for Stress, displacement and reaction force.

The Maximum displacement obtained is 1276mm at the wing tip and minimum displacement at the wing root which is 0mm

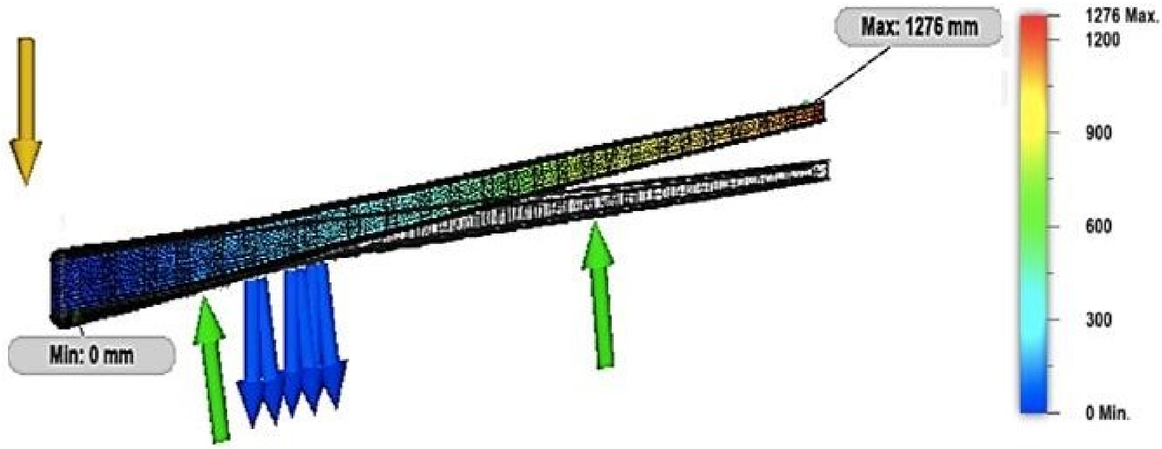


Fig 5.10. Displacement contour of optimized wing box.

The stress is obtained with maximum stress of 800.6Mpa at the wing root and 17.06Mpa at thewing tip.

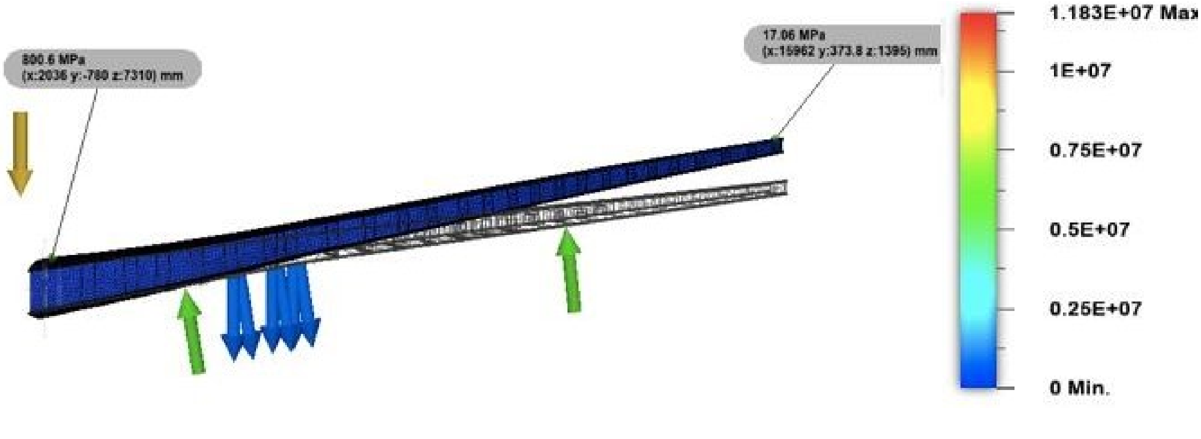


Fig 5.11. Stress contour of optimized wing box

Reaction force is obtained with maximum reaction force acting at the wing root 7.488e7N

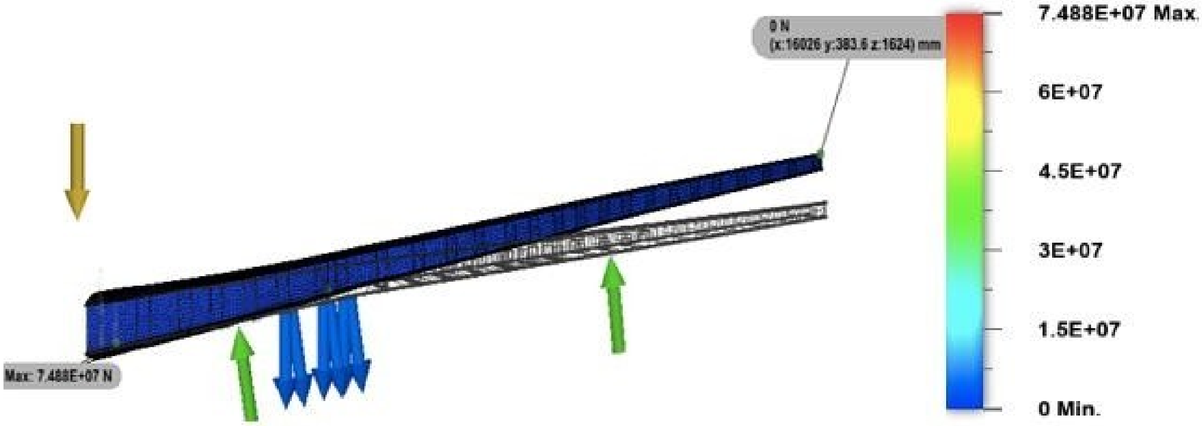


Fig 5.12. Reaction force contour of optimized wing box.

Above images shows the figures of the Static Structural analysis of optimized wing box.

The amount of material removed in the optimization of the wing box12487.276kg with wingskin and 10584.165kg without wing skin.

	Before optimization	After optimization	Percentage
Wing with Skin Weight	13460.756 kg	12487.276 kg	7.23%
Wing without SkinWeight	11557.64 kg	10584.165 kg	8.4%
Wing Stress	1160 MPa	800.6 MPa	30.98%
Wing Displacement	1085 mm	1276 mm	17.6%
Wing Reaction Force	9.61e7 N	7.48e7 N	22.08%

Table 5. Comparison of the wing box before and after optimization

CHAPTER 6

CONCLUSIONS

- The Wing box with the finalized geometry was modelled in Fusion 360.
- Fluid flow analysis of the basic wing box was done in Ansys Fluent to obtain the pressure loads.
- Static Structural Analysis of wing box was done in Fusion 360.
- Design Optimization of the wing box was obtained using Fusion 360 and is concluded that 85% of main target is the best for design optimization.
- Comparative study of wing box before optimization and after optimization was done and concluded that a weight reduction of 7.23% is achieved with skin and 8.40% without skin.

CHAPTER 7

FUTURE SCOPE

- Design optimization of the wing with leading and trailing edge maybe conducted by considering the fuel load.
- Design optimization of the wing with leading and trailing edge maybe obtained.
- Comparison of the conventional wing with the optimized wing.

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