

Study of Optimal Design of Spar Beam for the Wing of an Aircraft

¹Ajith V S, ²Dr. Ravikumar Paramasivam, ³K Vidhya

¹Asst. Professor, Jawaharlal College of Engineering and Technology,

²Professor, ARJ College of Engineering and Technology,

³Asst. Professor, Jawaharlal College of Engineering and Technology.

Abstract - The structure of an airframe represents one of the finest examples of strength to weight ratio in the field of mechanical engineering. The aim of this project is to study about the various types of aircraft wing spar structure and to optimize an aircraft wing spar beam for a six seated aircraft. The efficient design will be achieved by the use of strength of material approach. Software packages are to be used to design an aircraft wing spar structure and Finite Element Method (FEM) also be used to calculate the stresses developed at each station for a given bending moment. Several iterations will be carried out for the design optimization of the spar beam. The spar beam may be designed to yield at the design limit load. The results from the conventional design approach and the optimized design are to be compared. Material saving and economical design for operation, through the design optimization is to be studied.

Keywords - Ultimate Strength, Yield Strength, Fatigue Strength Fatigue Limit, Load Factor, Factor of Safety, Shear Force, Bending Moment, Young's Modulus, Section Modulus

1. INTRODUCTION

From the analysis of existing and future air travel conditions above, it is possible to postulate a new type of airline service; one that is aimed at the profitable business travel market. An airplane design to meet the functional, operational and safety requirements set by ultimate user. The actual process of design is a complex and long drawn out engineering task involving selection of aircraft type and shape, determination of geometric parameters, selection of power plant, structural design and analysis of various components. The structural and functional testing of airplane components is carried out simultaneously with the design work and prototype construction. The newly built aircraft spar is tested for strength and dependable functioning of its system using software's.

1.1. CONCEPTUAL DESIGN

Conceptual design is the process by which the design is initiated, carried to the point of creating a number of possible solutions, and narrowed down to a single best concept. It is sometimes called the feasibility study. It depends on what are the major factors for the designing aircraft spar.

1.1.1. Major aircraft components

1.1.1.1. Power plant Location:

The Power plant location is either padded or buried type engines are more preferred. Rear location is preferred for low drag, reduced shock, and to use whole thrust.

1.1.1.2. Engine selection:

The engine to be used is selected according to the following criteria: Power required, Cruise speed, Cost, Economy (fuel, maintenance, etc.), Redundancy, Useful load, Rate of climb, Stall Speed, Aerobatic capability, Gear configuration, .Construction material. Gross weight, etc.

1.1.1.3. WINGS

A wing is an appendage with a surface that produces lift for flight or propulsion through the atmosphere, or through another gaseous or liquid. A wing is an airfoil, which has a streamlined cross-sectional shape producing a useful lift to drag ratio.. The properties of the airflow around any moving object can - in principle - are found by solving the Navier-Stokes equations of fluid dynamics. The wings are airfoils attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight. Wings vary in design depending upon the aircraft type and its purpose. Most airplanes are designed so that the outer tips of the wings are higher than where the wings are attached to the fuselage. This upward angle is called the dihedral and helps keep the airplane from rolling unexpectedly during flight. Wings also carry the fuel for the airplane. The wing is a framework made up of spars, ribs, skin and (possibly) stringers.

1.1.1.5. LANDING GEAR

Landing gear is the structure that supports an aircraft on the ground and allows it to taxi, takeoff and land. Typically wheels are used, but skids, skis, floats or a combination of these and other elements can be deployed, depending on the surface. Landing gear usually includes wheels equipped with shock absorbers for solid ground, but some aircraft are equipped with skis for snow or floats for water, and/or skids or pontoons (helicopters).

1.2. PRELIMINARY DESIGN

It consists of the first stages of design and culminates in the presentation of the brochure containing the preliminary drawing and stating operational capabilities of the aircraft spar for approval by the manufacture and or the customer. This includes:

- Layout of the geometric model.

- Selection of power plant
- Aerodynamic calculation
- Preliminary structural design of spar
- Weight estimation
- Drafting the preliminary 3-view drawing

1.3. PROJECT BRIEF

For aerodynamic reasons, the wing cross section must have a streamlined shape commonly referred to as aerofoil sections. The aerodynamic forces on an aircraft change in magnitude, direction and location. Thus the required structure must be one that can efficiently resist loads causing combined tension, compression, bending and torsion. An aircraft wing is mainly subjected to lift, fuel, engine, landing gear, inertial, structural, nonstructural and other aerodynamic loads. In a cantilever wing, the wing bending moments decrease rapidly span wise from the maximum values at the fuselage support points. Spars are the main load carrying members in the wing running span wise direction. Wings of aircraft are attached at the root to the fuselage. Spars are stiffened enough to carry the loads and bending moments with minimum structural weight.

1.4. STATISTICAL DATA COLLECTION AND PROCESSING

The actual process of design is a complex and long drawn out engineering task involving selection of aircraft type and shape, determination of geometric parameters, selection of power plant, structural design, and analysis of various components. The structural and functional testing of airplane components is carried out simultaneously with the design work and prototype construction. The newly built aircraft spar is tested for strength and dependable functioning of its systems. Any design project needs the selection of a prototype of conceptual design. Then we have to study the design of similar aircraft spar (a non tapered spar). Here we are considering a prototype and a study aircraft to do the conceptual design of our strategic spar model. We are increasing the range of prototype and proposing a new design having structural integrity, improved endurance and improved load carrying characteristics.

1.5. DESIGN CRITERIA

To improve the range we need to calculate the maximum load took off by the aircraft which is lifting off by the total wing area. The total weight of the airplane is lifting off by the wing platform. Tail empennage is essential for the stability of the aircraft and design should be in such a way that it should regulate the whole wing fuselage assembly. Then the landing gear is fixed for the smooth landing and takeoff of our structural design. For this we have to determine the position of centre of mass of new aircraft such that it balances the whole aircraft on its own.

1.6. CENTRE OF MASS

The centre-of-gravity (CG) is the point at which an aircraft would balance if it were possible to suspend it at that point. It is the mass centre of the aircraft, or the theoretical point at which the entire weight of the aircraft is assumed to be concentrated. Its distance from the reference datum is determined by dividing the total moment by the total weight of the aircraft. The centre-of-gravity point affects the stability of the aircraft.

1.7. MOMENT OF INERTIA

The moment of inertia & section modulus provide information about the geometry of the shape being bent. The larger the value typically indicates a member that is more difficult to bend. The value is calculated based on which direction you are bending your material as well. Take a ruler and grab both ends like a beam. First hold it flat and try to bend it as if it had load on top. Now turn the ruler 90 degrees and try to bend it again. One direction is much stiffer than the other; this is due to the increased section modulus in one direction over another.

1.8. SECTION MODULUS

Section modulus, S , is another way of expressing I/c , where c is the distance from the neutral axis to the extreme fiber of the beam. Thus, maximum pure bending stress = M/S . Design guides such as the American Institute of Steel Construction have section modulus tables for various beam shapes to simplify beam capacity analysis.

2. AIRCRAFT MATERIALS

The most common metals used in aircraft construction are aluminum, magnesium, titanium, steel, and their alloys. Traditional metallic materials used in aircraft structures are Aluminum, Titanium and steel alloys. In the past three decades applications of advanced fiber composites have rapidly gained momentum. To date, some modern military jet fighters already contain composite materials up to 50% of their structural weight. Selection of aircraft materials depends on any considerations, which can in general be categorized as cost and structural performance. The key material properties that are pertinent to maintenance cost and structural performance are: Stiffness, Density, Strength, Durability, Damage tolerance. Corrosion. No single material is able to deliver all desired properties for all components of the aircraft structure. A combination of various materials is often necessary.

2.1. Aluminum alloy

It is widely used in modern aircraft 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 characteristic of aluminum is its lightweight. Among the aluminum alloys, the 2024 and 7075 alloys are perhaps the most used. The 2024 alloys (2024-T3, T42) have excellent fracture toughness and slow crack growth rate as well as good fatigue life. The code number following T for each aluminum alloy indicates the heat treatment process. The 7075 alloys (7075-T6, T6510) have higher strength than the 2024 but lower fracture toughness. The 2024-T3 is used in the fuselage and lower wing skins, which are prone to fatigue due to applications of cyclic tensile stresses. For the upper wing skins, which are subjected to compressive stresses, fatigue is less of a problem, and 7075-T6 is used. The recently developed Aluminum-Lithium alloys offer improved properties over conventional aluminum alloys. They are about 10% stiffer and 10% lighter and have superior fatigue performance.

2.2. Titanium alloy

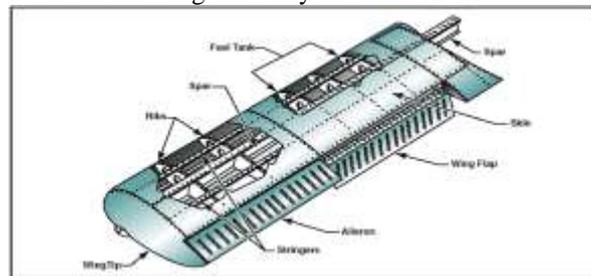
Titanium is a lightweight, strong, corrosion resistant metal. Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy. Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere. Titanium alloy such as Ti-6Al-4V (the number indicates the weight percentage of the alloying element) with a density of 4.5 g/cm^3 is lighter than steel (7.8 g/cm^3) but heavier than aluminum (2.7 g/cm^3). Its ultimate and yield stresses are almost double those of aluminum 7075-T6. Its corrosion resistance in general is superior to both steel and aluminum alloys. While aluminum is usually not for applications above 350° F , titanium, on the other hand, can be used continuously up to 1000° F . Titanium is difficult to machine, and thus the cost of machining titanium parts is high. Near net shape forming is an economic way to manufacture titanium parts. Despite its high cost, titanium has found increasing use in military aircraft. For instance, the F-15 contains 26% (structural weight) titanium.

2.3. Steel Alloys

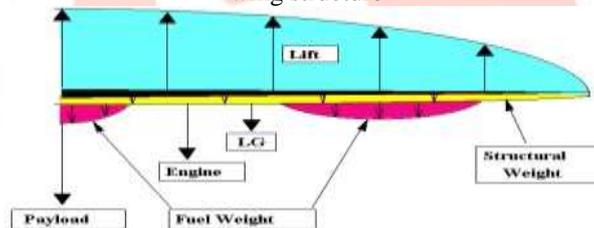
Among the three metallic materials, steel alloys have highest densities, and are used only where high strength, high yield stress are critical. Examples include landing gear units and highly loaded fittings. The high strength steel alloy 300 m is commonly used for landing gear components. Besides being heavy, steel alloys are generally poor in corrosion resistance. Components made of these alloys must be plated for corrosion. These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum. High-tensile steels will stand stress of 50 to 150 tons per square inch without failing. Such steels are made into tubes, rods, and wires. Another type of steel used extensively is stainless steel. Stainless steel resists corrosion and is particularly valuable for use in or near water.

3. INTRODUCTION TO SPAR

An aircraft wing is mainly subjected to lift, fuel, engine, and landing gear, inertial, structural, non-structural and other aerodynamic loads. The main load-bearing members in the wing are called spars. The spars are the principle structural members. Spars are strong beams which run span wise in the wing and carry the force and moments due to the span wise lift distribution.



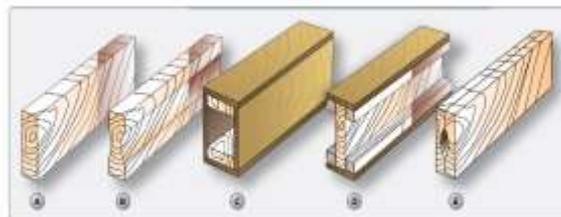
wing structure



Loads acting on the wing

Wings of aircraft are attached at the root to the fuselage. A wing has two spars. One spar is usually located near the front of the wing, and the other about two-thirds of the distance toward the wing's trailing edge. Spars run parallel to the lateral axis of the aircraft, from the fuselage toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss. Therefore the spar beams can be considered as a cantilever beam for the design purpose. The chord wise pressure and shear distributions on each airfoil are carried to the spars by the wing skin and airfoil-shaped structural frames called ribs. The ribs help the wing keep its airfoil shape, and together with the skin and spars form tubes and boxes which resist wing twisting or torsion. The pressure and shear distributions on the wing skin are collected by the ribs and transmitted to the spars. The loads on most ribs are relatively small, though some may carry concentrated loads from landing gear, engines, or external stores. Wing skins are usually quite thin, so they frequently have additional stiffeners or stringers attached to them. Stringers help transmit the skin surface loads to the ribs and spars, and they help keep the skin from bending too much under load.

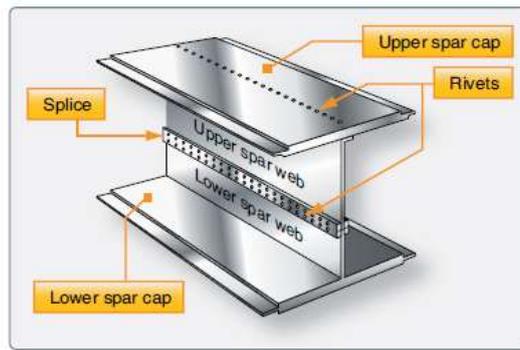
Spars may be made of metal, wood, or composite materials depending on the design criteria of a specific aircraft. They can be generally classified into four different types by their cross sectional configuration they may be solid, Box shaped, Partly hollow, I-beam



various configuration of spar beam

In an I-beam spar, the top and bottom of the I-beam are called the caps and the vertical section is called the web. The entire spar can be extruded from one piece of metal but often it is built up from multiple extrusions or formed angles. The web forms the

principal depth portion of the spar and the cap strips are attached to it. Together, these members carry the loads caused by wing bending, with the caps providing a foundation for attaching the skin.



Parts of I-beam spar

4. Design of Uniform Spar

4.1. Design Criterion

The design procedure involves need for project, identification of problem, information retrieval, selection of basic parameters, analytical analysis and layout design. The following design requirements and research studies are set for the project:

4.2. INFORMATION RETREIVAL: In this step I collect parameters of selected aircrafts. Later stages of the design process will benefit from knowledge of existing work published in the area of the project. Searching for such information will involve three tasks:

1. Finding data on existing and competitive aircraft spar.
2. Finding technical reports and articles relating to the project area and any advanced technologies to be incorporated.
3. Gathering performance parameters.

The aircraft spars are similar in their dimensions and performance capabilities. Calculations in zero approximation are based on use of the statically data for parameters and characteristics of already constructed aircraft spar of a similar class.

4.3. SELECTION OF BASIC PARAMETERS:

4.4. General Performance characteristics

Of Six seater aircraft

- 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

4.4.1. GeneralPerformance characteristics:

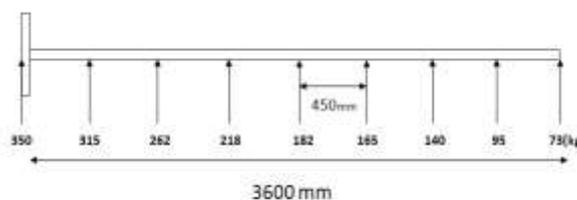
- Cruise speed : 905 Km/hr
- Max speed : 950 km/hr
- Range : 9070 km
- Max wing loading : 7975.5 N/m²
- Minimum thrust/weight : 0.287

4.5. STATICAL DATA OF SIMILAR AIRCRAFT SPAR (NON-TAPERED)

Clearly, there is a need of a reference form (study) which can come up with an optimized design. Consider an untapered, rectangular spar as shown below. The aircraft spar is considered as a cantilever with a decreased load distribution from the root to tip. This decrease is all the same whether the spar is a rectangular, I-section, tapered or non-tapered.

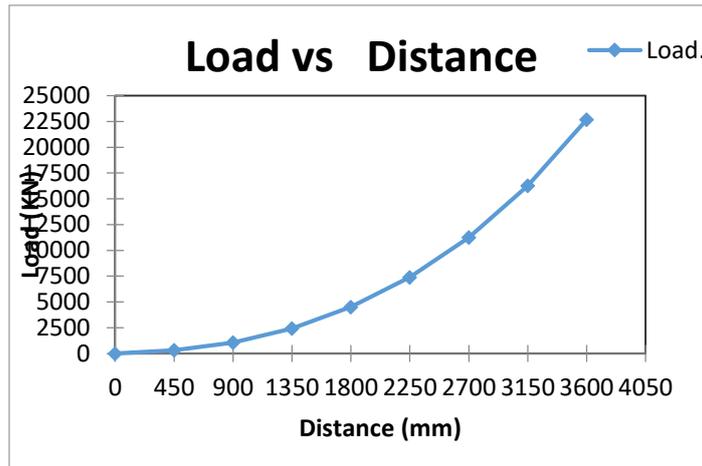
4.6. NON-TAPERED SPAR

Total length of the spar which I have considered is 3600mm which is the requirement for the selected aircraft. The spar is divided into 9 equal numbers of stations. Distance between each station is 450mm. All loadings are in kg.



Cantilever beam load distribution

The following plot shows the load distribution curve for the cantilever beam is shown in figure



Graph load – distance

4.7. ANALYTICAL ANALYSIS

4.7.1. DETERMINATION OF SHEAR FORCE

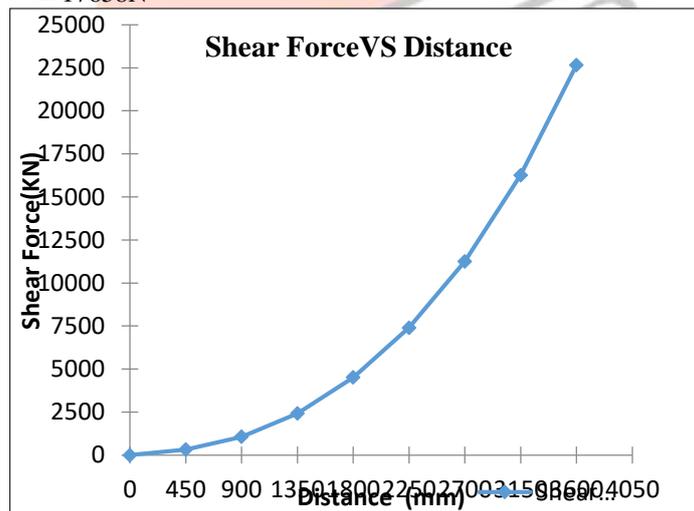
The first step in the design of a new aircraft spar is to obtain and estimate the shear force. The total take-off weight is divided into fuel weight, payload weight, empty weight etc.

Shear Force Calculation

Shear force of the airplane for zero approximation is determined by the formula received from the equation of shear force of cantilever beam.

SHEAR FORCES

- Shear force at free end = 716N
- Shear force at 450 mm = 1648.08N
- Shear force at 0900 mm = 3021.48N
- Shear force at 1350mm= 4640.63N
- Shear force at 1800mm= 6425.55N
- Shear force at 2250 mm = 8564.13N
- Shear force at 2700 mm = 11134.25N
- Shear force at 3150mm= 14224.5N
- Shear force at 3600mm = 17658N

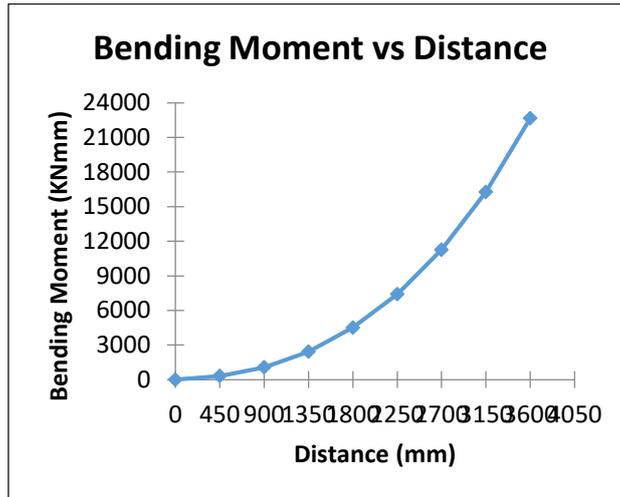


5.6.2. Determination Of Bending Moment

Bending Moments At Stations

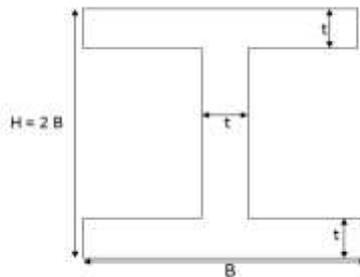
- Bending moment at free end = 0
- Bending moment at 450mm = 322.25 KNmm
- Bending moment at 900mm = 1063.89 KNmm
- Bending moment at 1350mm= 2423.56 KNmm
- Bending moment at 1800mm= 4512.6 KNmm
- Bending moment at 2250mm=7403.11 KNmm
- Bending moment at 2700mm=11256.97 KNmm

- Bending moment at 3150mm=16267.43 KNmm
- Bending moment at 3600mm=22668.46 KNmm



Graph: bending moment-distance
 5.7.1. I-SECTION GEOMETRY

Considering the I crosssection beam with following assumptions



Thickness $t = 3\text{mm}$

Area	1116.84 mm ²
I_{xx}	6295156 mm ⁴
I_{yy}	443741.4 mm ⁴
CG (Relative to origin)	X = 48.035mm Y = 93.07mm
Shear centre (Relative to origin)	X = 48.035mm Y = 93.07mm

5.9 GEOMETRICAL MODEL OF UNIFORM SPAR

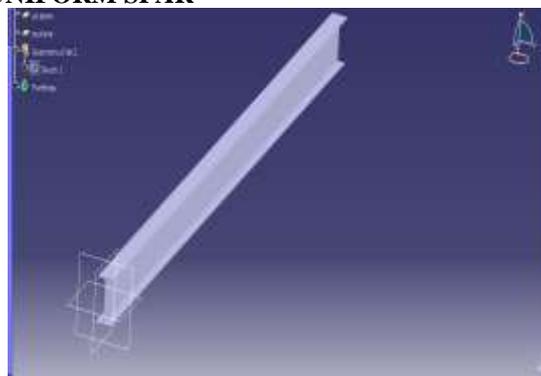


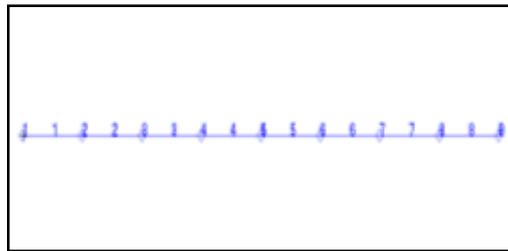
Fig: 5.3 Design of uniform spar

5.10 Finite element model of the spar

Finite element meshing is carried out for all the components of the spar. Fine meshing is done at the critical sections where stresses are expected to be more. We can analyze the spar beam in one dimensionally as a beam element and two dimensionally.

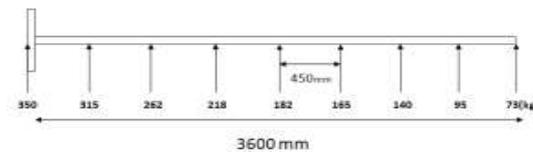
The following figures show the details about the finite element mesh generated on the structure using FEM.

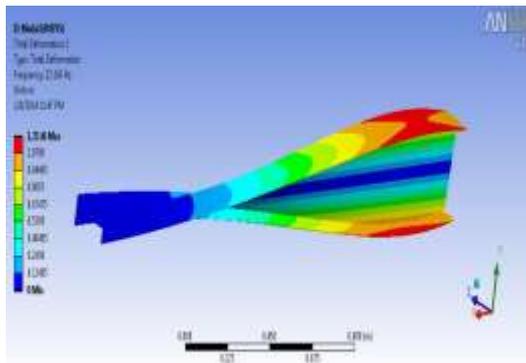
5.10.1 One dimensional Finite Element Model of the Spar



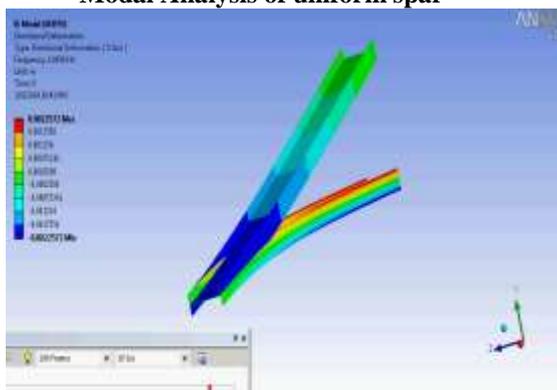
One dimensional Finite Element Model of the Spar

Total numbers of nodes created are 9 at each 450mm and total numbers of elements are 8.





Modal Analysis of uniform spar



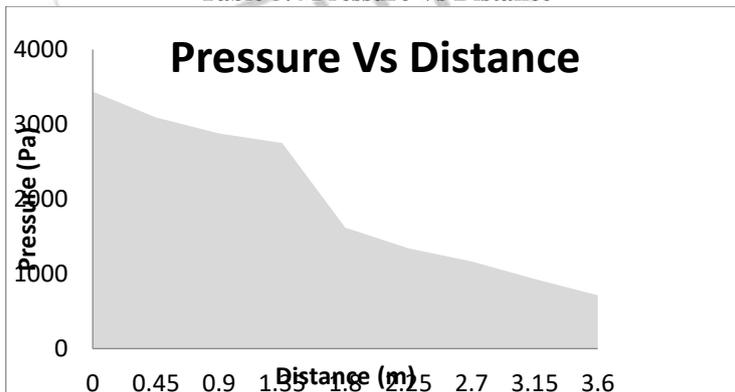
Directional Deformation

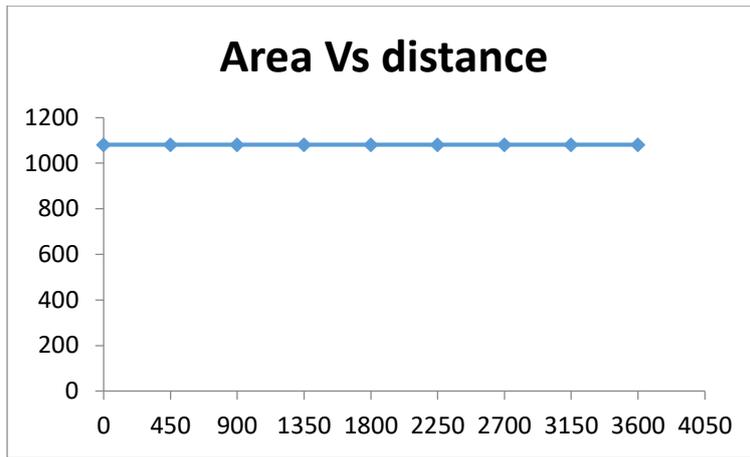
Displacement contour of spar is shown in fig 5.6 and is 158mm at the free end. This value is same as in one dimensional analysis.

5.11 Properties of spar beam

X [m].	Pressure [Pa]
0	3434
.450	3090
.900	2875
1.350	2750
1.800	1619
2.250	1343.
2.700	1167
3.150	932
3.600	716.16

Table 5.4 Pressure Vs Distance





5.12 Results for uniform wing Spar.

Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Elastic Strain	Maximum Principal Elastic Strain	Minimum Principal Elastic Strain
Minimum	0. m	-1.5038e-003 m	1.6437e-006 m/m	1.6285e-006 m/m	-6.7206e-004 m/m
Maximum	8.7473e-002 m	1.5944e-003 m	6.5041e-004 m/m	6.7492e-004 m/m	1.4418e-006 m/m

Tabulation: 5. 5

Type	Maximum Shear Elastic Strain	Elastic Strain Intensity	Normal Elastic Strain	Shear Elastic Strain	Strain Energy
Minimum		2.7461e-008 m/m	-6.5147e-004 m/m	-2.522e-004 m/m	1.8397e-008 J
Maximum		8.834e-004 m/m	6.5497e-004 m/m	2.522e-004 m/m	0.29462 J

Tabulation: 5. 6

Type	Equivalent (von-Mises) Stress	Maximum Principal Stress	Minimum Principal Stress	Maximum Shear Stress	Stress Intensity
Minimum	3687.4 Pa	-2.4408e+007 Pa	-1.4219e+008 Pa	2112.4 Pa	4224.7 Pa
Maximum	1.3008e+008 Pa	1.4302e+008 Pa	2.4408e+007 Pa	6.7954e+007 Pa	1.3591e+008 Pa

Tabulation: 5. 7

Type	Normal Stress	Shear Stress
Minimum	-1.3902e+008 Pa	-1.94e+007 Pa
Maximum	1.3995e+008 Pa	1.94e+007 Pa

Tabulation: 5. 8

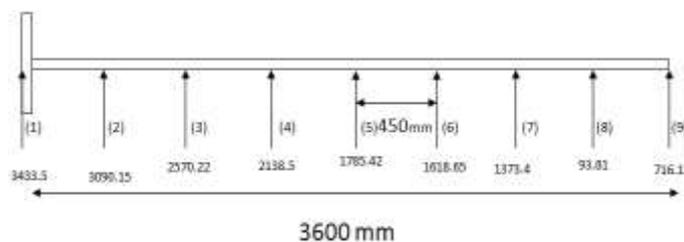
Mass of the tapered spar beam is 21.977 kg.

Weight of the tapered spar beam is 215.562kN.

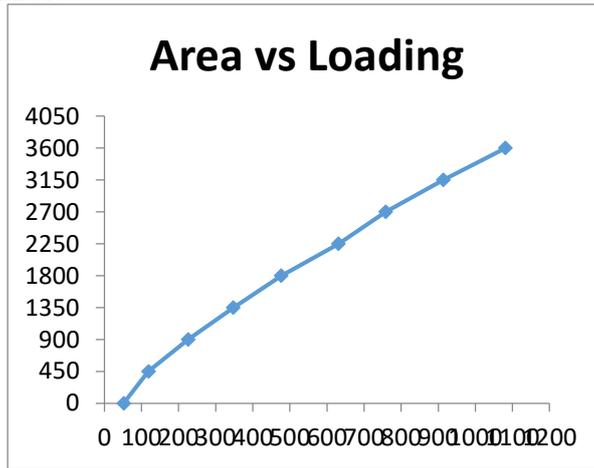
6. DESIGN OF TAPERED SPAR

Stress analysis of the uniform spar shows that stress values at other stations on the beam except at the fixed end is lower than the design stress value. So our aim is to design a beam in such a way that the designed stresses at every station should be same for the same loads acting on the beam. Unwanted material can be removed so that weight of the beam can be optimized through this method. For this maximum bending moment at corresponding station is calculated that leads to determine the cross-section dimensions.

6.1 Calculations

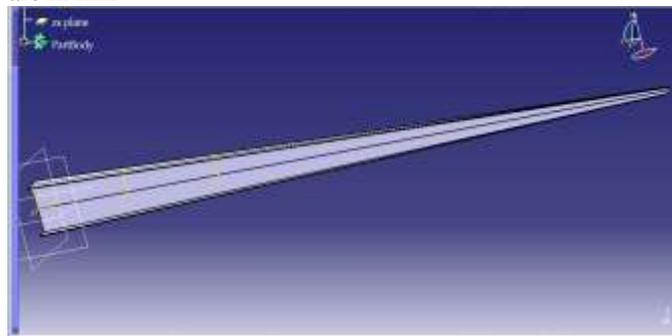


6.2 TAPERED BEAM CROSSECTIONS



Geometric configuration of the tapered beam

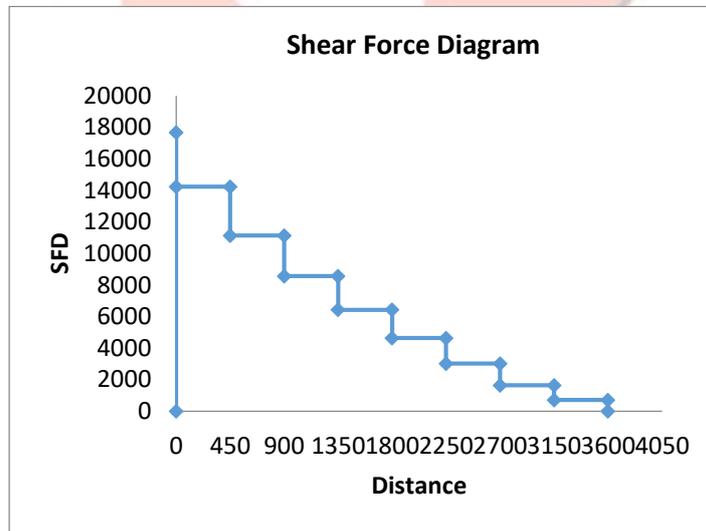
Geometric modeling is carried out by using CATIA V5 software. Each cross-section and its dimensions of CAD model are shown below. All dimensions are in mm



Design of tapered beam

6.3 Shear force and bending moment of tapered section

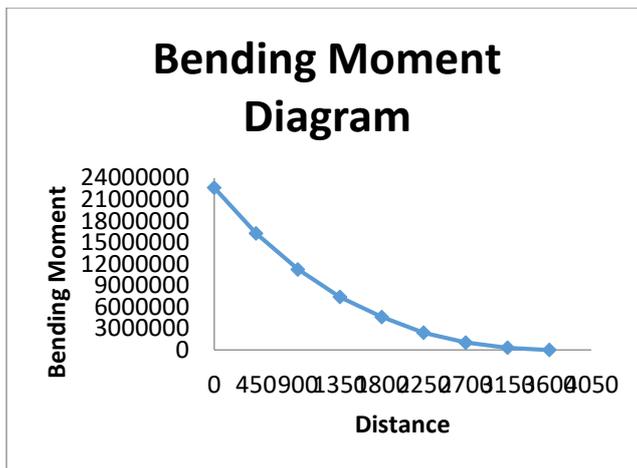
6.3.1 Shear force diagram



Shear force diagram of tapered spar

The shear force diagram of the spar is plotted in the above figure.

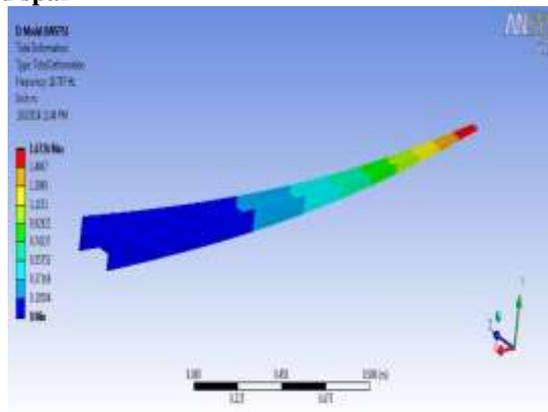
6.3.2 Bending moment diagram



bending moment diagram of tapered spar

The bending moment diagram of the spar is plotted in the above figure.

6.3.3 Displacement contour of tapered spar



Displacement contour of tapered spar

6.4 Results of Tapered Section

Type	Total Deformation				
Mode	1.	2.	3.	4.	5.
Minimum	0 m				
Maximum	1.6726 m	1.2146 m	2.8717 m	1.6626 m	2.841 m
Reported Frequency	10.707 Hz	23.143 Hz	28.626 Hz	41.63 Hz	47.984 Hz

Table 6. 1

Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Elastic Strain	Maximum Principal Elastic Strain	Minimum Principal Elastic Strain
Minimum	0 m	-6.0868e-005 m	1.2028e-007 m/m	8.0179e-008 m/m	-5.9007e-005 m/m
Maximum	3.7324e-003 m	6.0974e-005 m	5.9987e-005 m/m	6.3645e-005 m/m	-4.2451e-008 m/m

Table 6. 2

Type	Maximum Shear Elastic Strain	Elastic Strain Intensity	Normal Elastic Strain	Shear Elastic Strain	Strain Energy
Minimum	1.5768e-007 m/m		-5.4327e-005 m/m	-3.3352e-005 m/m	4.818e-011 J
Maximum	8.292e-005 m/m		5.9797e-005 m/m	3.1453e-005 m/m	8.236e-004 J

Table 6. 3

Type	Equivalent (von-Mises) Stress	Maximum Principal Stress	Minimum Principal Stress	Stress Intensity	Normal Stress
Minimum	24957 Pa	-3.2731e+006 Pa	-1.2693e+007 Pa	24258 Pa	-1.1943e+007 Pa
Maximum	1.1697e+007 Pa	1.3962e+007 Pa	3.252e+006 Pa	1.2757e+007 Pa	1.337e+007 Pa

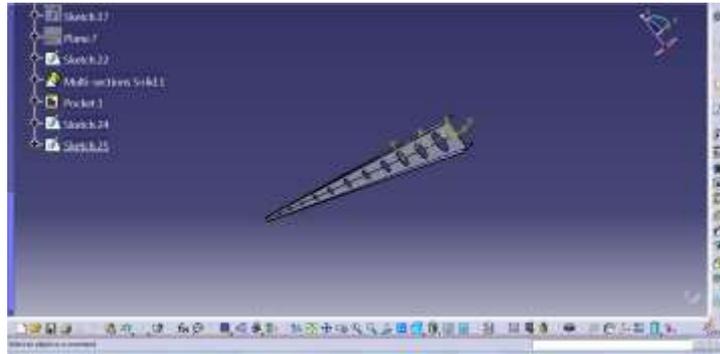
Table 6. 4

Mass of the tapered spar beam is 10.329 kg.
 Weight of the tapered spar beam is 101.3279kg

7. WEIGHT OPTIMISATION

Weight optimization of the tapered beam can be done again by introduction of cut outs. These are also known as lightening holes introduced on the minimum stress regions in the web. The introduction of lightening holes is done to enhance the weight reduction. Cut outs introduced are circular and its dimensions determined based on the minimum stress region as shown in figure. Holes are carefully placed considering the various strength of material aspects on the spar web. Thus reducing the material used and there by weight.

7.1 Geometrical model of tapered spar with cut outs



Design of tapered spar with cut outs

7.2 Properties of the tapered spar with cut-outs

The above designed tapered spar has a mass of 9.3025 kg. Introduction cut outs reduces 10% percentage of weight of the tapered spar design.

7.3 Result obtained from the finite element analysis for the tapered spar

7.3.1 Displacement contour of tapered spar with cut-outs

It can be seen that the deflection pattern has not changed by a lot from that of the tapered spar. This is due to the fact that the material removal is made such that it is from or from the vicinity of the neutral axis.

7.3.2 Results from Analysis

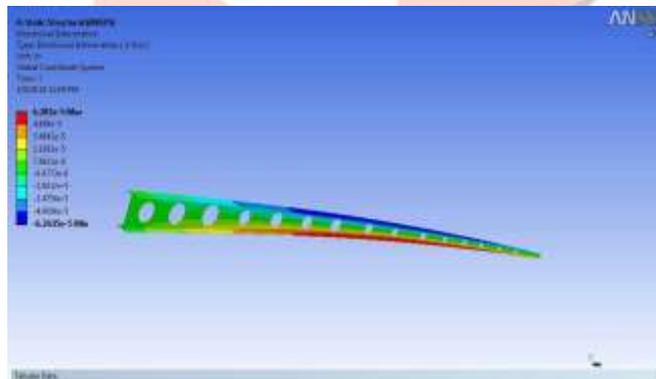


Fig 7.2 Directional Deformation of the spar

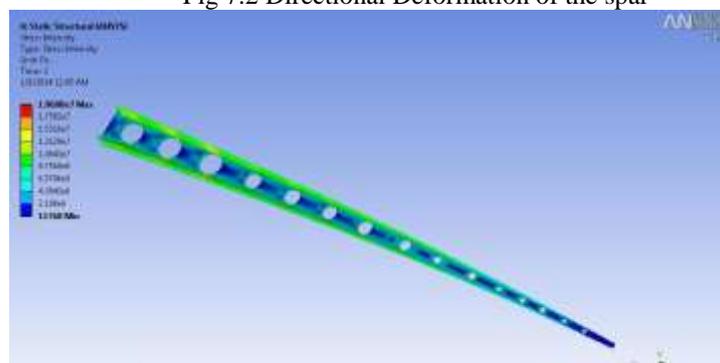


Fig. 7.3 stress intensity of spar

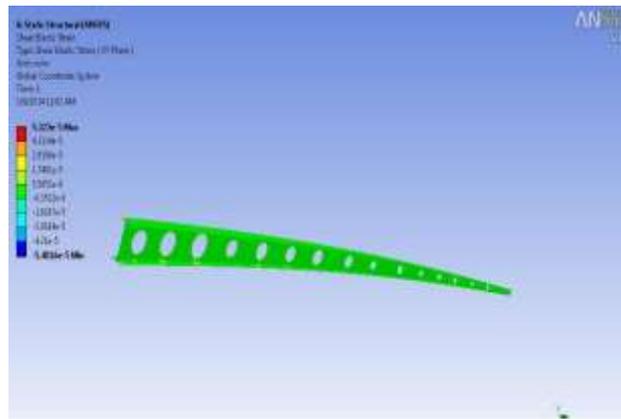


Fig. 7.4 Shear Elastic Strain of Spar

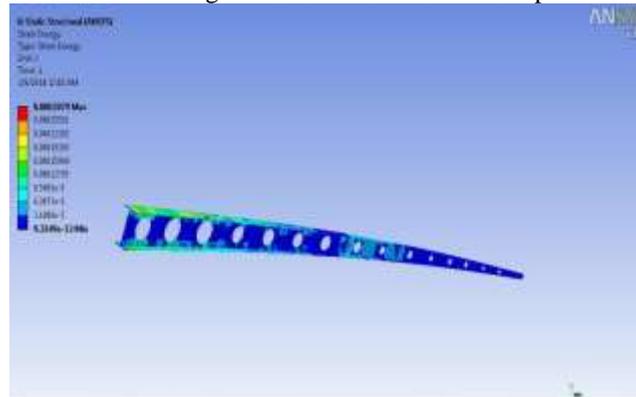


Fig.7.5 Strain Energy of Spar

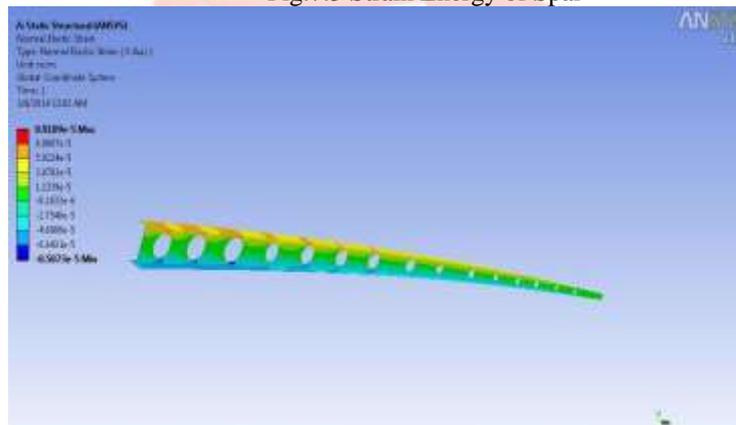
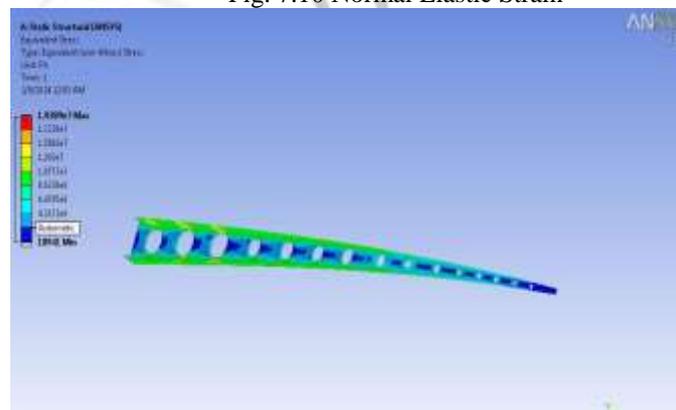
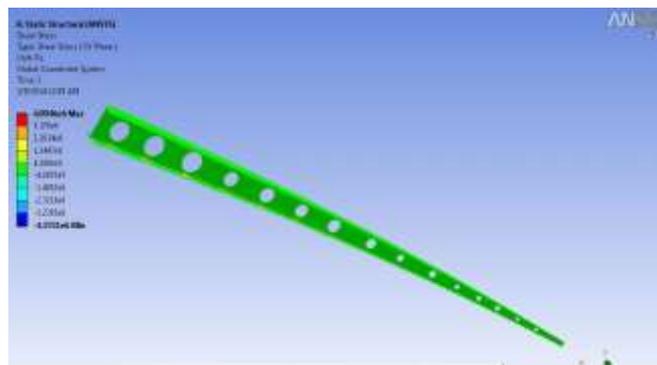


Fig. 7.10 Normal Elastic Strain



Equivalent Stress



Shear Stress of Spar

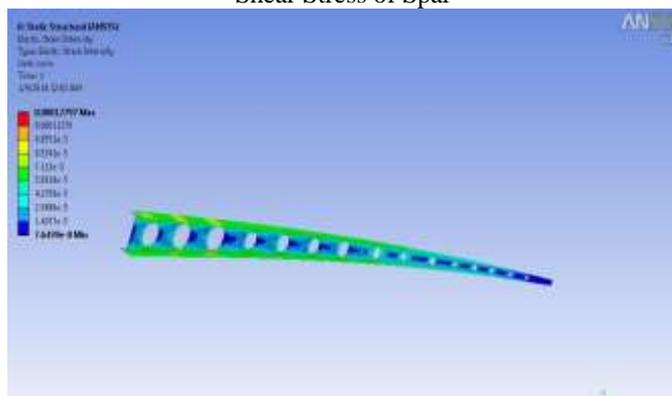


Fig. 7.13 Elastic Strain Intensity

7.5 Results of Tapered Section (with cutouts).

Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Elastic Strain	Maximum Principal Elastic Strain	Minimum Principal Elastic Strain
Minimum	0. m	-6.2635e-005 m	5.4703e-008 m/m	1.6656e-008 m/m	-9.7518e-005 m/m
Maximum	3.8629e-003 m	6.282e-005 m	9.6947e-005 m/m	9.3916e-005 m/m	-3.2233e-009 m/m

Table 7. 1

Type	Elastic Strain Intensity	Normal Elastic Strain	Shear Elastic Strain	Strain Energy	Equivalent (von-Mises) Stress
Minimum	7.6439e-008 m/m	-8.5873e-005 m/m	-5.4016e-005 m/m	9.3349e-013 J	10941 Pa
Maximum	1.2797e-004 m/m	8.9109e-005 m/m	5.323e-005 m/m	2.679e-004 J	1.9389e+007 Pa

Table 7,2

Object Name	Maximum Principal Stress	Stress intensity	Normal Stress	Shear Stress
Minimum	-5.4806e+006 Pa	11760 Pa	-1.7894e+007 Pa	-4.1551e+006 Pa
Maximum	1.9118e+007 Pa	1.9689e+007 Pa	1.7801e+007 Pa	4.0946e+006 Pa

Table 7.3

Mass of the tapered spar beam is 9.3025 kg.
 Weight of the tapered spar beam is 91.257kN

8. RESULT AND DISCUSSION

The primary aim of my project is to design an aircraft spar beam was to increase the structural properties of the prototype design of spar without compromising its strength or load carrying capability. The conceptual design started with the collection of design parameters from the existing aircraft spar. This is probably the most important phase since it helps us to roughly size our aircraft spar and to modify and improve its design. A spar beam is designed using simple strength of material approach. Series of stress analysis has been done with the help of finite element method. This results weight of the uniform spar the mass of 62.096 kg has reduced to 10.329 kg by introducing a tapered section. And again by introducing cut outs in the tapered section again the mass of the same spar beam can be optimized from 10.329 kg to 9.3025 kg. So 1 weight reduction of 9.93% percentage could be obtained by introducing cut outs and structurally an efficient beam has been designed and optimized.

REFERENCES

- [1] T.H G MEGSON, Aircraft structures for engineering students.
- [2] Sridhar Chinthapalli , Mosthafa S A Elsayed ,Ramin Sedaghati “Development of a preliminary structural design optimization method of aircraft wing box stringer panels” Elsevier journal, Aerospace science and technology in 17 December 2009.
- [3] G. Schuhmacher , I.Murra , L.Wang “ Multidisciplinary design and optimization of wing box” in 6 September 2002
- [4] Robert H.Sues and Mohammed A Aminpour “Reliability based MDO for aerospace systems” in 19 April 2001.4
- [5] Robert M. Taylor and Terrence A Weisshaar “Improved structural design using evolutionary finite element modeling”.
- [6] J.T. Staley and D J Lege “Advances in aluminum alloy products for structural applications in transportation” volume 3 in November 1993.
- [7] Sean Wakamaya “ Journal of aircraft” Vol. 32 No. 4 August 1995
- [8] F Hurlimann , R Kelm , M Dugas , G Kress “ Investigation of local load introduction method in aircraft pre design ” in 28 April 2011.
- [9] Abbani Rinku , Prasanth R “ Structural optimization of aircraft components” in 2008
- [10] T H G Megson “aircraft structures for engineering students”
- [11] S Timoshenko “Strength of materials”
- [12] William D. Callister “Fundamentals of material science and engineering”
- [13] R Ramamrutham “Strength of materials”
- [14]Cláudio H. S. Del Menezzi “Flexural properties of I – beams” WCTE in 2010
- [15] Milan stefanovic and Robert N.Yancey “ Simulation driven weight optimization of composite UAV spar”. Altair Engineering.

