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Research Article

Design and Structural Analysis of Skid Landing Gear

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Abstract

The undercarriage or landing gear in aviation is the structure that supports an aircraft on the ground and allows it to taxi, takeoff and land. A helicopter is an aircraft that can take off and land vertically also called a rotary aircraft, it can hover and rotate in the air and can move sideways and backwards while aloft. Here the type of landing gear is studied and the designing process is done through CATIA (Computer Aided Three Dimensional Interactive Application). The results from analyzing the stress strain state for the skid landing gear with regards for the physically and geometrically nonlinear scheme of deformation were compared.

Keywords: *The Skid Landing Gear, Composites, Designing, Structural Analysis, landing.*

1. Introduction

The undercarriage or landing gear in aviation 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).

A helicopter is an aircraft that can take off and land vertically. Also called a rotary aircraft, it can hover and rotate in the air and can move sideways and backwards while aloft. It can change direction very quickly and can stop moving completely and begin hovering. Skids are used mainly because they weigh less than wheels.

2. Skid Landing Gear Components

The standard landing gear assembly (landing gear) supports the helicopter when it is in contact with the ground. The landing gear can withstand loads made during landing, ground handling, and provides a stable platform to prevent ground resonance. The landing gear primarily absorbs normal landing forces, with the capabilities to absorb severe landing forces during overload conditions. The landing gear dimensions are based on the required minimum roll-over and minimum pitch-over angles. A minimum angle of 27 degrees is maintained from the center of gravity (CG) location to the skid-to ground contact point.

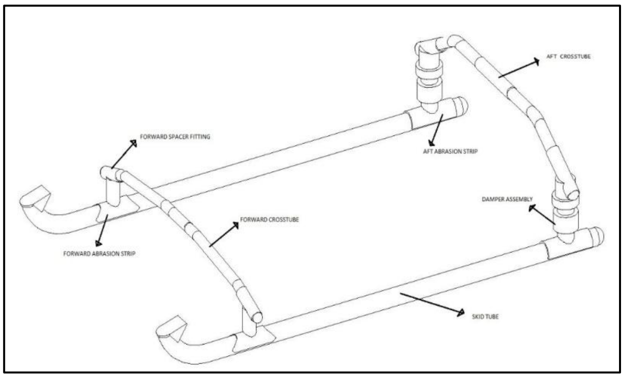

Fig 1. Skid Landing Gear Components

2.1 Parts

1. Forward and Aft Cross Tubes
2. Forward and Aft Saddle Assemblies
3. Side Stop Clamp Assemblies
4. Abrasion Strip
5. Landing Gear Damper Assemblies
6. Skid Tubes

3. Composites

A composite material is made by combining two or more materials to give a unique combination of properties. Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials - matrix and reinforcement. At least one portion of each type is required

3.1 Advantages of Composites

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a. Very high specific strength. This means very high strength and low weight.
b. Great freedom of shape. Double curved and complex parts can be simple produced.
c. Excellent fatigue endurance concerning number of load cycles (many times higher than with metals) and residual fatigue strength (aramide and carbon epoxy laminates retain more than 60% of their residual static strength, which is far more higher than is possible with metals.)
d. Excellent chemical resistance against acids, chemicals etc

3.2Alloy

3.2.1aluminum Alloy 7075

Aluminum alloys have strong corrosion resistance. At sub zero temperatures, their strength increases, thus making them a useful low-temperature alloy and their strength decreases if they are subjected to very high temperatures. The aluminum 7075 alloy has high strength. The following datasheet gives more details about the aluminum 7075 alloy.

Table1. The Chemical Composition of Aluminum Alloy 7075.

Element	Content (%)
Aluminum, Al	90
Zinc, Zn	5.6
Magnesium, Mg	2.5
Copper, Cu	1.6
Chromium, Cr	0.23

Physical Properties: The physical properties of aluminum 7075 alloy are tabulated below.

Table2. The physical Properties of aluminum Alloy 7075 Mechanical Properties

Properties	Metric	Imperial
Density	2.8 g/cm^3	0.101 lb./in^3
Melting point	483°C	900°F

The mechanical properties of aluminum 7075 alloy are outlined in the following table.

Table3. The Mechanical Properties of aluminum Alloy 7075

Properties	Metric	Imperial
Tensile strength	220 MPa	31909 psi
Yield strength	95 MPa	13779 psi
Shear strength	150 MPa	21756 psi
Fatigue strength	160 MPa	23206 psi
Elastic modulus	70-80 GPa	10153-11603 ksi
Poisson's ratio	0.33	0.33
Elongation at break	17%	17%
Hardness	60	60

Applications: Aluminum 7075 alloy is mainly used in manufacturing aircraft and other aerospace applications.

3.2.2Titanium Alloy Ti6Al-4V

Ti6Al-4V is the most widely used of all the alpha-beta titanium alloys. It may be heat treated for high strength in welded construction at service temperatures through 600°F. Harden ability is limited and sections over about one inch may not develop full properties. Chemical Composition: The composition range for Ti6Al4V is provided in below table:

Table4. The Chemical Composition of Titanium Alloy Ti6Al-4V

Material	AMS 4967 min	AMS 4967 max
Aluminum	5.50	6.75
Vanadium	3.50	4.50
Carbon	-	0.08
Nitrogen	-	0.05
Oxygen	-	0.20
Hydrogen	-	0.0125
Iron	-	0.30
Yttrium	-	0.005
Others, each	-	0.10
Others, total	-	0.40
Titanium	Remainder	

Physical Properties of Titanium Ti6Al-4V: The physical properties of Titanium Ti6AL-4V are listed in below table:

Table5. The Physical Properties of Titanium Ti6Al-4V.

Density	4.428784 g/cm^3
Melting point	1609.4 ^{0}C

Mechanical Properties: The mechanical properties titanium alloy Ti6Al-4V, specified, AMS 4911, annealed sheet& plate are provided in below table:

Table6. The Mechanical Properties of Ti6Al-4V.

Size up to inch	Tensile strength MPa	0.2% yield strength ksi	Elongation %	Hardness
>0.025≤0.063	923.897	868.739	10	36
>0.063≤0.184	923.897	868.739	10	36
>0.1874≤4.000	923.897	868.739	10	36

Applications: Typical Applications for the titanium alloy Ti 6Al-4V include:
- ✓ Turbine blades, discs and rings
- ✓ Aircraft structural components
- ✓ Fasteners
- ✓ Medical and dental implant
- ✓ Hand tool
- ✓ Sporting equipment
- ✓

3.2.3 300M Alloy Steel

300M alloy steel is a through hardening alloy having a typical tensile strength of 1900 – 2100 MPa after final heat treatment. It has a density of 7.83 g/cm^3.Chemical Composition: The chemical composition of the 300M alloy steel in wt. % is tabulated below.

Table7. The Chemical Properties of 300M Alloy Steel.

Element	Min.	Max.
C	0.39	0.45
Cu	-	0.35
Si	1.45	1.8
MN	0.6	0.9
P	-	0.01
S	-	0.01
S+P	-	0.025
Cr	0.7	0.95
Mo	0.3	0.5
Ni	1.65	2
V	0.05	0.10

Physical properties: The Physical properties of 300M alloy Steel are listed below.

Table8. The Physical Properties of 300M Alloy Steel.

Density (g/cm^3)	27.67
Specific Gravity	7.83
Specific Heat	0.116
Melting point (^{0}F)	2590
Thermal Conductivity	21
Mean Coefficient Thermal Expansion	6.6
Modulus of Elasticity Tension	29

Mechanical Properties: The typical mechanical properties of the 300M alloy steel after heat treatment is summarized in the below table.

Table9. The Mechanical Properties of 300M Alloy Steel.

	Yield Stress	Tensile Strength	Elongation	Reduction of Area
Longitudinal	1550 MPa Min.	1900 MPa Min. 2100 MPA Max.	8% Min.	30% Min.
Transverse	1550 MPa Min.	1900 MPa Min. 2100 MPA Max.	5% Min.	20% Min.

Applications: The major applications of 300M alloy steel are listed below:
- ✓ Aircraft Landing Gear
- ✓ Drive shafts
- ✓ High Strength bolts
- ✓ Ears

3. Designing

Designing of the landing gear is done in two important steps
- ➢ Part Design.
- ➢ Sketcher.
- ➢ Assembly Design.

CATIA workbench appears as follows:

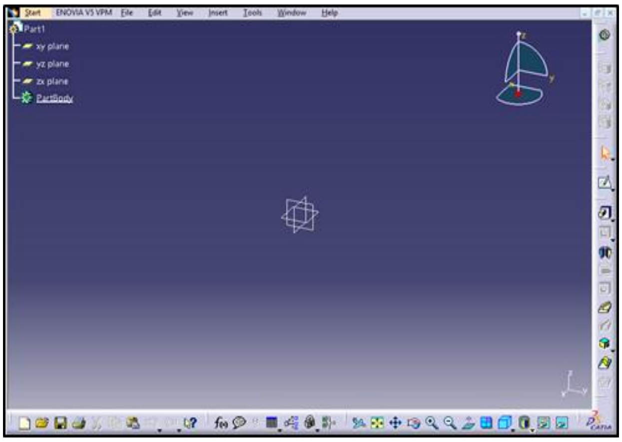


Fig 2. CATIA Work Bench

- ✓ Designing of Skid Tube: This is the important part of the landing gear it is the base
- ✓ Gears

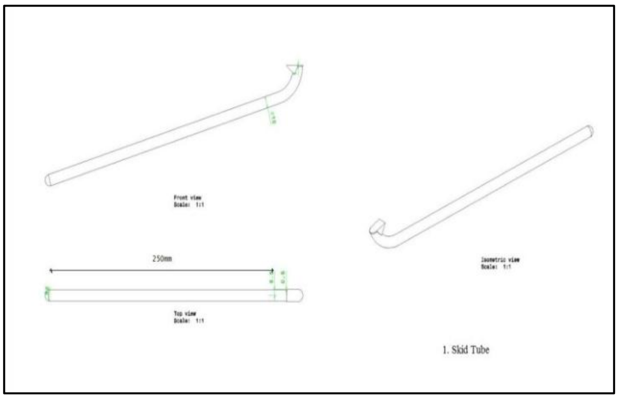


Fig 3. Dimensions of Skid Tube

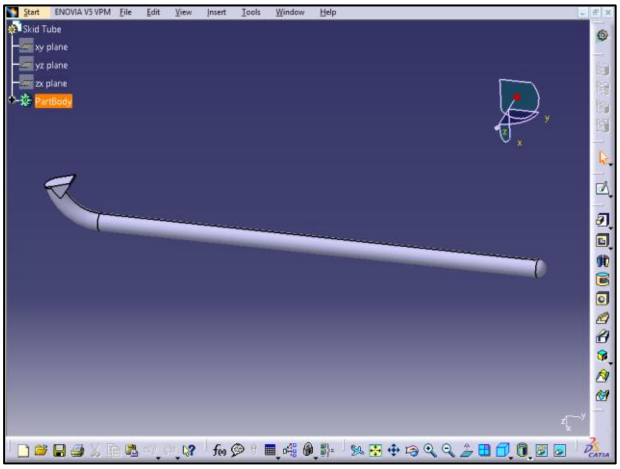


Fig 4. Design of Skid Tube

Designing of Damper Assembly: The landing gear damper assemblies are bidirectional hydraulic units that attach to the aft cross tube assembly and skid tubes

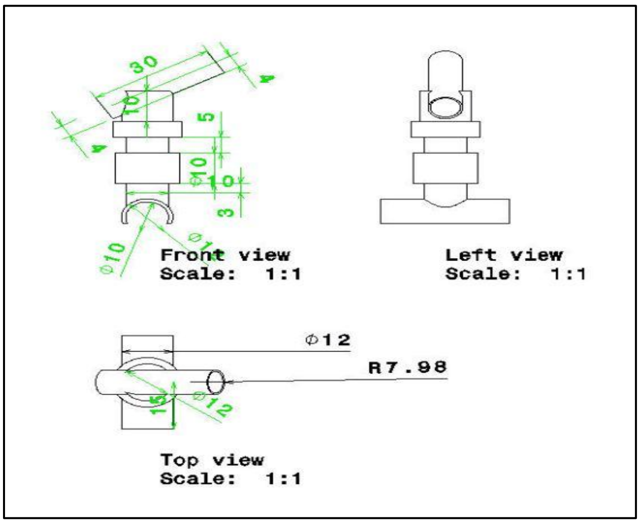


Fig 5. Dimensions of Damper Assembly

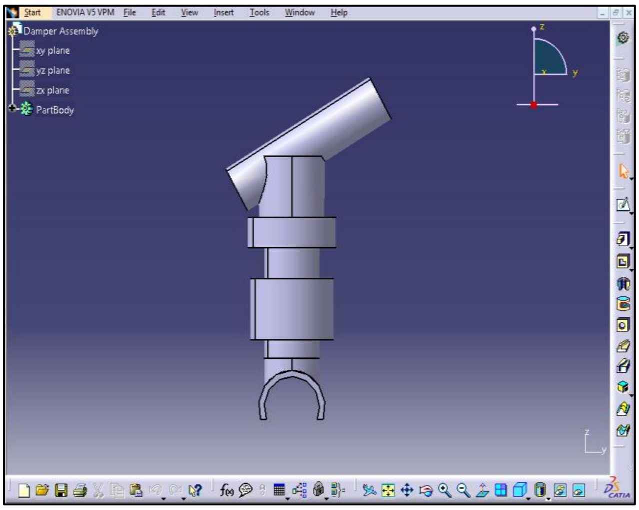


Fig 6. Design of Damper Assembly

Designing of Abrasion Strip: Abrasion strip is the forward attachments for the skid tubes and forward cross tube assembly.

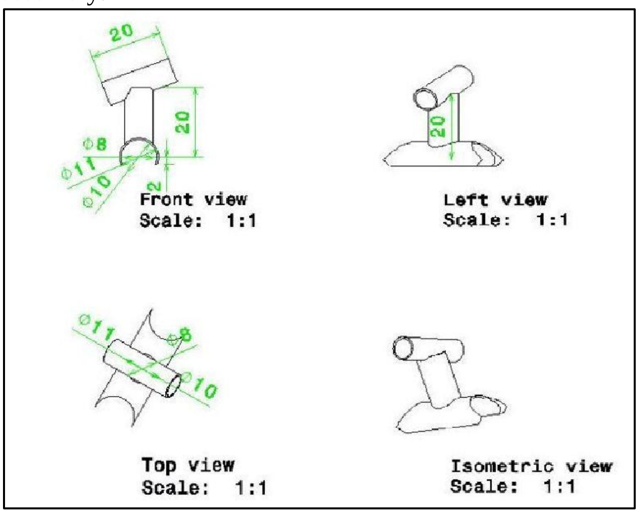


Fig7. Dimensions of Abrasion Strip

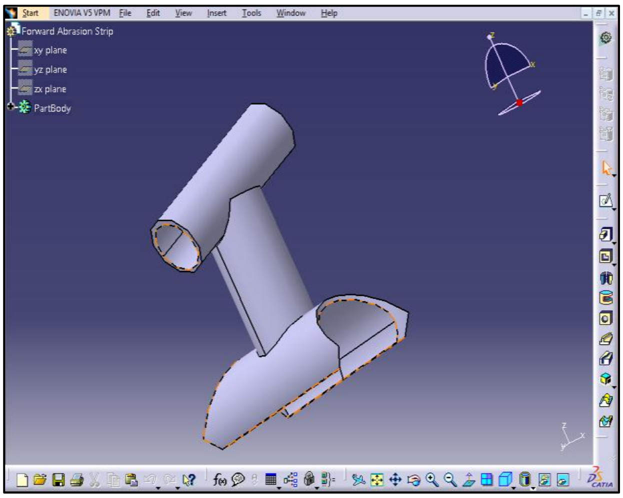


Fig 8. Design of Abrasion Strip

Designing Of Forward Cross Tube: Forward cross tube provide energy absorbing capabilities during normal or severe landings.

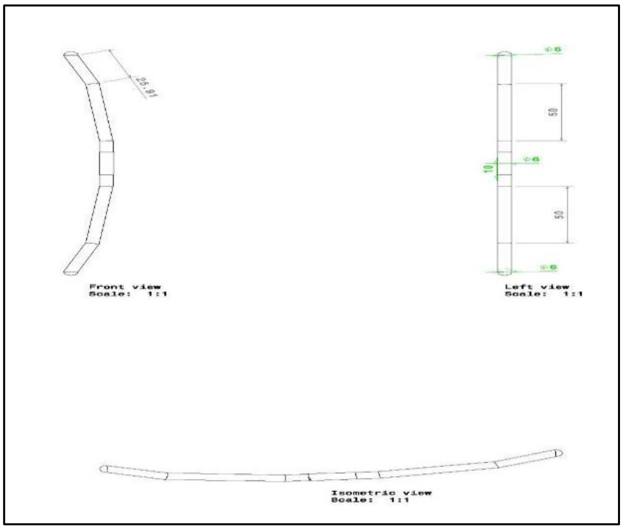


Fig 9. Dimensions of Forward Cross Tube

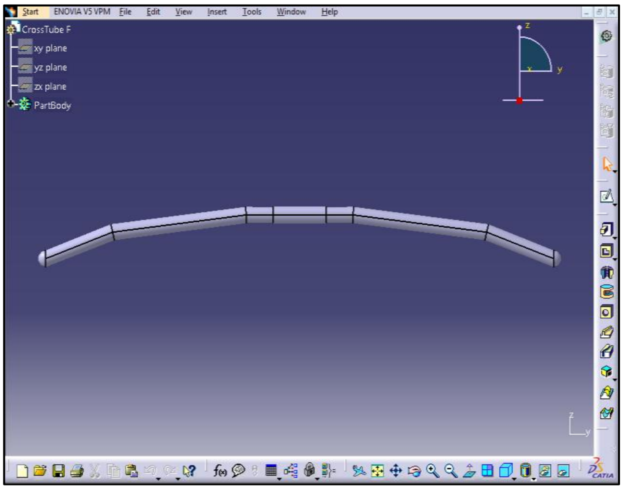


Fig10. Design of Forward Cross Tube

Designing of Aft Cross Tube: Aft cross tube provides energy absorbing capabilities during normal or severe landings.

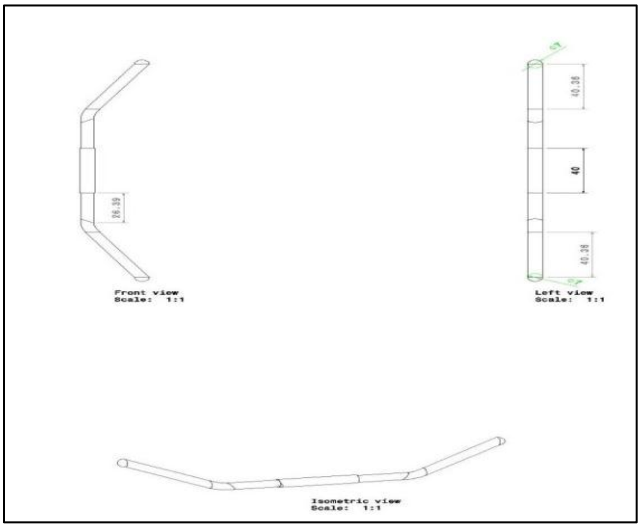


Fig11.Dimensions of Aft Cross Tube

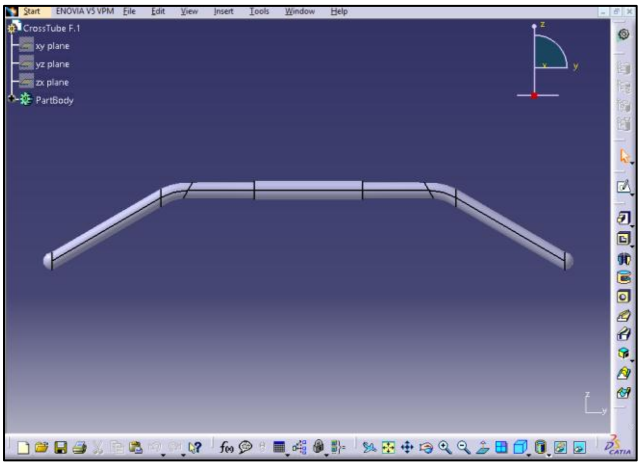


Fig12. Design of Aft Cross Tube

Assembly design

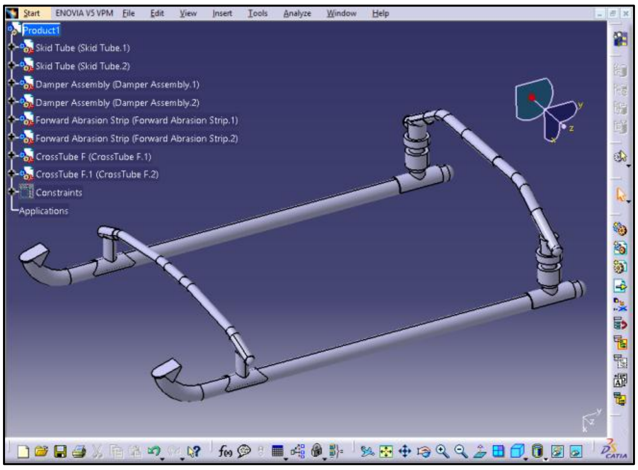


Fig13. Assemble of Aft Cross Tube

The top view of assembled skid landing gear:

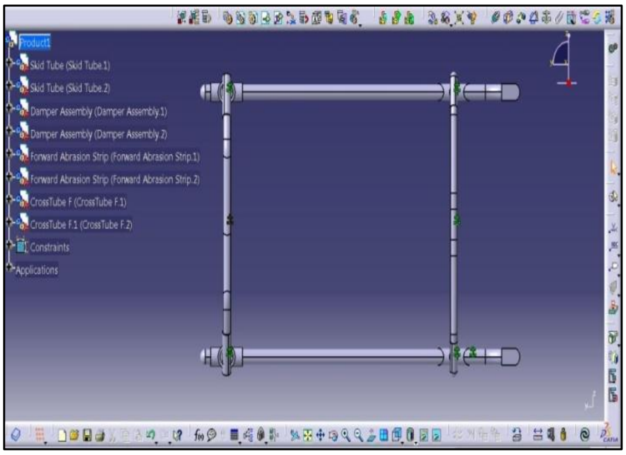


Fig14. Top view of skid landing gear

The front view of skid landing gear:

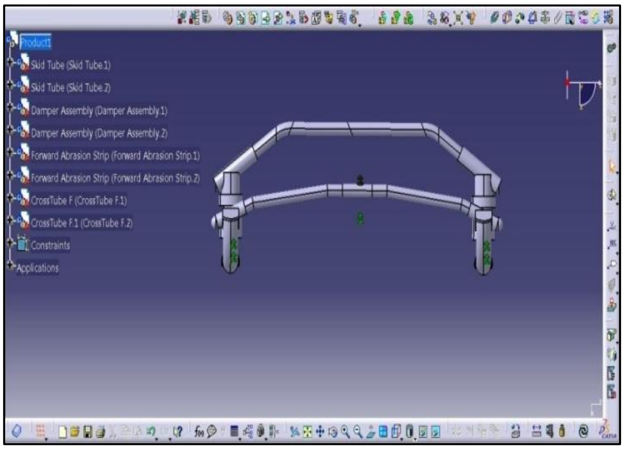


Fig15. Front view of skid landing gear

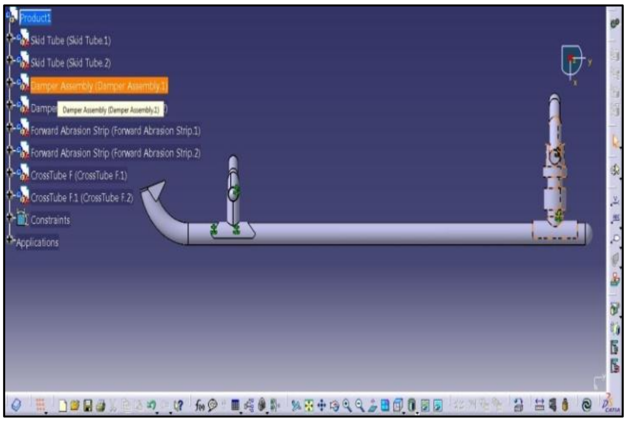


Fig16. Side view of skid landing gear

5. Structural Analysis

Importing of Skid Landing Gear

The Skid Landing Gear which is designed in CATIA is now imported in to ANSYS.

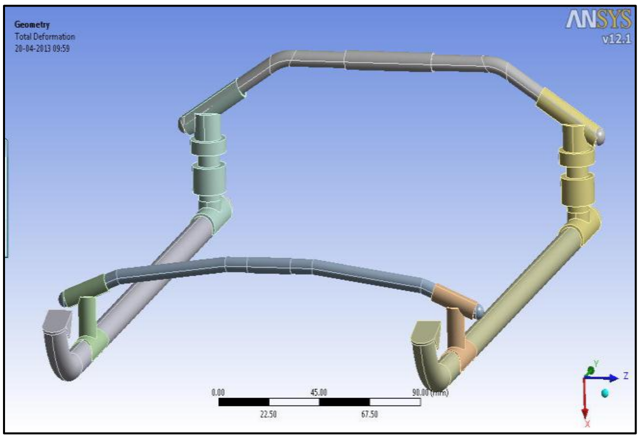


Fig17. Assembled part in ANSYS

Then the Skid Tubes, Abrasion Strips and Damper Assembly are fixed.

Meshing of Skid Landing Gear

The meshing of Skid Landing Gear is done by giving mesh length of 0.8mm. The meshing type is a triangular mesh. There are 67,978 Elements and 1, 27,657 Nodes.

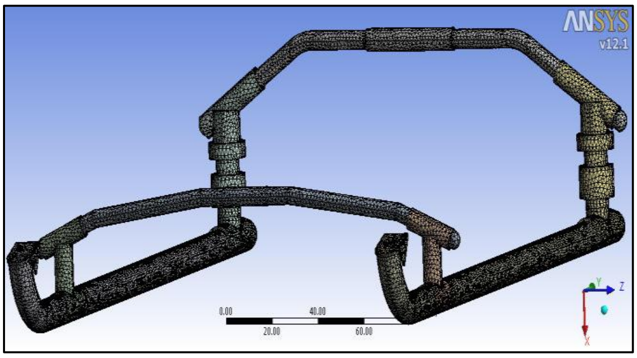


Fig18. Meshing of Skid Landing Gear

Fixed Supports and Loads

After the meshing is done the next step is to make skid tubes as fixed and loads are applied on the forward and aftcross tubes of loads 100N in the X-direction.

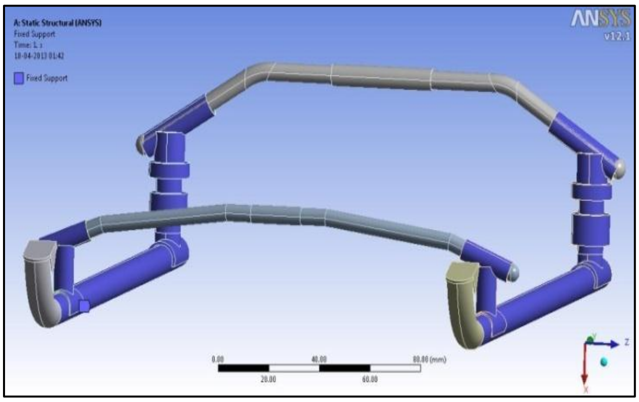


Fig19. Fixed supports

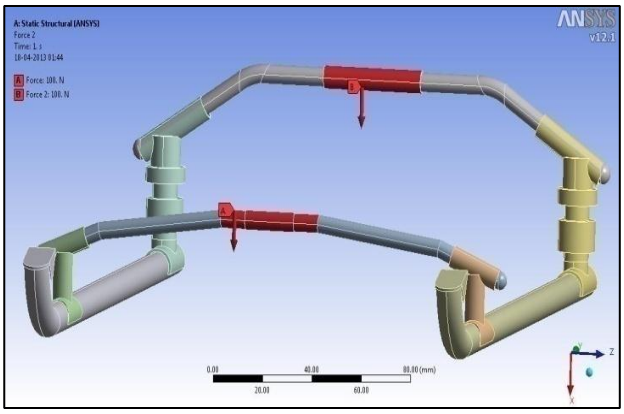


Fig 20. Loads on Forward and Aft cross tubes

Solutions

Aluminum alloys 7075 Results

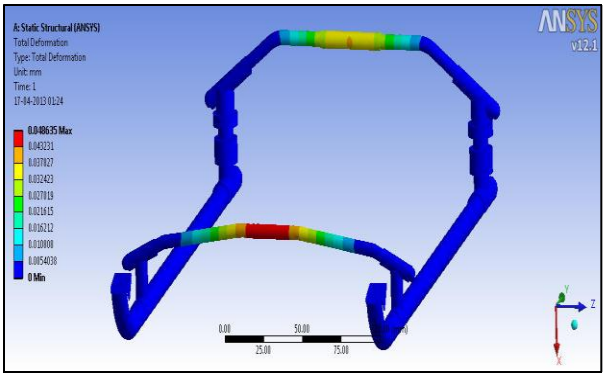


Fig 21. Total Deformation with Aluminum Alloy 7075

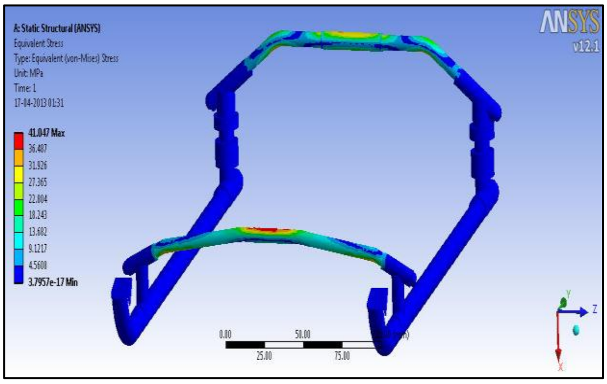


Fig 22. Equivalent Stress of Aluminum Alloy 7075

Aluminum alloy 7075 Results are listed below

Table10. Aluminum alloy 7075 Results

Results		
	Deformation	Equivalent Stress
Minimum	0mm	3.7957E-017 MPa
Maximum	0.048635mm	41.047E-17 MPa

Titanium Alloy Ti6Al-4V Results

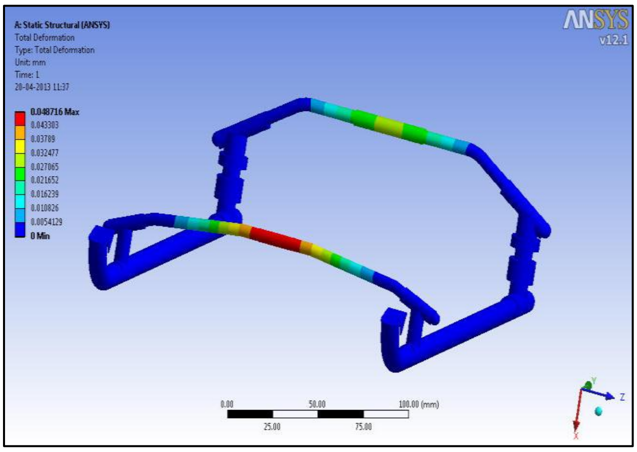


Fig 23. Total Deformation of Titanium Alloy Ti6Al-4V

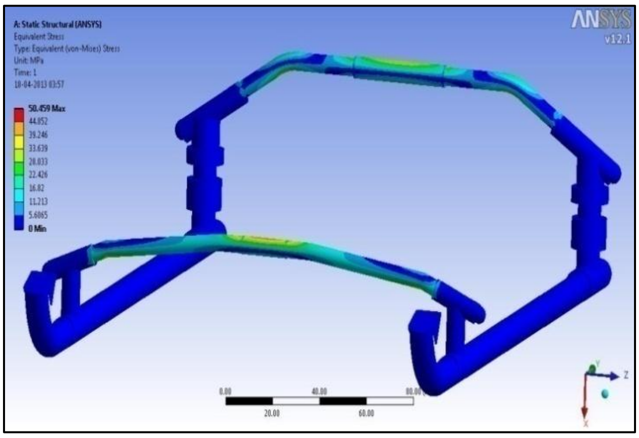


Fig 24. Equivalent Stress of Titanium Alloy Ti6Al-4V

Titanium Ti6Al-4V Results are listed below

Table11. Titanium Ti6Al-4V Results

Results		
	Deformation	Equivalent Stress
Minimum	0 mm	4.4405E-17 MPa
Maximum	0.048773 mm	50.459E-17 MPa

300M Alloy Steel Results

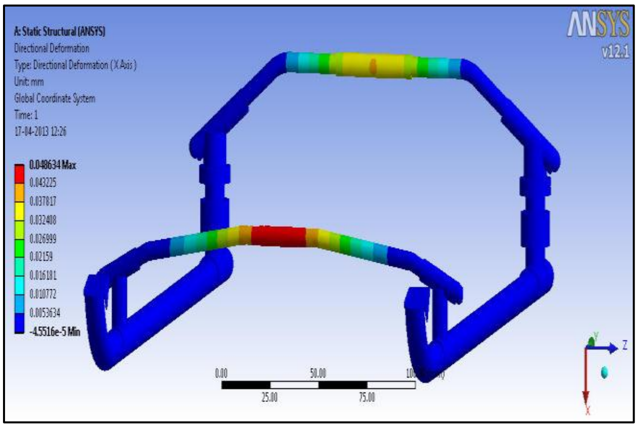


Fig 25. Total Deformation of 300M Alloy Steel

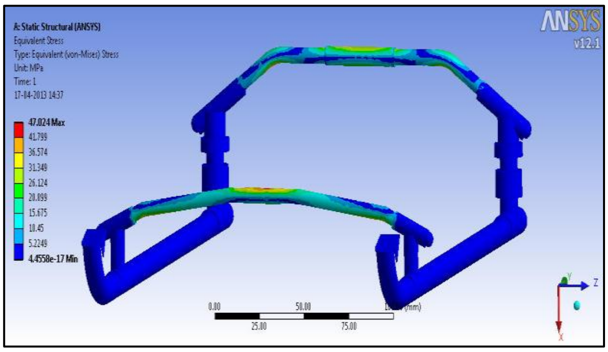


Fig 26. Equivalent Stress of 300M Alloy Steel

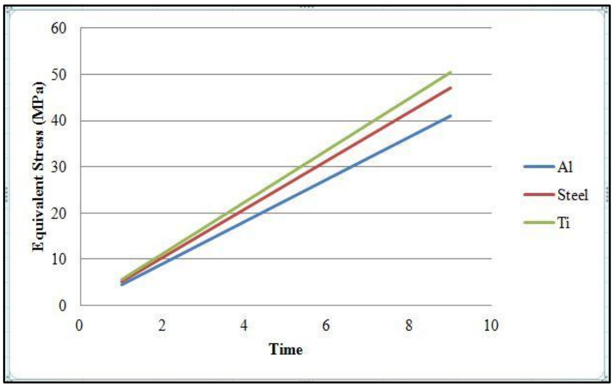
300M Alloy Steel Results are listed below:

Table12. 300M Alloy Steel Results

Results		
	Deformation	Equivalent Stress
Minimum	0 mm	4.4558E-17 MPa
Maximum	0.048634 mm	47.24E-17 MPa

From the above results a comparison graph is drawn as follows:

Equivalent Stress Vs Time



Graph1. Equivalent stress Vs Time

4. Discussion &Conclusion

Table13. Maximum Stresses of Materials

Materials	Max. Stresses (MPa)
Titanium Alloy Ti6Al4V	50.459
300M Alloy Steel	47.024
Aluminum Alloy 7075	41.047

From the above solutions Titanium Alloy Ti6Al4V has high equivalent strength compared to all other materials but the cost of components and equipment properly designed in Titanium is never as high as the price by weight of the metal suggests. Many designs are based on use of metal by surface area rather than by weight. The strength, lower density and good corrosion resistance of titanium are all factors which keeps its cost down.

The 300M Alloy steel which is a low alloy, vacuum melted, and very high strength as it is a mixture of silicon, vanadium and slightly more carbon and molybdenum. It has very good combination of strength at 1930 – 2100 MPa, toughness, fatigue and good ductility.

The Aluminum Alloy 7075 having low equivalent stress but it is the mixture of Zinc which is the primary alloying element. It is a strong, with strength comparable to many other materials, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high costs limit its use to applications where cheaper alloys are not suitable.

1. The Experiment is conducted for Design and Structural Analysis of Skid Landing Gear and results were analyzed.
2. The material which can resists to maximum stress has a high strength.
3. Thus it may be concluded that the Titanium Ti6 Al-4V alloy has higher Equivalent Stress compared to the other materials.

References

Roskam J, 1989, *Airplane Design: Part IV*, 2nd Edition, DAR Corporation, Kansas.

Stinton, Darrol, 1966, *The Anatomy of Airplane*, 1st Edition, Oxford Press

Daniel P. Raymer, 1999, *Aircraft Design: A Conceptual Approach*, 3rd Edition, AIAA Education Series, New York.Mechanics of composite materials - Autar K. Kaw.

Aircraft Landing Gear Design: Principles and Practices – Norman S. Currey, Lockheed Aeronautical Systems Company, Marietta, Geoegia.

Pritchard I J. *An overview of landing gear dynamics.* NASA TM-1999-209143, 1999.

T. Catt, D. Cowling, A. Shepherd, *Active landing gear control for improved ride quality during ground roll*, SDL Report No. 232, Stirling Dynamics Limited, 1992.

E.A. Ossa *Failure analysis of a civil aircraft landing gear* Engineering Failure Analysis 13 (2006) 1177–1183, 2005 Elsevier Ltd

F. Bagnoli, F. Dolce, M. Colavita, M. Bernabei*Fatigue fracture of a main landing gear swinging leve in a civil aircraft*, Engineering Failur**e Analysis 15 (2008) 755–765, 2007 Elsevier Ltd.**

WU Dong-su, GU Hong-bin, LIU Hui*GA-Based Model Predictive Control of Semi-Active Landing Gear*, Chinese Journal of Aeronautics 20(2007) 47-54, 2007 Elsevier Ltd.

Hongyu Zhou, Thomas L. Attard, Bin Zhao, Jiangtao Yu, Wensheng Lu, Lewei Tong *Experimental study of retrofitted reinforced concrete shear wall and concrete-encased steel girders using a new CarbonFlex composite for damage stabilization*Engineering Failure Analysis, 2013 Elsevier Ltd

ZHU Shixing, WANG Peng, TIAN Jing *Experimental Research on Aircraft Landing Gear DropTest Based on MRF Damper*Elsevier Procedia Engineering 15 (2011) 4712 – 4717.

Zhang Wen, Zhang Zhi, Zhu Qidan, XuShiyue*Dynamics Model of Carrier-based Aircraft Landing GearsLanded on Dynamic Deck*Elsevier Chinese Journal of Aeronautics 22(2009) 371-379.

StefaniaGualdi, Marco Morandini, Gian Luca Ghiringhelli*Anti-skid induced aircraft landing gear instability* Elsevier, Aerospace Science and Technology 12 (2008) 627–63

Taro Imamura, Tohru Hirai, Kazuhisa Amemiya, Yuzuru Yokokawa, ShunjiEnomoto, Kazuomi Yamamoto, *Aerodynamic and Aeroacoustic Simulations of a Two-wheel Landing Gear*Elsevier Procedia IUTAM 1 (2010) 293–30

Gupta, P.A. Kelly, M. Ehrgott, S. Bickerton *A surrogate model based evolutionary game-theoretic approachfor optimizing non-isothermal compression RTM processes*Composites Science and Technology 84 (2013) 92–100, Elsevier.

Ronald F. Gibson *A review of recent research on mechanics of multifunctional compositematerials and structures* Composite Structures 92 (2010) 2793–2810, Elsevier.

Alessandro Airoldi, GerardusJanszen*A design solution for a crashworthy landing gear with a new triggering mechanism for the plastic collapse of metallic tubes*Aerospace Science and Technology 9 (2005) 445–455, Elsevier.

R. Arravind, M. Saravanan, R. Mohamed Rijuvan*Structural Analysis of Landing Strut MadeupOf Carbon FibreComposite Material*IJMPE, ISSN (PRINT): 2320-2092, Volume – 1, Issue – 1, 2013

T. Catt, D. Cowling, A. Shepherd, *Active landing gear control for improved ride quality during ground roll*, SDL Report No. 232, Stirling Dynamics Limited, 1992

Zhang Lei, Jiang Hongzhou, Li Hongren, *Object-oriented landing gear model in a PC-based flight simulator*, Simulation Modelling Practice and Theory 16 (2008) 1514–1532, 2008 Elsevier Ltd

Autar K. Kaw,Mechanics of Composite Materials, 2nd Edition,2006 by Taylor & Francis Group, LLC.