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MODELING AND STRUCTURAL ANALYSIS OF CIVIL TRANSPORT AIRCRAFT NOSE LANDING GEAR USING FEM

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Abstract: An aircraft landing gear system must absorb the kinetic energy produced by a landing impact and excitations caused by the aircraft travelling over an uneven runway surface. This is the necessary requirement of a successfully designed landing system. The oleo-pneumatic shock is the most common type of shock absorber landing gear system used in aircrafts. It dissipates the kinetic energy produced by impacts arising when an airplane lands at high speed but also offers a comfortable ride to passengers when the airplane taxies at low speed. The objective of this project is to determine the stress ,displacement ,strain, shear stress of of a nose gear using the different materials like Ferrium M54, Ti 10Al 2Fe 3v , Ti 6Al-6v-2sn , Al 7075 of an aircraft during landing using structural finite element analysis. The landing gear was first modeled using catia software and then imported into Ansys software perform a satic and modal analysis. The apply the working forces on Nose landing gear were taken the boundary conditions. finally concluded the which material is the suitable for landing gear based on the stress , displacement ,strain, shear stress values.

Keywords—*Landing gear, shock absorber, loads, stresses, rebound chamber models.*

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I INTRODUCTION

The purpose of the landing gear in an aircraft is to provide a suspension system during taxi, take-off and landing. It is designed to absorb and dissipate the kinetic energy of landing impact, thereby reducing the impact loads transmitted to the airframe. Aircrafts are one of the greatest invention of human as it is a highly complex product. Having such a vehicle is very useful for easy and comfortable travels across the world. Aircrafts are used in multiple ways, they are use in commercial purpose as well as military purpose. It mainly reduces time of travel and provide luxury to the passengers also the making and using of aircrafts provided lots of employability options. An aircraft has lots of sub systems and components which are used in together to make it operable. Some of the main parts are fuselage, landing gears, cockpit, wings, engine, ailerons, rudder etc. all the parts were made keeping in mind that the product have to fly deep in sky so weight, stresses, deformation etc are taking in consideration before manufacturing the parts. Keeping these things in mind a design of each component and system was made and material selection has to be done wisely. To make an aircraft tough, strong, and light now a days, design and analysis were done in softwares.

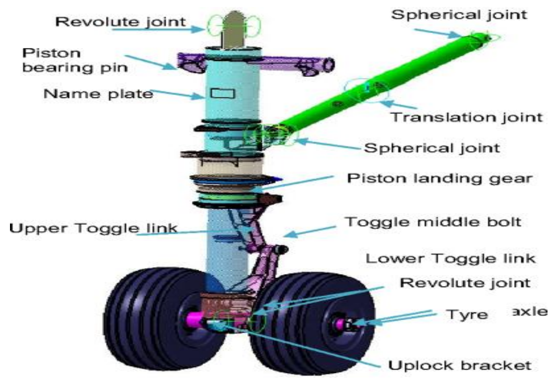

FIGURE 1 PARTS OF LANDING GEAR

Before manufacturing every component and sub system were designed and analyzed to get better results and it is much easier to be rectified. The landing gear system is one of the most crucial system of an aircraft as it supports the craft when it is not flying, allowing it to take off, land, and taxi without damage. Wheels are typically used but skids, skis, floats or a combination of these and other elements can be deployed depending both on the surface and on whether the craft only operates vertically (VTOL) or is able to taxi along the surface. Faster aircraft usually have retractable undercarriages, which folds away during flight to reduce air resistance or drag. Aircraft landing gear usually includes wheels equipped with simple shock absorbers, or more advanced air/oil oleo struts, for runway and rough terrain landing. Some aircraft are equipped with skis for snow or floats for water, and/or skids or pontoons (helicopters). The undercarriage is a relatively heavy part of the vehicle; it can be as much as 7% of the take-off weight, but more typically is 4–5%.

1.2 TRICYCLE TYPE LANDING GEAR

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear

1.2.1MAIN LANDING GEAR

The main gear on a tricycle-type landing gear arrangement is attached to reinforced wing structure or fuselage structure. The number and location of wheels on the main gear vary. Many main gear have two or more wheels

FIGURE 2MAIN GEAR OF A TRICYCLE-TYPE LANDING GEAR

1.2.2NOSE LANDING GEAR

The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gear is directed through mechanical linkage to the rudder pedals. Heavy aircraft typically utilize hydraulic power to steer the nose gear. Control is achieved through an independent tiller in the flight deck. The purpose of the landing gear in an aircraft is to provide a suspension system during taxi, take-off and landing. It is designed to absorb and dissipate the kinetic energy of landing impact, thereby reducing the impact loads transmitted to the airframe.

FIGURE 3 NOSE LANDING GEAR

TRICYCLE LANDING GEAR:

The tricycle-type landing gear arrangement consists of many parts and assemblies. These include air/oil shock struts, gear alignment units, support units, retraction and safety devices, steering systems, wheel and brake assemblies, etc.

1.3 FUNCTIONS OF LANDING GEARS

Landing gear provides following functions for an aircraft:

- Provides ground support i.e. bears weight of the aircraft on the ground.
- Facilitates rolling of the aircraft during landing, take-off, taxing and towing operations.
- Absorbs shocks during landing, take-off, taxing and towing and saves the air frame structures.
- Withstands side loads of cross-wind
- Provide facility for steering action
- Provides facilities for braking action
- Provides facilities for anti-skidding

II. LITERATURE REVIEW

The survey of literature devoted to the most commonly applied landing gear system, such as landing gears equipped with hydraulic-pneumatic shock absorbers. Reviewing the literature, in particular attention will be paid to the way in which the dynamic properties of wheel, shock absorber and aircraft structures are taken into account, and to the way in which the loads due the landing impacts are calculated.

V. d. Neut et.al. is a very extensive investigation in the field of symmetrical landing impact loads and is devoted in particular to the problem of defining critical loading cases for nose wheel landing gears. Ferrium m54 material study the The tyre-shock absorber combination of the nose wheel landing gear is represented by a linear spring, but for the main wheel landing gear the shock absorber damping characteristics are represented by velocity squared damping forces. The unstrung mass is neglected while wheel and shock absorber spring characteristics are represented by linear springs. Further, the drop test interpretation problem of how to take into account static lift forces is already recognized.

With regard to the analytic approach to the problem in the USA, first of all the work of E. G. Keller should be mentioned. This investigation formulates in an appropriate way the equations of motion of wheel and shock absorber, and calculates the vertical landing gear loads of a rigid aircraft. It is described how in an elastic structure the accelerations have to be calculated when the landing gear forces are known as a function of time.

Jerzy Malachowsk his research on the most effective methods of aircrafts' landing gears design as well as the evaluation of the gear's condition during utilization period and possibilities of extending its durability are the subject of numerous studies, including the ones by leading worldwide aviation companies and national scientific centers. It is indicated in these studies that numerical analysis of the strength of the construction elements of the examined aircraft's part (beside experimental research) is a necessary stage of proper methodology of aviation research, in particular in programming and reliability evaluation and development of methods of increasing durability in case of solutions already used in practice.

In terms of design procedure, the landing gear is the last aircraft major component which is designed. In another word, all major components (such as wing, tail, fuselage, and propulsion system) must be designed prior to the design of landing gear. Furthermore, the aircraft most aft center of gravity (cg) and the most forward cg must be known for landing gear design. In some instances, the landing gear design may drive the aircraft designer to change the aircraft configuration to satisfy landing gear design requirements.

Many of the organisation had tried to solve the static issues like buckling, bending etc. As per engineers of Virginia tech, the design of the new landing gear must be as simple as possible, since complexity drives up the cost faster than weight. However, weight also appears to be inversely proportional to the level of complexity. With the reduction in the complexity level, e.g., the number of supports, structural members are forced to withstand a higher load, which in term increases the structural weight due to an increase in cross-sectional area. Therefore, a balance must be reached between simplicity and weight, and this can only be accomplished through parametric studies of different landing gear configuration.

Titanium and titanium alloys have proven their worth over the decades. They are technically superior for various applications including aerospace industries and marine equipment. They are also utilized in commercial products due to their cost effectiveness . Titanium alloys have great static strength, fatigue strength and fracture toughness. Moreover, titanium alloys have replaced steel-based components like frames and joints which requires more strength, thus reducing the overall weight.

Vinicius A. R. Henriques discussed some remarkable properties of titanium, namely, composite compatibility and heat resistance. TIMETAL 834 is castable, and hence require minimal tooling. It also has good weldability with all the existing welding techniques for titanium, in addition to good forgeability. It is being used as blades in aeroengines. Another alloy of titanium, Ti-7Al-4Mo which is mainly used as compressor blades, possess higher strength and creep resistance than Ti6Al-4V. Aluminium, which is the most commercially used alpha stabilizer is added to titanium. It contributes to increase the tensile strength and creep strength along with additional advantage of low density. Molybdenum is a beta stabilizer, which provides the advantage of lower deformation and makes it heat treatable. Material of the shock absorber strut plays a pivotal role in providing strength to the whole landing gear assembly of the aircraft. In this paper outer cylinder of the shock absorber is analysed for three different titanium alloys to compare the results. The material used in landing gear should be light weight and be able to absorb shocks. The objective is to compare other two titanium alloys with the commonly used Ti-6Al-4V. All the analysis related to this paper is done in ANSYS 19.2.

D. Joseph manuel ,Titanium and Titanium Matrix Composites Over the years, titanium metal matrix composites (Titanium 10V-2Fe-3V) have been considered and developed further for use in aircraft engine and airframe applications. For airframes, the high specific modulus of Titanium has been the impetus as it can reduce up to 600 pounds in aircraft. Ti 10V-2Fe-3Al is also known as Ti10-2-3. This is a near-beta alloy used in applications requiring high strength (in the 180,000 tensile ranges). Titanium10-2-3 combines the best hot-die forgeability of any commercial titanium with excellent high strength toughness, deep hardenabilty, ductility, fracture, toughness and high cycle fatigue strength.

Dr. V. Jaya Prasad, Stress analysis plays important role to find structural safety and integrity of assemblies. The previous estimation of stress helps to find appropriate material and geometrical dimensions. While comparison the results of the mentioned materials, Titanium 10V-2Fe-3Al has the highest factor of safety, and therefore the least value of maximum stress developed and deflection.

The design of light landing gear by conducting structural analysis and design optimization was analyzed by Essam Albahkali and Mohammed Alqhtani by conducting experiments on landing gear using impact analysis. Review of literature survey on different types of landing gears shows that landing gear is analyzed for safety of the structure and effort was made to identify the faults occurring in them. However there is limited literature available on conventional landing gear made of ASM7075-T6 material. The present study deals with the structural analysis and optimization of landing gear's leg made of ASM7075-T6 material and the analysis was carried out using ANSYS (Version 13).

III .PROJECT OVERVIEW

3.1 NEED FOR THE STUDY:

As a step toward gaining a better understanding of the construction of the landing gear. This study was designed to analyze the structural analysis of landing gear for different materials. The study investigates the best suitable material for the landing gear construction by examining the stress, deformation, strain, shear stress developed due to loading conditions and find out the frequencies in modal analysis due to the deformation.

3.2 OBJECTIVES OF THE WORK

1. To model the Nose landing gear design in using CATIA software and analysis using the ansys 16.2.
2. To perform structural analysis for examining the stresses, deflections, shear stress, strain developed in structure at design load conditions.
3. To determine the response modal analysis for observing range of frequency developed in the structure using modal analysis.
4. To reduce the weight of the structure using optimization process using with different materials.
5. Finally concluded the suitable materials of the landing gear in these materials Ferrium M54, Ti 10Al 2Fe 3v , Ti 6Al-6v-2sn , Al 7075**.**

3.3 METHODOLOGY

The analysis of landing gear will be done for different materials. The landing gear with different alloys will be tested by applying a force during the landing under structural analysis in ANSYS 16.2. Then the total deformation, Vonmisses stress, shear stress and strain were calculated for different alloys after applying the boundary conditions.

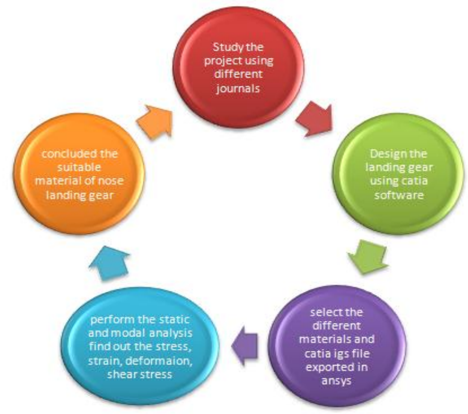

FIGURE 4 METHODOLOGY

3.4 PROBLEM IDENTIFICATION:

Improper material leads to the failure steel material are heavy weight and easily formed corrosion Titanium alloy are the high strength materials in this project choose the steel, aluminum ,titanium materials compared the all materials finally concluded the suitable materials due to the titanium is the less stress ,strains, shear stresses . From the literature, it is observed that significant amount of research work has been conducted in the area of landing gear. It has been established that there is a need to overcome problems associated with conflicting requirements such as strength and stiffness of landing gear, and at the same time able to withstand the weight impact of the aircraft and avoid the structural damage while landing. Researchers have proposed suitable materials such as aluminum, titanium, Mg, etc. that are able to withstand the weight impact of the aircraft.

3.5 LEAD SPECIFICATIONS OF SUBSONIC CIVIL TRANSPORT AIRCRAFT:-

The specification of aircraft is taken from the aircraft manual book. Based on the specifications mentioned landing gear is designed. Detailed procedure for designing the landing gear is illustrated below:

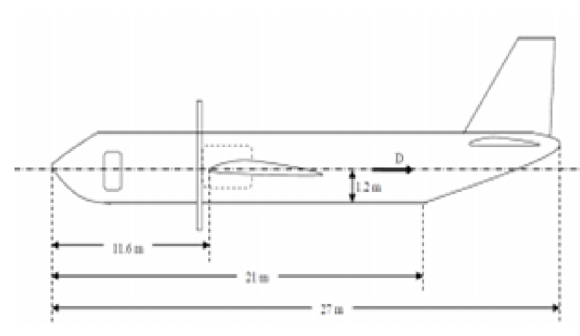

FIGURE 5 AIRCRAFT SPECIFICATION

Maximum takeoff weight = 18,000 kg,

Diameter of the Propeller = 3.8 m

Wing: Span (S) = 60 m2 ,

NACA 6 series Aspect Ratio (AR) = 12,

Forward CG= 18% of mean Aerodynamic chord

After CG= 30%of Mean aerodynamic chord

Distance b/w main gear and forward CG= 1.916m

Distance b/w main Gear and after CG = 1.827m

LOAD CALCULATION:-

Load on nose gear:

$F_n = 0.15 \times W$

$= 2700$ kg

= 26487 N

Load on Main gear:

$F_m = 0.85 \times W$

$= 15{,}300$ kg

= 150093 N

3.5.1 SHOCK STRUT(UPPER OUTER CYLINDER)

Length of the upper outer cylinder:1049mm

Diameter of upper outer cylinder:184.56mm

Diameter of bottom of shock strut:180 mm

Top portion of cylinder of upper outer cylinder:145

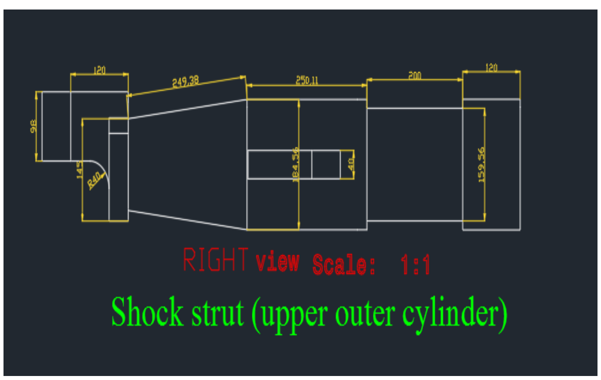

Figure 6UPPER OUTER CYLINDER

3.5.2 SHOCK STRUCT LOWER INNER CYLINDER (PISTON):

Length of the lower outer cylinder: 1430mm

Diameter of lower outer cylinder: 240 mm

Diameter of bottom of shock strut: 220mm

Top portion of cylinder of lower inner cylinder:145

Length of the piston: 960mm

Height of the link adjust: 140mm

Diameter of axle holder shaft: 220mm

Lower inner cylinder disc 400

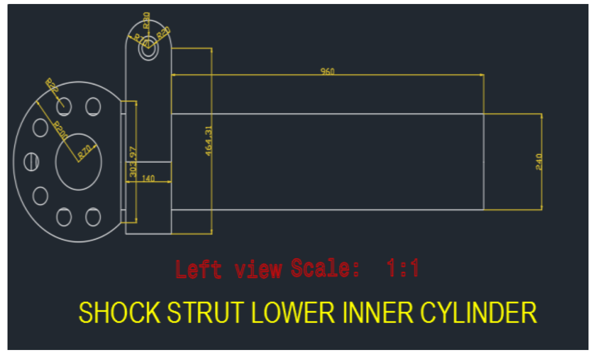

Figure 7 LOWER INNER CYLINDER

3.5.3 AXLE SHAFT:

Diameter of the Axle shaft:120

Diameter of the disc hub plate: 320

Thickness of the plate:30

Radius of the middle shaft: 20 and 10

Length of the axle shaft :388mm

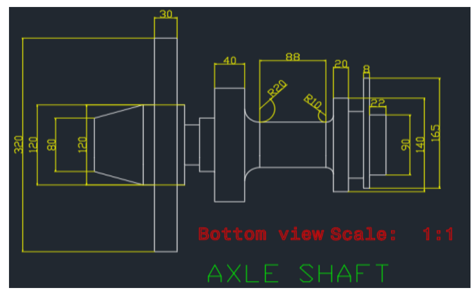

Figure 8 AXLE SHAFT

3.5.4 DISC DIMENSIONS:

Radius of the rotor plate is 100mm

Cylinder outer radius is 45mm

Cylinder inner radius is 20mm

Height of the disc is 359mm

Length of the cylinder is 100mm

Length of the small cylinder is 89mm

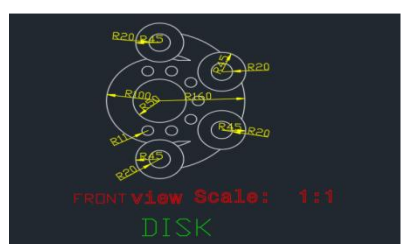

FIGURE 9DISC HUB

3.5.5 LINK DIMENSIONS:

Radius of the upper link outer radius is 17.5mm

Radius of the upper link inner radius is 10mm

Radius of the lower link outer radius is 35mm

Radius of the lower link inner radius is 15 mm

Thickness of the link is 35mm

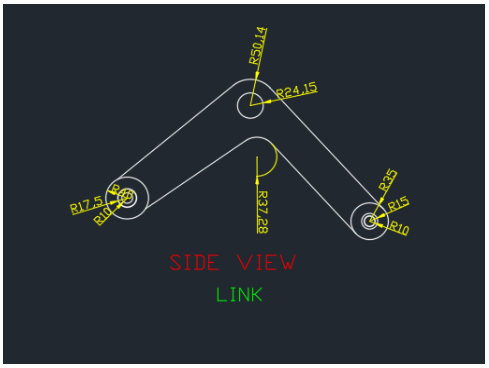

FIGURE 10 LINK

3.6 Material properties:

Material properties	Density g/cm³	Passions ratio (µ)	Young's modulus (Gpa)	Ultimate Tensile strength (Mpa)
Ti 10Al 2Fe 3v	4.659	0.32	110	1260
Ti 6Al-6v-2sn	4.54	0.32	110.3	1050
Al 7075	2.81	0.32	70	560
Ferrium M54	7.85	0.29	196	2020

IV DESIGN CONCEPT OF LANDING GEAR

The concept design starts with a study of all design specifications and airworthiness regulations. A concept is then evolved while meeting the functional and regulatory requirements. Major design drivers are performance, safety, cost,time frame, technology and resources. The landing gear location is arrived at and type of landing gear is selected. The landing gear geometry is defined along with kinematics. Steering concepts are also identified in this phase. The ground loads are estimated using dynamic simulations for material selection and preliminary sizing of components. The actuation mechanisms and loads are also worked out in this phase. Various tradeoff studies are performed to enhance weight, volume and cost. Based on these trade-off studies a best concept is selected.

4.1 SHOCK STRUT (UPPER OUTER CYLINDER):

Go to the sketcher workbench select xy plane create the half of the view as per the below dimensions now go to the part design workbench in sketch based features apply shaft option apply angle is 360 degrees again go to the sketcher create the top side hinge shape as per the dimensions apply pad in part design workbench again go to the sketcher workbench create the bottom link as per dimensions.

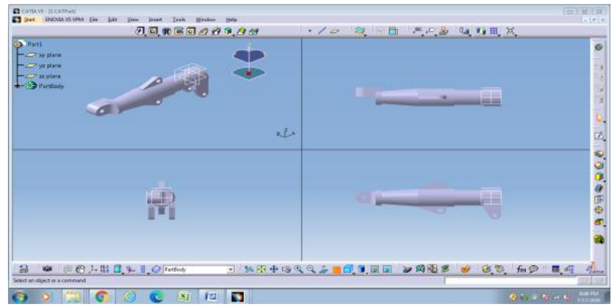

FIGURE 11 SHOCK STRUT DESIGNED IN CATIA

4.2 SHOCK STRUCT LOWER INNER CYLINDER (PISTON):

Go to the sketcher workbench create the circle now go the part design workbench apply pad now go to the yz plane create the circle apply pad as per dimensions now again go to the sketcher create the circle and small circle axle holder as shown the below figures

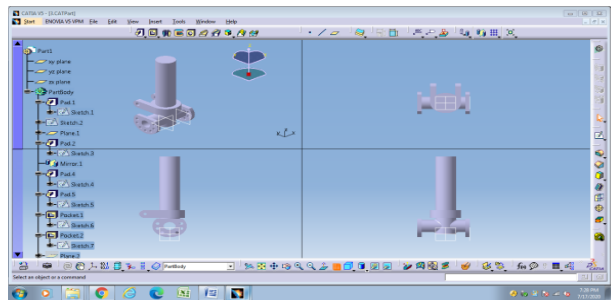

FIGURE 12LOWER INNER DESIGNED IN CATIA

4.3 AXLE SHAFT:

Go to the sketcher workbench create the half of the axle shaft with dimension after go to the part design workbench apply shaft option as shown below figures

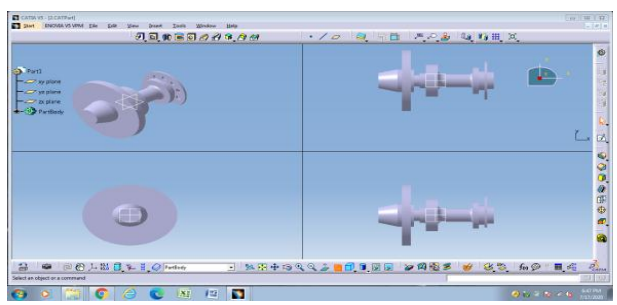

FIGURE 13 AXLE SHAFT DESIGNED IN CATIA

4.4 DISC HUB:

Go to the sketcher workbench create the two circles as per the dimensions now go to the pad option apply thickness is 20mm again go to the sketcher workbench create the small circles now go to the circular pattern option now go to the create the cylinders as per the dimension as shown below figures.

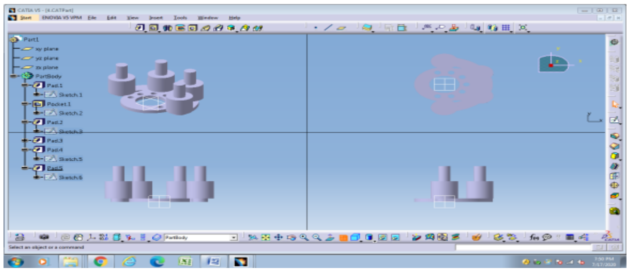

FIGURE 14 DISC HUB

4.5 LINK :

Create the two circle in sketcher workbench thickness is 35 and radius of the link outer hinge in 35mm angle is 60 now go to the part design work bench apply pad is 48mm.

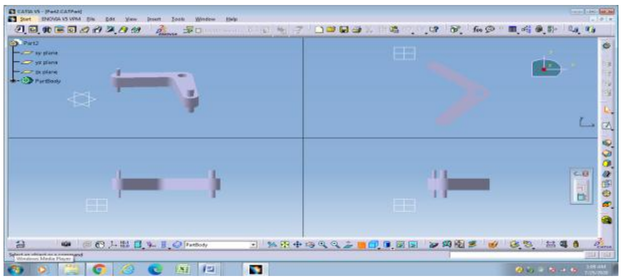

FIGURE 15 LINK DESIGNED IN CATIA

4.6 ASSEMBLY ALL PARTS IN ASSEMBLY WORKBENCH:

After created the parts now go to the assembly workbench go to the existing workbench first upper cylinder fix the part using constraints tool bar now go to the existing component with position imported all parts lower cylinder, axle, disc, bolts, link as shown below figures

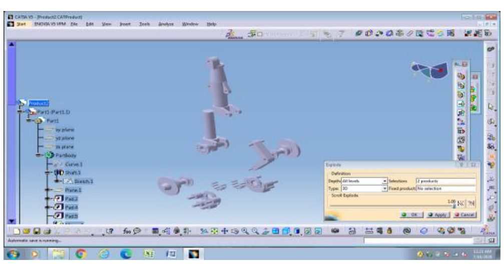

FIGURE 16 ASSEMBLY OF NOSE LANDING GEAR

V ANALYSIS PROCEDURE IN ANSYS:

Designed component in catia workbench after imported into ansys workbench now select the steady state thermal analysis

1.ENGINEEERING MATERIALS (MATERIAL PROPERTIES).

2.CREATE OR IMPORT GEOMENTRY.

3.MODEL(APPLY MESHING).

4.SET UP(BOUNDARY CONDITIONS)

5.SOLUTION

6.RESULTS

5.1 STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include.

5.2 MODAL ANAYSIS:

In modal analysis free natural vibration frequencies of roll cage frame was found out for the first 6 modes keeping the suspension members and the attached member of the mounts constrained. All the modes that were found out were rigid body mode. Vibrations can also be induced due to the bumps or road but as their intensity would be low it is not considered. Although the bumps and vibration due to reciprocating engine.

5.3MESHING AND BOUNDARY CONDITIONS:

In order to get accurate results, it is required to have smaller aspect ratios and hence tetrahedron meshing is used for outer cylinder as it provides aspect ratio close to unity. It provides a greater number of elements in the mesh. Therefore, a patch conforming method is utilized to generate Tetrahedron meshing to carry out the calculations. A total of 49344 Nodes and 25340 elements were generated.

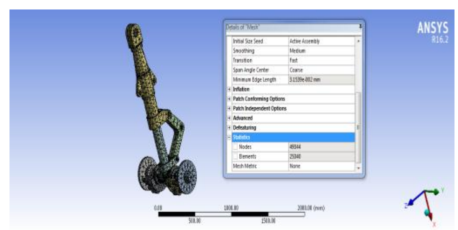

FIGURE 17MESH :NODES:49344, ELEMENTS 25340

5.4 BOUNDARY CONDITIONS:

Two boundary conditions are applied. First, fixed support at the bottom end of the component. Second, a force of 26487 at face at top end as shown below figure.

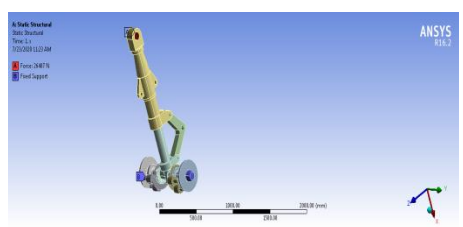

FIGURE 18 BOUNDARY CONDITIONS

VI RESULTS AND DISCUSSIONS

In this project, the Nose landing gear is analyzed Static and Modal analysis method with the following materials (Ferrium M54, Ti 10Al 2Fe 3v, Ti 6Al-6v-2sn, Al 7075) to find out the best material. Vertical load applied to the designed landing gear in all the cases is 26487N. This value is referred from civil transport aircraft. The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally deformations, stress, strain, shear stress values are find out as shown below figures

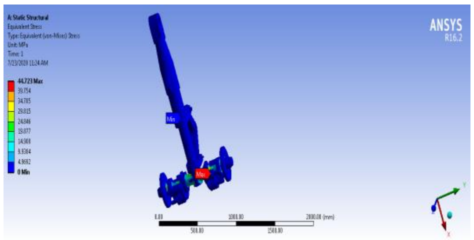

FIGURE 19 VON-MISSES STRESS OF TI 10AL-2FE-3V MATERIAL

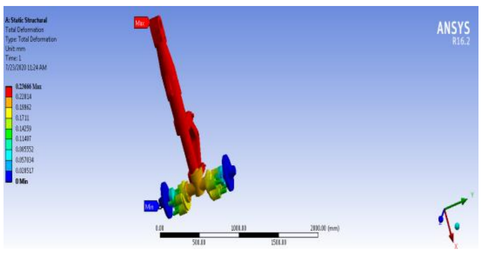

FIGURE 20TOTAL DEFORMATION OF TI 10AL-2FE-3V MATERIAL

VII GRAPHS:

The Static structural analysis of Different materials are done and results are obtained for Equivalent (Von-Mises) stress, Shear stress, total deformation, strain. These results are plotted graphically and a comparison is made between these results.

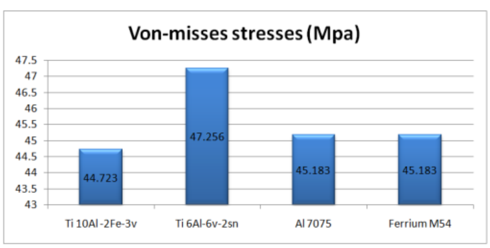

FIGURE 21VONMISSES STRESS GRAPH

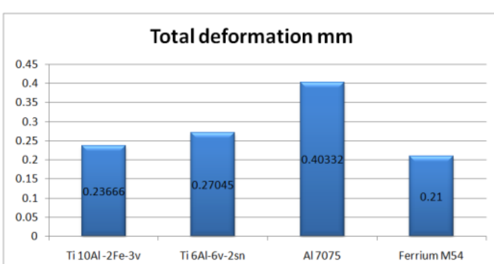

FIGURE 22 TOTAL DEFORMATION GRAPH

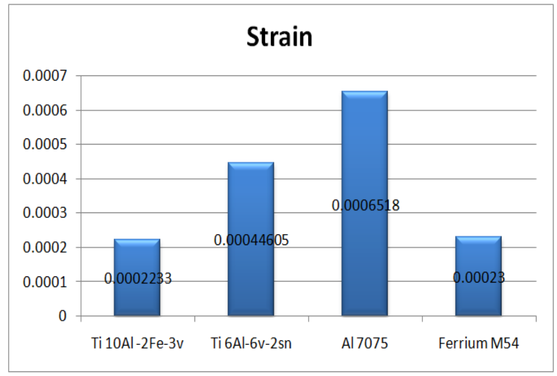

FIGURE 23 STRAIN GRAPH

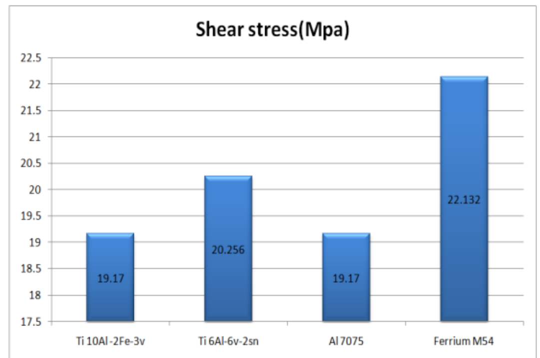

FIGURE 24SHEAR STRESS GRAPH

7.1 FERRIUM M54 MATERIAL:

Modes	Frequency(Hz)	Total deformation(mm)
Mode 1	1.253	0.252
Mode 2	3.562	0.924
Mode 3	6.220	2.253
Mode 4	10.85	3.112
Mode 5	35.47	4.696
Mode 6	44.14	6.352

FIGURE 25RESULTS OF FERRIUM M54 MATERIAL

7.2 Ti 10Al-2Fe-3v MATERIAL:

Modes	Frequency(Hz)	Total deformation(mm)
Mode 1	1.342	0.264
Mode 2	4.762	1.102
Mode 3	7.975	1.260
Mode 4	12.632	2.560
Mode 5	38.48	4.586
Mode 6	49.14	5.591

FIGURE 26MODAL ANALYSIS RESULTS OF TI 10 AL-2FE-3V MATERIAL

VIII CONCLUSION

The landing gear unit is designed using the CATIA V5 and the same is considered to evaluate or validate the structural behavior of the four different materials (Ferrium M54, Ti 10Al 2Fe 3v, Ti 6Al-6v-2sn, Al 7075) By considering parameters like von-misses stresses, strains, deformation, shear stresses of material under applied load

It is observed results in static analysis from above figures that, Ti 10Al 2Fe 3v, has less vonmisses stress concentration (44.723 MPa) than other three materials.

The deformation of material under load conditions for (Ferrium M54, Ti 10Al 2Fe 3v) respectively. Among the 2 different materials, the less deformation of material is observed (0.21,0.23 mm) when compared with other two materials.

The strain of material under load conditions for (Ferrium M54, Ti 10Al 2Fe 3v) respectively. Among the 2 different materials, the less Strain of material is observed (0.00022,0.00023) when compared with other two materials.

The shear stress of material under load conditions for (Ferrium M54, AL7075) respectively. Among the 2 different materials, the less shear stress of material is observed (19.17 Mpa) when compared with other two materials.

In modal anlaysis done two materials because of who has less von-misses stresses, strains, deformation, shear stresses that material are done modal analysis Ti 10Al 2Fe 3v is the best materials it comes good results due to the less deformation with various frequencies.

Hence it can conclude that, the use of Ti 10Al 2Fe 3v over steel materials because of less stress, strain, deformation, shear stress, preferable this Ti 10Al 2Fe 3v material with stand the load bearing capacity. This alloy has unique combination of excellent hot-die forgeability and excellent high strength toughness and deep hardenabilty .This is best suitable material for any kind of landing since the aircraft best results in static and modal anlaysis.

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