ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

# Design and Fabrication of Multipurpose Vehicle

**Ali Imran S[1*], Bilal U[1], Gohar M[2]**

[1]COMSATS University of Science & Technology, Sahiwal, Punjab, Pakistan

[2]Department of Mathematics, Shanghai University, Shanghai, China

**Abstract**: In the era of mechanical world you have to deal with new technology and ideas so the first thing is design which should be stable in surrounding. To get the final product we will use such a frame which can be modified for car, boat and as well as for helicopter. Frame have to deal with three type of moving objects so it is important to analysis before it's fabrication, that it can bear forces. We should have to visualize it's modification and material.

**Keywords:** Fabrication; Design analysis; Meshing; Simulation; Shear stress

## I. INTRODUCTION

We have to analysis different materials for best result that can help to bear the forces. The software solid works is used here to check elasticity of different materials. This belongs to static simulation in solid works [1,2]. There are different types of helicopter and here we are dealing with a flying machine having rotor above and tail rotor. Helicopter is such a vehicle which don't need runway and can make stable itself by different mechanisms. But there are complexions for its flight so we have to deal with different theories to solve complexions like momentum theory of hover, vortex theory, moment theory of climb, element theory, dynamic theories for blades power losses due to drag and flight for forward, rear, and right side [3]. In fluid dynamics, the momentum theory or disk actuator theory is a theory describing a mathematical model of an ideal actuator disk; the rotor is modeled as an infinitely thin disc, inducing a constant velocity along the axis of rotation. The basic state of a helicopter is hovering. This disc creates a flow around the rotor. Under certain mathematical premises of the fluid, there can be extracted a mathematical connection between power, radius of the rotor, torque and induced velocity. The rotor is modeled as an infinitely thin disc, inducing a constant velocity along the axis of rotation. The basic state of a helicopter is hovering. This disc creates a flow around the rotor. Under certain mathematical premises of the fluid, there can be extracted a mathematical connection between power, radius of the rotor, torque and induced velocity [4]. For a helicopter it is important study about the blades and blade element theory is an important article it is a mathematical process It involves breaking a blade down into several small parts then determining the forces on each of these small blade elements. These forces are then integrated along the entire blade and over one rotor revolution in order to obtain the forces and moments produced by the entire propeller or rotor. One of the key difficulties lies in modeling the induced velocity on the rotor disk. Because of this the blade element theory is often combined with the momentum theory to provide additional relationships necessary to describe the induced velocity on the rotor disk [5]. Blades have very importance for the flight of helicopter, blades we are going to use made of aluminum and have all properties of aerodynamics, symmetrical blade of naca with airfoil database coordinates(naca 0012) [6]. Data are presented for lift coefficients from near zero through maximum values at Mach numbers from 0.30 to 0.86 and Reynolds numbers of 3.0 × 10 to the sixth power with transition fixed. A limited amount of data is presented near zero and maximum lift for a Reynolds number of 6.0 × 10 to the sixth power with transition fixed. In addition, transition free data is presented through the Mach number range from 0.30 to 0.86 for near zero lift and a Reynolds number of 3.0 × 10 to the sixth power [7]. The analysis of the two dimensional subsonic flow over a National Advisory Committee for Aeronautics (NACA) 0012 air foil at various angles of attack and operating at a Reynolds number of $3 \times 10^6$ is presented. The flow was obtained by solving the steady-state governing equations of continuity and momentum conservation combined with one of three turbulence models [shear stress transport (SST)] aiming to the validation of these models through the comparison of the predictions and the free field experimental measurements for the selected air foil. The aim of the work was to show the behaviour of the air foil at these conditions

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Vol. 6, Issue 8, August2017

and to establish a verified solution method. The computational domain was composed of 80000 cells emerged in a structured way, taking care of the refinement of the grid near the air foil in order to enclose the boundary layer approach. Calculations were done for constant air velocity altering only the angle of attack for every turbulence model tested. This work highlighted two areas in computational fluid dynamics (CFD) that require further investigation: transition point prediction and turbulence modelling. The laminar to turbulent transition point was modeled in order to get accurate results for the drag coefficient at various Reynolds numbers. In addition, calculations showed that the turbulence models used in commercial CFD codes does not give yet accurate results at high angles of attack [8]. A comprehensive data base is given for the low speed aerodynamic characteristics of the NACA 0012 airfoil section. The Langley low-turbulence pressure tunnel is the facility used to obtain the data. Included in the report are the effects of Mach number and Reynolds number and transition fixing on the aerodynamic characteristics. Presented are also comparisons of some of the results with previously published data and with theoretical estimates The Mach number varied from 0.05 to 0.36. The Reynolds number, based on model chord, varied from 3 × 10 to the 6th to 12 × 10 to the 6th power [9]. To get actual results of helicopter blades, 8in × 10 feet cord and length of blade respectively simulated done in software solid works the results were close to actual report the results are for maximum and minimum rpm and also for maximum angle of attack and for minimum angle of attack [10]. A portable boat for all commercial and recreational uses, with particular application to shallow water situations. The boat comprises a multi-tube flotation perimeter hull constructed of connected, epoxy-laminated foam cores and totally encased with a vinyl polyester fabric; a reinforced floor portion and, a full rear transom means. This water craft is strong, yet flexible, unsinkable and virtually impervious to punctures and abrasion damage. These positive benefits are accomplished without sacrificing the advantages of lightweight construction and ease of transportation [11]. Mechanism for transmitting power to two members from a common power source, one of these members having to be driven continuously and the other having either to be halted, to be driven by said common power source, or to be used as a motor for driving the rest member which is then disconnected from the source. Such a power transmitting mechanism can be applied to helicopters with advantage, the first continuously driven member being the hydraulic, electrical or pneumatic ancillary systems and the second member the rotor or rotors [12]. A model helicopter rotor pitch control mechanism is provided. The mechanism comprises a seesaw; a stabilizer bar attached to said seesaw; a mixing lever pivotally supported by said stabilizer bar, said mixing lever having a first end and a second end; an upper swash lever to which said first end is connected by way of a rod and a main rotor grip to which said second end is connected by way of said rodn [13]. A stabilizer bar has an aerodynamically shaped member, such as a winglet, on opposite ends thereof, and the bar is connected to rotate on its longitudinal axis and is mounted to tilt about a pivot axis at right angles thereto connecting it to a rotor shaft that also carries a pair of rotor blades the pitch of which can be changed about their longitudinal axis, that is parallel with the stabilizer bar pivot axis. A pair of oppositely directed mixing levers on opposite sides of the rotor shaft and connected parallel with the stabilizer bar for tilting movement there with is connected by first control linkages to diametrically opposite sides of a wobble plate assembly, and by second control linkages to vary the pitch of the pair of rotor blades. An arm attached to the stabilizer bar in the plane of the aerodynamically shaped members has an end disposed in alignment with the pivot axis of the stabilizer bar that is connected by a control rod to the wobble plate assembly 90° from the connections of the first control linkages, for cyclic adjustments of the pitch of the aerodynamically shaped members [14].

### 1.1. Objective

- The objective of this project is to design and fabricate such an automative that can fly, run and as well as float on water.
- purpose to facilitate the users for three different rides in a singleoautomotive vehicle.
- This vehicle wold be very helpfull for military purpose. You can take any ride at any time at any situation, whether you want to cross a road or water or mountains.
- Here are some steps we are going to take to complete our objectiveOptimization of the controller gains of 2DOF controllers such as 2DOF-PI, 2DOF-PID and 2DOF-IDD controller in a two area wind thermal system using FPA.

### 1.2. Aim of Work

- Structural designe in software.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

- Simulation of different structure and blades.
- Fabrication.
- Assembling (that make possible to can Fly, run and float over water).

### 1.3. Methodology

The methodology is show in Figure 1.

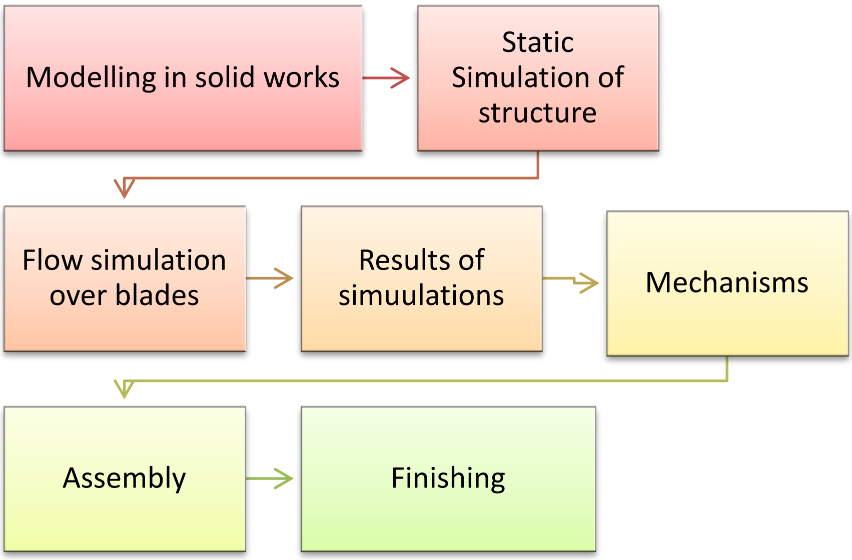



**Figure 1: Methodology.**

### 1.4. Physical Form of Model for Visualize

Physical form of model shown in Figure 2.

**Figure 2: Two area thermal wind system.**

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

## II. STRUCTURE SIMULATION

Here the basic structure is simulated for different materials under 4000 N force from the front side which different nodes which shows that how much force it can bear. First i use Aluminimum (6063-T6) and then steel (ANSI 4130 steel normalized at 870c) and after that i simulate for iron (ductile iron).

Simulation results shows that iron is best to that we can use in our structure and is easily available in Pakistan (Table 1).

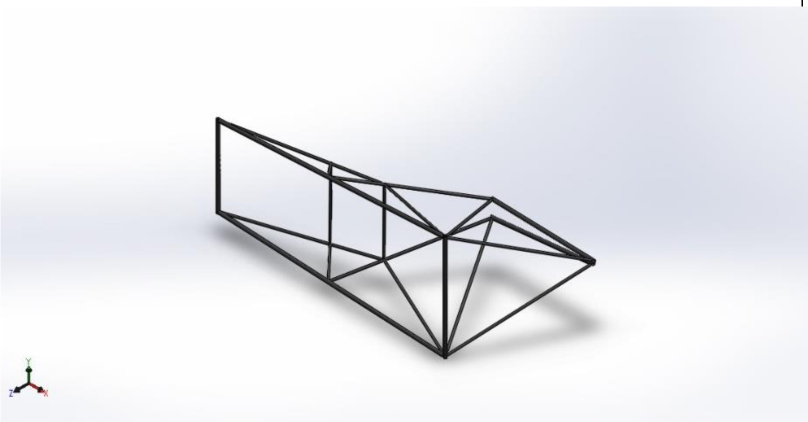
| | | |
|---|---|---|
|  | **Simulation of Chassis** | |
| | Date: Thursday, July 27, 2017<br>Designer: Ali imran<br>Study name: basic frame<br>Analysis type: Static | |
| | **Table of Contents** | |
| | Description | 1 |
| | Assumptions | 2 |
| | Model Information | 2 |
| | Study Properties | 7 |
| | Units | 7 |
| | Material Properties | 8 |
| | Loads and Fixtures | 9 |
| | Connector Definitions | 10 |
| | Contact Information | 10 |
| | Mesh information | 11 |
| | Sensor Details | 11 |
| | Resultant Forces | 12 |
| | Beams | 13 |
| | Study Results | 18 |
| | Conclusion | 19 |

**Table 1: Simulation of chassis.**

### 2.1. Description

It is about the simulation for the structure of vehicle.

### 2.2. Assumptions

In this we assume that the base is fixed and 3500 N force is applied normal to the top plane to check the stability of structure under that force.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

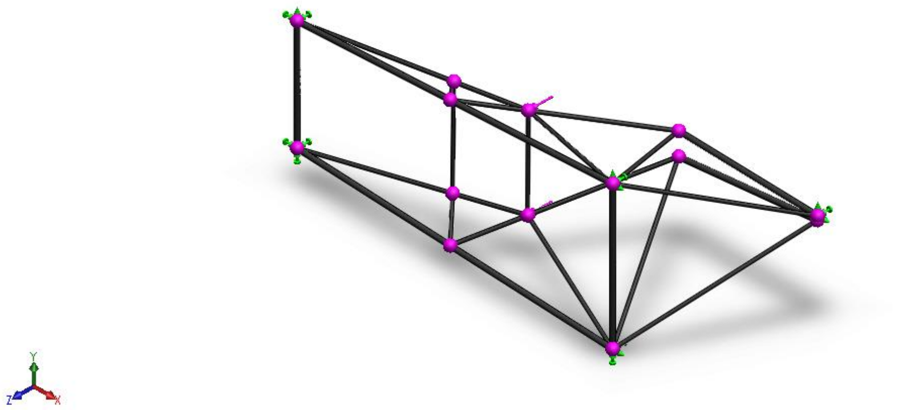
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

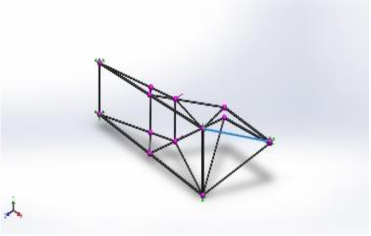
**Vol. 6, Issue 8, August2017**

### 2.3. Model Information

Model information showm in Table 2.




Model name: Chassis 2
Current Configuration: Predeterminado<Como mecanizada>

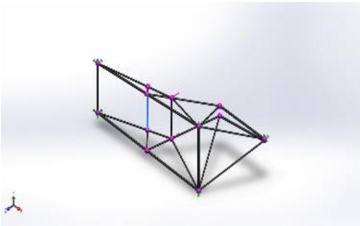
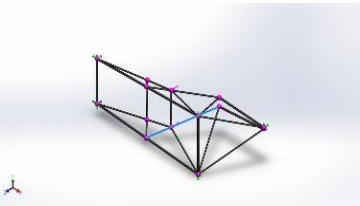
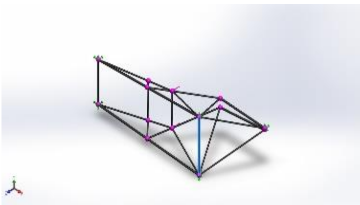
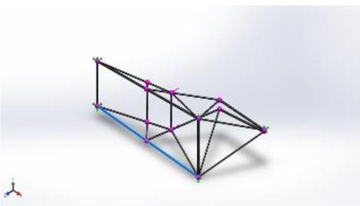
| **Beam Bodies:** | | |
|---|---|---|
| **Document Name and Reference** | **Formulation** | **Properties** |
| Beam-1(Recortar/Extender18)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005m$^2$<br>Length: 841.994 mm<br>Volume: 5.47295e-005 m$^3$<br>Mass Density: 7100 kg/m$^3$<br>Mass: 0.388579 kg<br>Weight: 3.80808 N |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

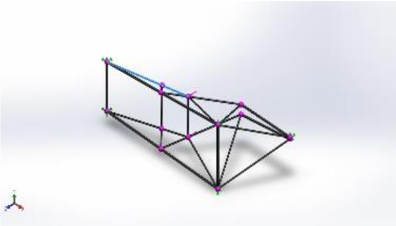
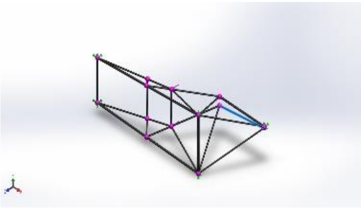
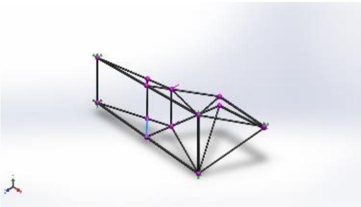
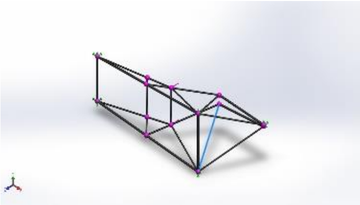
| | | |
|---|---|---|
| Beam-2(Miembro estructural5)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length: 502.075 mm<br>Volume: 3.26402e-005 $m^3$<br>Mass Density: 7100 kg/$m^3$<br>Mass: 0.231745 kg<br>Weight: 2.2711 N |
| Beam-3(Recortar/Extender13)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:884.548 mm<br>Volume:5.74797e-005 $m^3$<br>Mass Density:7100 kg/$m^3$<br>Mass:0.408106 kg<br>Weight:3.99944 N |
| Beam-4(Recortar/Extender13)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:754.507 mm<br>Volume:8.04211e-005 $m^3$<br>Mass Density:7100 kg/$m^3$<br>Mass:0.57099 kg<br>Weight:5.5957 N |
| Beam-5(Recortar/Extender5)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:1619.52 mm<br>Volume:0.000172169 $m^3$<br>Mass Density:7100 kg/$m^3$<br>Mass:1.2224 kg<br>Weight:11.9795 N |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

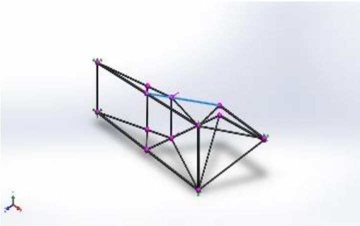
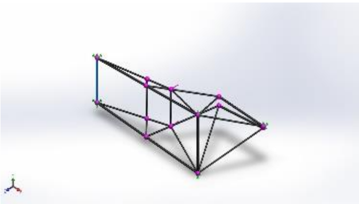
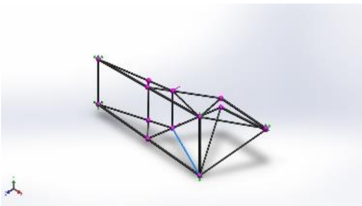
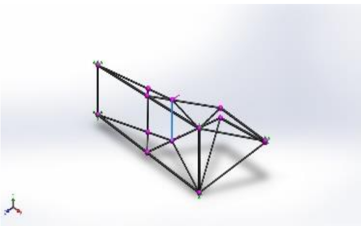
| | | |
|---|---|---|
| Beam-6(Recortar/Extender2)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:969.942 mm<br>Volume:6.31334e-005 $m^3$<br>Mass Density:7100 kg/$m^3$<br>Mass:0.448247 kg<br>Weight:4.39282 N |
| Beam-7(Recortar/Extender19)  | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:735.41 mm<br>Volume:7.8341e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.556221 kg<br>Weight:5.45097 N |
| Beam-8(Miembro estructural5)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:236.633 mm<br>Volume:1.53758e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.109168 kg<br>Weight:1.06985 N |
| Beam-9(Recortar/Extender17)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:859.654 mm<br>Volume:5.54902e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.393981 kg<br>Weight:3.86101 N |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

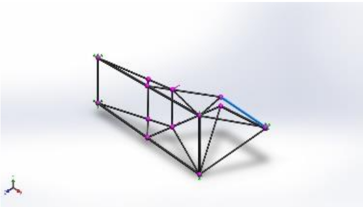
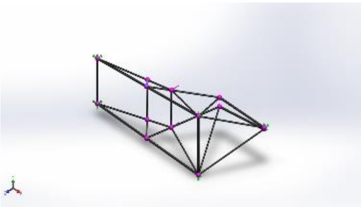
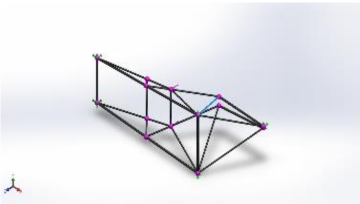
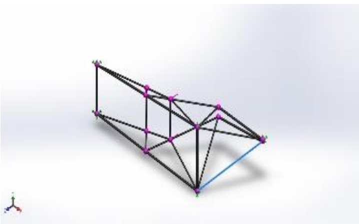
| | | |
|---|---|---|
| Beam-10(Recortar/Extender14)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:884.646 mm<br>Volume:5.74884e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.408168 kg<br>Weight:4.00004 N |
| Beam-11(Recortar/Extender4)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:583.915 mm<br>Volume:6.22305e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.441836 kg<br>Weight:4.33 N |
| Beam-12(Recortar/Extender8)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:728.445 mm<br>Volume:4.7377e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.336377 kg<br>Weight:3.29649 N |
| Beam-13(Miembro estructural7)<br> | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:469.584 mm<br>Volume:3.05191e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.216686 kg<br>Weight:2.12352 N |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

| | | |
|---|---|---|
| Beam-14(Recortar/Extender18)  | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:735.414 mm<br>Volume:7.8367e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.556406 kg<br>Weight:5.45278 N |
| Beam-15(Miembro structural5)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:235.632 mm<br>Volume:1.53185e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.108761 kg<br>Weight:1.06586 N |
| Beam-16(Recortar/Extender15)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:850.724 mm<br>Volume:5.52962e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.392603 kg<br>Weight:3.84751 N |
| Beam-17(Recortar/Extender19)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:861.334 mm<br>Volume:5.59916e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.397541 kg<br>Weight:3.8959 N |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

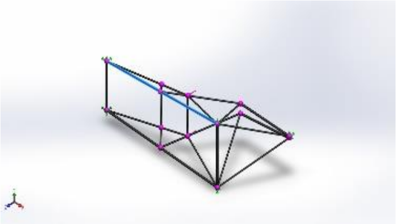
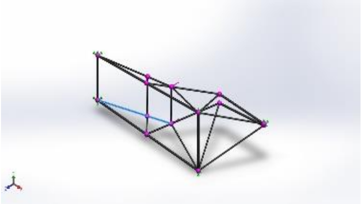
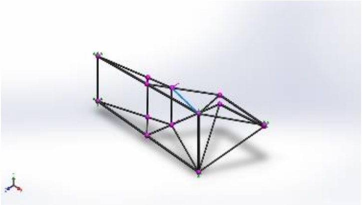
| | | |
|---|---|---|
| Beam-18(Recortar/Extender10)  | Beam – Uniform C/S | Section Standard-iso/pipe/22.2 × 1.65<br>Section Area: 0.000106524 $m^2$<br>Length:1619.52 mm<br>Volume:0.000172158 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:1.22232 kg<br>Weight:11.9788 N |
| Beam-19(Recortar/Extender4)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:968.814 mm<br>Volume:6.3026e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.447484 kg<br>Weight:4.38535 N<br>. |
| Beam-20(Miembro estructural8)  | Beam – Uniform C/S | Section Standard-iso/pipe/14.2 × 1.65<br>Section Area: 6.50545e-005 $m^2$<br>Length:738.248 mm<br>Volume:4.80264e-005 $m^3$<br>Mass Density:7100 kg/ $m^3$<br>Mass:0.340987 kg<br>Weight:3.34168 N |

**Table 2: Model information shown.**

### 2.4. Study Properties

Study properties of modal shown in Table 3.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

| **Study name** | **Basic frame** |
|---|---|
| Analysis type | Static |
| Mesh type | Beam Mesh |
| Solver type | Direct sparse solver |
| In plane Effect | Off |
| Soft Spring | Off |
| Inertial Relief | Off |
| Incompatible bonding options | Automatic |
| Large displacement | Off |
| Compute free body forces | On |
| Result folder | SOLIDWORKS document |

**Table 3: Study properties.**

### 2.5. Units

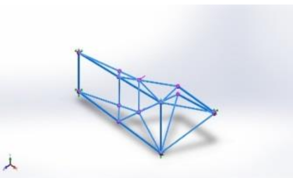
Units for modal shown in Table 4.

| **Unit system:** | **SI (MKS)** |
|---|---|
| Length/Displacement | mm |
| Temperature | Kelvin |
| Angular velocity | Rad/sec |
| Pressure/Stress | $N/m^2$ |

**Table 4: Units for modal.**

### 2.6. Material Properties

Material Properties for modal shown in Table 5.

| **Model Reference** | **Properties** | | **Components** |
|---|---|---|---|
|  | Name: | Ductile Iron | SolidBody 1(Recortar/Extender18)(Chassis 2), |
| | Model type: | Linear Elastic Isotropic | SolidBody 2(Miembro estructural5)(Chassis 2), |
| | Default failure criterion: | Max von Mises Stress | SolidBody 3(Recortar/Extender16)(Chassis 2), |
| | Yield strength: | 5.51485e+008 $N/m^2$ | SolidBody 4(Recortar/Extender13[1])(Chassis 2), |
| | Tensile strength: | 8.61695e+008 $N/m^2$ | SolidBody 5(Recortar/Extender5)(Chassis 2), |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

| | | | |
|---|---|---|---|
| | Elastic modulus: | 1.2e+011 N/m$^2$ | SolidBody 6(Recortar/Extender2)(Chassis 2), |
| | Poisson's ratio: | 0.31 | SolidBody 7(Recortar/Extender19)(Chassis 2), |
| | Mass density: | 7100 kg/m$^3$ | SolidBody 8(Miembro estructural5)(Chassis 2), |
| | Shear modulus: | 7.7e+010 N/m$^2$ | SolidBody 9(Recortar/Extender17)(Chassis 2), |
| | Thermal expansion coefficient: | 1.1e-005 /Kelvin | SolidBody 10(Recortar/Extender14)(Chassis 2), |
| | | | SolidBody 11(Recortar/Extender4)(Chassis 2), |
| | | | SolidBody 12(Recortar/Extender8)(Chassis 2), |
| | | | SolidBody 13(Miembro estructural7)(Chassis 2), |
| | | | SolidBody 14(Recortar/Extender18)(Chassis 2), |
| | | | SolidBody 15(Miembro estructural5)(Chassis 2), |
| | | | SolidBody 16(Recortar/Extender15)(Chassis 2), |
| | | | SolidBody 17(Recortar/Extender19)(Chassis 2), |
| | | | SolidBody 18(Recortar/Extender10)(Chassis 2), |
| | | | SolidBody 19(Recortar/Extender4)(Chassis 2), |
| | | | SolidBody 20(Miembro estructural8)(Chassis 2) |

Curve Data: N/A

**Table 5: Material Properties for modal.**

**2.7. Loads and Fixtures**

Fixtures and Loads for the modal shown in Tables 6a and 6b.

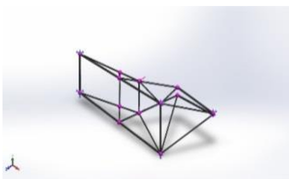
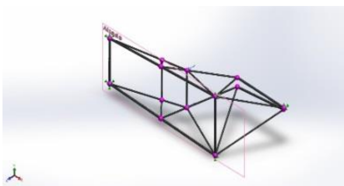
| Fixture name | Fixture Image | Fixture Details | |
|---|---|---|---|
| Fixed-1 |  | Entities: 5 Joint(s)<br>Type: Fixed Geometry | 5 Joint(s)<br>Fixed Geometry |

**Table 6a: Fixtures for the modal.**

| Load name | Load Image | Load Details |
|---|---|---|
| Force-1 |  | Entities: 1 plane(s), 2 Joint(s)<br>Reference: Alzado<br>Type: Apply force<br>Values: ---, ---, 4000 N<br>Moments: ---, ---, --- N.m |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

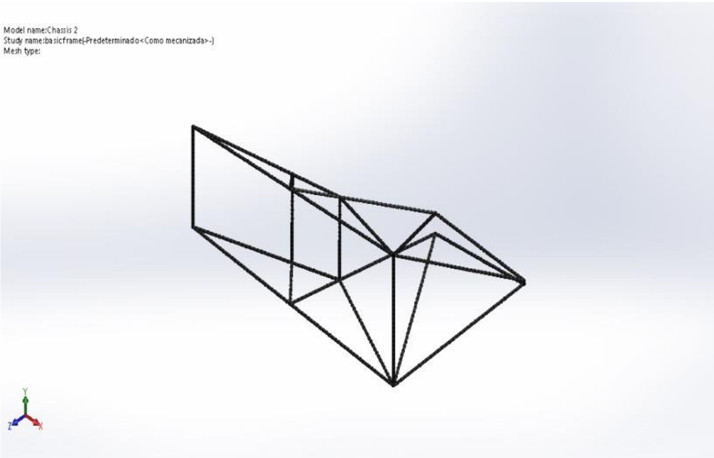
**Table 6b: Loads for the modal.**

### 2.8. Connector Definitions

In this type simulation joint connection are used (Table 7).

Mesh type: Beam Mesh.

| | |
|---|---|
| **Total Nodes** | 654 |
| **Total Elements** | 647 |
| **Time to complete mesh(hh;mm;ss):** | 00:00:05 |
| **Computer name:** | |




Sensor Details: No Data

**Table 7: Simulation joint connection.**

### 2.9. Resultant Forces

Resultant forces are shown in Tables 8a and 8b.

**Reaction forces:**

| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---|---|---|---|---|---|
| Entire Model | N | 0 | 4.58E-05 | -8000 | 8000 |

**Table 8a: Reaction forces.**

**Reaction moments:**

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Vol. 6, Issue 8, August2017

| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---|---|---|---|---|---|
| Entire Model | N.m | 1.974 | -41.8032 | 25.1283 | 48.8143 |

**Table 8b: Reaction forces.**

**Beams:**

Table 9 shows the beams for modal.

| Beam Name | Joints | Axial(N) | Shear1(N) | Shear2(N) | Moment1 (N.m) | Moment2 (N.m) | Torque (N.m) |
|---|---|---|---|---|---|---|---|
| Beam-1 (Recortar/Extender18) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-2 (Miembro estructural5) | 1 | -40.0169 | 0.537179 | -2.66546 | -1.39843 | 1.06968 | -0.0528 |
| | 2 | 40.0169 | -0.53717 | 2.66549 | 2.7367 | -0.8 | 0.052801 |
| Beam-3 (Recortar/Extender16) | 1 | 83.2541 | -2.49757 | 23.1447 | -0.67384 | -0.42627 | -1.62257 |
| | 2 | 1236.2 | -12.3295 | 62.1854 | 19.5964 | 4.39345 | 5.46851 |
| | 3 | -83.2541 | 2.4977 | -23.1447 | -6.37262 | -0.33417 | 1.62257 |
| Beam-4 (Recortar/Extender13) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-5 (Recortar/Extender5) | 1 | -32.2843 | -8.33024 | 27.224 | 10.1458 | 2.58291 | 1.57174 |
| | 2 | 30.3626 | 13.5015 | -21.9962 | -9.29866 | -5.2024 | -1.47819 |
| | 3 | 32.2843 | 8.33023 | -27.224 | 10.7174 | 3.80096 | -1.57175 |
| Beam-6 (Recortar/Extender2) | 1 | -3109.61 | 2.02089 | -13.6337 | -0.51535 | -0.83889 | -2.30182 |
| | 2 | 3109.61 | -2.02093 | 13.6337 | -3.45106 | 0.250515 | 2.30182 |
| | 3 | -3097.82 | -7.07085 | 1.98845 | 0.522619 | 2.52537 | -1.22846 |
| Beam-7 (Recortar/Extender19) | 1 | -1120.78 | 80.9452 | -39.4193 | 21.5301 | 42.3837 | 14.5386 |
| | 2 | 1121.6 | -80.2633 | 41.0491 | 8.19046 | 15.7565 | -14.524 |
| | 3 | 1120.78 | -80.9452 | 39.4193 | -21.315 | -41.942 | -14.5386 |
| Beam-8 (Miembro estructural5) | 1 | -30.7501 | -9.97106 | 19.7017 | -1.25194 | -1.54023 | 0.434858 |
| | 2 | 30.8713 | 9.51257 | -19.7388 | -3.38194 | -0.73978 | -0.44265 |
| Beam-9 (Recortar/Extender17) | 1 | -1123.14 | 2.03797 | 6.54529 | -0.13198 | 0.035793 | 2.26522 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

Vol. 6, Issue 8, August2017

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 1123.14 | -2.03857 | -6.54576 | 5.84027 | -1.81378 | -2.26522 |
| Beam-10 (Recortar/Extender14) | 1 | -54.7123 | 0.596797 | -25.3643 | 6.21567 | 0.027132 | -1.79176 |
| | 2 | -2126.98 | 13.6375 | -56.5479 | 17.9579 | 4.51776 | 5.0185 |
| | 3 | -54.6196 | -0.44915 | -25.5663 | -0.99893 | 0.083215 | -1.88085 |
| Beam-11 (Recortar/Extender4) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-12 (Recortar/Extender8) | 1 | -5511.2 | -9.36763 | 1.99804 | -1.49085 | -0.96445 | -1.84576 |
| | 2 | 5511.21 | -4.81002 | 3.16763 | -0.73142 | -2.21235 | 1.84857 |
| Beam-13 (Miembro estructural7) | 1 | 1732.17 | 1.53026 | -0.48636 | 0.86666 | 6.28292 | 0.010904 |
| | 2 | -1731.84 | 8.28008 | -33.069 | 0.158441 | -4.04222 | 0.068035 |
| Beam-14 (Recortar/Extender18) | 1 | -1963.06 | -76.3519 | -37.4036 | 19.8284 | -40.5568 | -13.6683 |
| | 2 | 1963.06 | 76.3522 | 37.413 | 7.10556 | -14.4167 | 13.6683 |
| Beam-15 (Miembro estructural5) | 1 | 18.4393 | 7.80705 | -19.0907 | -0.74406 | -1.10577 | 0.743421 |
| | 2 | -18.5428 | -8.19836 | 18.8245 | -3.71311 | -0.81325 | -0.74836 |
| Beam-16 (Recortar/Extender15) | 1 | 1996.36 | -1.3643 | 5.89712 | -5.48878 | -1.32482 | 2.10449 |
| | 2 | -1996.36 | 1.36325 | -5.89627 | 0.34605 | 0.134622 | -2.10449 |
| Beam-17 (Recortar/Extender19) | 1 | -1.94264 | 0.097391 | 0.002419 | 0.000927 | -0.0291 | 0.086961 |
| | 2 | 1.94264 | -0.09739 | -0.00242 | 0.001209 | -0.05691 | -0.08696 |
| Beam-18 (Recortar/Extender10) | 1 | -17.6287 | 12.5074 | -15.3478 | 6.49639 | 4.74013 | -1.69907 |
| | 2 | -18.7444 | 6.40297 | -19.133 | -7.52362 | -3.08562 | -1.8066 |
| | 3 | 17.6287 | -12.5074 | 15.3478 | 6.41326 | 5.78034 | 1.69907 |
| Beam-19 (Recortar/Extender4) | 1 | -4575.23 | 3.63362 | 9.34393 | -0.16405 | -1.15494 | 2.52382 |
| | 2 | 4575.22 | -12.3043 | -5.72179 | 2.82964 | -0.15588 | -2.5189 |
| | 3 | -4553.9 | -9.65857 | -1.05629 | -0.17314 | 3.39869 | 0.921853 |
| Beam-20 (Miembro estructural8) | 1 | 4463.51 | -2.41114 | -3.44493 | 0.732984 | -1.3731 | -1.96406 |
| | 2 | -4463.13 | 55.0289 | 20.4017 | 2.2173 | -1.83042 | 1.98254 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Vol. 6, Issue 8, August2017

**Table 9: Beams for modal**.

**Beam stresses:**

Tables 10a- 10c shows the Beam Stresses for modal.

| Beam Name | Joints | Axial(N/m$^2$) | Bending Dir1 (N/m$^2$) | Bending Dir2(N/m$^2$) | Torsional (N/m$^2$) | Upper bound axial and bending (N/m$^2$) |
|---|---|---|---|---|---|---|
| Beam-1 (Recortar/Extender18) | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 |
| Beam-2 (Miembro estructural5) | 1 | 615128 | 7.62046e+006 | 5.82901e+006 | -143861 | 1.02093e+007 |
| | 2 | 615128 | 1.49131e+007 | 4.35941e+006 | 143865 | 1.61523e+007 |
| Beam-3 (Recortar/Extender16) | 1 | -1.27976e+006 | 3.67195e+006 | -2.3229e+006 | -4.42093e+006 | 5.62476e+006 |
| | 2 | 1.90025e+007 | 1.06787e+008 | -2.39412e+007 | 1.48998e+007 | 1.2844e+008 |
| | 3 | -1.27976e+006 | -3.47263e+007 | 1.82097e+006 | 4.42094e+006 | 3.60538e+007 |
| Beam-4 (Recortar/Extender13) | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 |
| Beam-5 (Recortar/Extender5) | 1 | -303072 | 1.98993e+007 | -5.06597e+006 | 1.54135e+006 | 2.08371e+007 |
| | 2 | 285031 | -1.82378e+007 | 1.02037e+007 | -1.44962e+006 | 2.11832e+007 |
| | 3 | -303072 | -2.10205e+007 | 7.45498e+006 | -1.54137e+006 | 2.26064e+007 |
| Beam-6 (Recortar/Extender2) | 1 | -4.78e+007 | -2.80829e+006 | 4.57137e+006 | -6.27164e+006 | 5.31651e+007 |
| | 2 | -4.78e+007 | 1.88059e+007 | 1.36513e+006 | 6.27165e+006 | 6.66554e+007 |
| | 3 | -4.76188e+007 | 2.84791e+006 | -1.37615e+007 | -3.34712e+006 | 6.16719e+007 |
| Beam-7 (Recortar/Extender19) | 1 | 1.05215e+007 | -4.22278e+007 | 8.31289e+007 | 1.42576e+007 | 1.03761e+008 |
| | 2 | 1.05291e+007 | 1.60643e+007 | -3.09038e+007 | -1.42433e+007 | 4.53588e+007 |
| | 3 | 1.05215e+007 | -4.18059e+007 | 8.22625e+007 | -1.42576e+007 | 1.02797e+008 |
| Beam-8 (Miembro estructural5) | 1 | 472682 | 6.82222e+006 | -8.39316e+006 | 1.18484e+006 | 1.12888e+007 |
| | 2 | 474545 | -1.84292e+007 | 4.03126e+006 | -1.20607e+006 | 1.93395e+007 |
| Beam-9 (Recortar/Extender17) | 1 | -1.72647e+007 | -719214 | -195047 | 6.17192e+006 | 1.80098e+007 |
| | 2 | -1.72647e+007 | -3.18254e+007 | -9.88381e+006 | -6.17193e+006 | 5.05895e+007 |
| Beam-10 (Recortar/Extender14) | 1 | -841022 | 3.3871e+007 | -147848 | -4.88192e+006 | 3.47124e+007 |
| | 2 | 3.26954e+007 | -9.78578e+007 | 2.46186e+007 | 1.36737e+007 | 1.33602e+008 |
| | 3 | -839597 | -5.44345e+006 | -453461 | -5.12466e+006 | 6.30191e+006 |
| Beam-11 | 1 | 0 | 0 | 0 | 0 | 0 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

| | | | | | | |
|---|---|---|---|---|---|---|
| (Recortar/Extender4) | 2 | 0 | 0 | 0 | 0 | 0 |
| Beam-12 (Recortar/Extender8) | 1 | -8.47166e+007 | -8.12409e+006 | 5.25558e+006 | - 5.02904e+006 | 9.43925e+007 |
| | 2 | -8.47167e+007 | 3.9857e+006 | -1.20558e+007 | 5.03672e+006 | 9.74142e+007 |
| Beam-13 (Miembro estructural7) | 1 | -2.66265e+007 | -4.72269e+006 | 3.42375e+007 | 29710.7 | 6.11881e+007 |
| | 2 | -2.66213e+007 | 863390 | 2.20273e+007 | 185372 | 4.86655e+007 |
| Beam-14 (Recortar/Extender18) | 1 | 1.84284e+007 | -3.88903e+007 | -7.95456e+007 | - 1.34041e+007 | 1.06972e+008 |
| | 2 | 1.84284e+007 | 1.39364e+007 | 2.82761e+007 | 1.34041e+007 | 4.99524e+007 |
| Beam-15 (Miembro estructural5) | 1 | 283443 | -4.05459e+006 | 6.02566e+006 | 2.02556e+006 | 7.54625e+006 |
| | 2 | 285035 | 2.02338e+007 | -4.43163e+006 | - 2.03902e+006 | 2.09985e+007 |
| Beam-16 (Recortar/Extender15) | 1 | -3.06874e+007 | 2.991e+007 | -7.21931e+006 | 5.73401e+006 | 6.14563e+007 |
| | 2 | -3.06874e+007 | 1.88573e+006 | -733594 | -5.734e+006 | 3.27108e+007 |
| Beam-17 (Recortar/Extender19) | 1 | -29861.7 | 5052.03 | 158595 | 236939 | 188537 |
| | 2 | -29861.7 | -6589.06 | -310138 | -236939 | 340069 |
| Beam-18 (Recortar/Extender10) | 1 | 165491 | -1.27416e+007 | 9.29701e+006 | - 1.66623e+006 | 1.59384e+007 |
| | 2 | -175965 | -1.47564e+007 | 6.05196e+006 | - 1.77168e+006 | 1.61252e+007 |
| | 3 | 165491 | 1.25786e+007 | -1.13372e+007 | 1.66622e+006 | 1.70993e+007 |
| Beam-19 (Recortar/Extender4) | 1 | -7.03291e+007 | -893953 | 6.29359e+006 | 6.87652e+006 | 7.66859e+007 |
| | 2 | -7.0329e+007 | -1.54195e+007 | -849432 | - 6.86311e+006 | 8.57719e+007 |
| | 3 | -7.00013e+007 | -943503 | -1.85205e+007 | 2.51173e+006 | 8.85458e+007 |
| Beam-20 (Miembro estructural8) | 1 | -6.86118e+007 | -3.99425e+006 | -7.48242e+006 | - 5.35138e+006 | 7.70936e+007 |
| | 2 | -6.86059e+007 | 1.20828e+007 | 9.97448e+006 | 5.40172e+006 | 8.42738e+007 |

**Table 10a: Beam Stresses for modal.**

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

# International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

| **Name** | **Type** | **Min** | **Max** |
|---|---|---|---|
| Stress1 | Upper bound axial and bending | 0.000e+000 $N/m^2$ | 1.336e+008 $N/m^2$ |

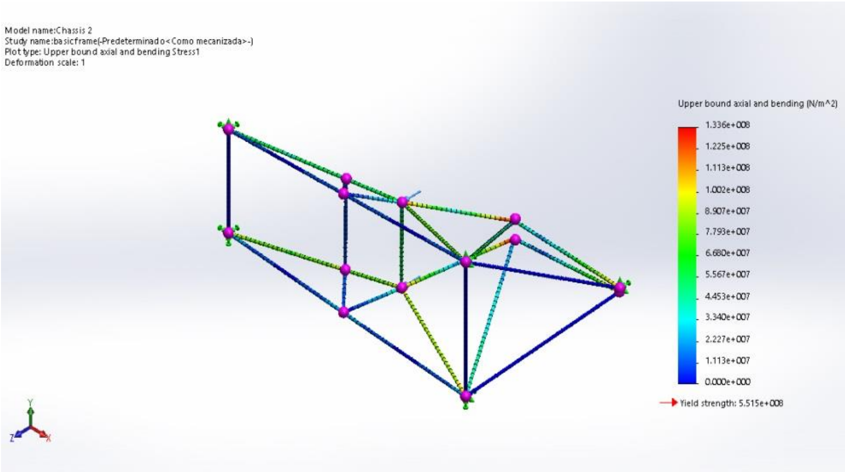
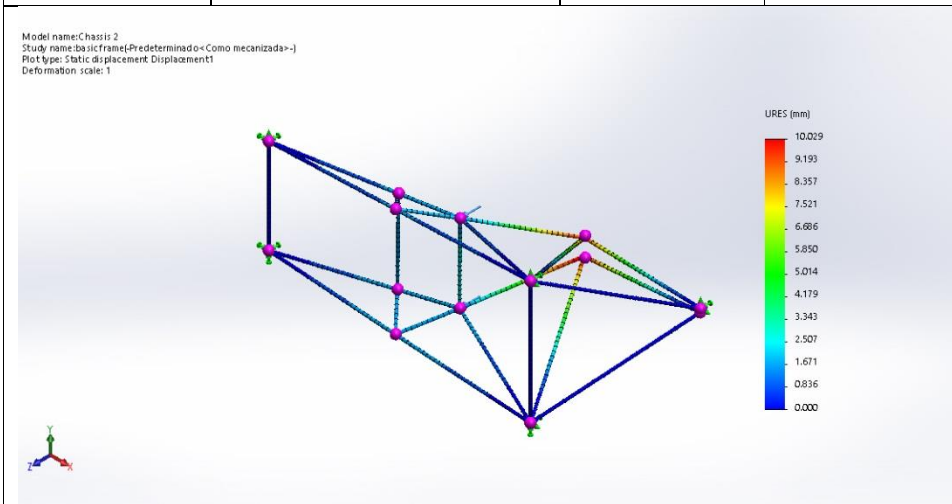



**Table 10b: Stress 1.**

| Name | Type | Min | Max |
|---|---|---|---|
| Displacement1 | URES: Resultant Displacement | 0.000 mm | 10.029 mm |




Chassis 2-basic frame-Displacement-Displacement1

**Table 10c: Displacement 1.**

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Vol. 6, Issue 8, August2017

## III. OVERVIEW

From the simulation of software we come to know that it can bear the force of 4000 N because by applying force it did not cross the elastic limit and from von-mesis theory it is clear that material is below the yielding force in the action of force.

## IV. FLOW SIMULATION

Flow simulation is basically thrust which is created by the blades and thrust is different at different angles. The blade we used for the flow simulation is Naca-0012 it is symmetrical as it is clear from its airfoil four digit section. First digit show the maximum height of the mean camber of blade in percent of cord and here digit is 0. Second digit shows the maximum height of camber from the leading edge intends of cord and here it is 0. Last two digit shows the thickness of blade in percent of cord digits are 12. Here the thrust results are at 650 rpm which is maximum rpm according to our theoretical calculations and at various angles (Table 11).

| $\lambda r$ **Tip speed** | $C_t$ **Thrust coeffecient** | **N rpm** |
|---|---|---|
| 150 | 0.0036 | 470 |
| 160 | 0.00321 | 501 |
| 170 | 0.00271 | 532 |
| 180 | 0.0025 | 564 |
| 190 | 0.0021 | 595 |
| 210 | 0.0018 | 650 |

**Table 11: Flow simulation.**

These calculations should be in specific range and our calculations are in range due to which we get good results.

### 4.1. Standard Values

In flow range = 6.4 to 14.3 m/s
Coefficient of thrust = 0.004 to 0.006
Calculations:
In Flow range = 6.998 m/s
Coefficient of thrust = 0.00434
Induced power = 32.16 hp
Total power = 65 hp

### 4.2. General Information

**Objective of the simulation:**
We want get desired inflow for the flight of vehicle and according to this simulation our climb rate is perfect which we need. These are basic results for every helicopter.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

### 4.3. Analysis Environment

| | |
|---|---|
| **Software Product:** | Flow Simulation 2016 SP4.0. Build: 3501 |
| **CPU Type:** | Intel(R) Core(TM) i3-4030U CPU @ 1.90GHz |
| **CPU Speed:** | 1900 MHz |
| **RAM:** | 8096 MB / 134217727 MB |
| **Operating System:** | Windows 10 (or higher) (Version 10.0.14393) |

| | |
|---|---|
| **Model Information:** | |
| **Model Name:** | Assembly for blades.SLDASM |
| **Project Name:** | blade simulation results |

| | |
|---|---|
| **Project Comments:** | |
| **Unit System:** | SI (m-kg-s) |
| **Analysis Type:** | External (not exclude internal spaces) |

### 4.4. Size of Computational Domain

Table 12 shows size of the computational domain.

| | |
|---|---|
| X min | -3.577 m |
| X max | 3.577 m |
| Y min | -0.498 m |
| Y max | 0.100 m |
| Z min | -3.644 m |
| Z max | 3.638 m |

**Table 12: Computational domain.**

### 4.5. Simulation Parameters

Mesh Settings: Basic Mesh.

Basic Mesh Dimensions (Table 13).

| | |
|---|---|
| **Number of cells in X** | 100 |
| **Number of cells in Y** | 50 |
| **Number of cells in Z** | 50 |

**Table 13: Basic mesh dimensions.**

**Analysis mesh:**

Total Cell count: 407816
Fluid Cells: 407816
Solid Cells: 30806

Partial Cells: 56600
Trimmed Cells: 0

**Additional physical calculation options:**

Heat Transfer Analysis:
Heat conduction in solids: Off
Flow Type: Laminar and turbulent
Time-Dependent Analysis: Off
Gravity: Off
Radiation:
Humidity: Off

### 4.6. Material Settings

Material Settings: Fluids, Air.

### 4.7. Ambient Conditions

The ambient conditions for the modal simulation (Table 14).

| | |
|---|---|
| **Thermodynamic parameters** | Static Pressure: 101325.00 Pa<br>Temperature: 293.20 K |
| **Velocity parameters** | Velocity vector<br>Velocity in X direction: 0 m/s<br>Velocity in Y direction: 0 m/s<br>Velocity in Z direction: 0 m/s |
| **Turbulence parameters** | |

**Table 14: Ambient conditions for the modal simulation.**

### 4.8. Goals

Surface Goals: SG Force (Y) 1(Table 15).

| **Type** | **Surface Goal** |
|---|---|
| Goal type | Force (Y) |
| Faces | Face<3>@blade for simulation-1 |
| | Face<1>@blade for simulation-1 |
| | Face<2>@blade for simulation-2 |
| | Face<2>@blade for simulation-1 |
| | Face<1>@blade for simulation-2 |
| | Face<3>@blade for simulation-2 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Vol. 6, Issue 8, August2017

| | |
|---|---|
| Coordinate system | Global coordinate system |
| Use in convergence | On |

**Table 15: Surface goals: SG force (Y).**

### 4.9. Analysis Time

Calculation Time: 10998 s
Number of Iterations: 93

### 4.10. Results for Minimum Angle

Analysis Goals (Table 16).

| Name | Unit | Value | Progress | Criteria | Delta | Use in convergence |
|---|---|---|---|---|---|---|
| SG Force (Y) 1 | N | 4994.54 | 100 | 272.989 | 262.1 | On |

**Table 16: Analysis goals.**

### 4.11. Global Min-Max-Table

Global Min-Max (Table 17).

| Name | Minimum | Maximum |
|---|---|---|
| Density (Fluid) [kg/m^3] | 0.94 | 1.38 |
| Pressure [Pa] | 78582.59 | 127052.68 |
| Temperature [K] | 275.35 | 320.63 |
| Temperature (Fluid) [K] | 275.35 | 320.63 |
| Velocity [m/s] | 4.30E-04 | 236.214 |
| Velocity (X) [m/s] | -63.266 | 62.065 |
| Velocity (Y) [m/s] | -61.66 | 57.588 |
| Velocity (Z) [m/s] | -236.003 | 235.972 |
| Mach Number [ ] | 1.25E-06 | 0.69 |
| Mach Number RRF [ ] | 0 | 0.88 |
| Velocity RRF [m/s] | 0 | 293.952 |
| Velocity RRF (X) [m/s] | -237.479 | 237.552 |
| Velocity RRF (Y) [m/s] | -61.66 | 57.588 |
| Velocity RRF (Z) [m/s] | -293.626 | 293.778 |
| Vorticity [1/s] | 1.60E-04 | 32805.5 |
| Relative Pressure [Pa] | -22742.41 | 25727.68 |
| Shear Stress [Pa] | 0 | 146.76 |
| Heat Transfer Coefficient [W/m^2/K] | 0 | 0 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An UGC Approved Journal)*

**Vol. 6, Issue 8, August2017**

| | | |
|---|---|---|
| Surface Heat Flux [W/m^2] | 0 | 0 |
| Surface Heat Flux (Convective) [W/m^2] | 0 | 0 |

**Table 17: Global min-max.**

## V. CONCLUSION

**Minimum Angle**

I was required climb rate between 15 to 20 m/s and this simulation has good results at its maximum rpm 650 rpm and at angle of attack nearly 5 degree. These results are for minimum angle.

**Maximum Angle**

Now we simulate at maximum angle between 10 to15 degree at this angle we get 10327 N thrust force which shows that it is good for climb rate.

## VI. REFERENCES

[1] Van De RAJM, Wai CPB, Helicopter rotor. frame and fins 2008; 581: 341.
[2] Kurowski, Engineering Analysis with SolidWorks SimulatioN. SDC publications 2013; 2013.
[3] Johnson W, Helicopter theory. Courier Corporation 2012.
[4] Seddon JM, Newman S, Basic helicopter aerodynamicsi vol. 40: John Wiley & Sons, 2011.
[5] Carpenter PJ, Fridovich B, Effect of a rapid blade-pitch increase on the thrust and induced-velocity response of a full-scale helicopter rotor. 1953.
[6] McAlister KW, Carr LW, Dynamic stall experiments on the NACA 0012 airfoil. 1978.
[7] Harris CD, Two-dimensional aerodynamic characteristics of the NACA 0012 airfoil in the Langley 8 foot transonic pressure tunnel. 1981.
[8] Eleni DC, Athanasios TL, et al. Evaluation of the turbulence models for the simulation of the flow over a National Advisory Committee for Aeronautics (NACA) 0012 airfoil. Journal of Mechanical Engineering Research 2012; 4: 100-111.
[9] Ladson CL, Effects of independent variation of Mach and Reynolds numbers on the low-speed aerodynamic characteristics of the NACA 0012 airfoil section, 1988.
[10] Matsson JE, An Introduction to SolidWorks Flow Simulation. SDC publications 2013; 2013.
[11] Robinson GR, Portable foam tube boat with flexible shell. Google Patents 1997.
[12] Charles FH, Control of rotating wing aircraft. Google Patents 1948.
[13] Kunii M, Kamiya Y, Model helicopter rotor pitch control mechanism. Google Patents 2003.
[14] Kavan F, Stabilizing and control device for two-bladed helicopter rotors. Google Patents 1978.