DESIGN AND ANALYSIS OF NOSE LANDING GEAR

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ABSTRACT – *Linear Static Analysis is done to predict the phenomenon in advance so that materials and geometrical dimensions can be selected wisely. Optimisation can also be done by evaluating those results so as to get perfect design of any product. Nose landing gear is one of the most crucial part of an aircraft as it feels approx. 5% of aircraft's weight and is used for landing, take-off as well as steering purpose.*
The present work shows a CAD design of nose landing gear of Boeing 747-8 and a finite element modelling is done to evaluate the results of stresses and deformations by using different materials so as to get the characterstics of a material and also for the selection of materials.

Key Words: Linear Static Analysis, Tet Collapse, Nose Landing Gear, RBE3, Ferrium S53, Al 2040, Ti 10-2-3.

1. INTRODUCTION

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. Before manufacturing every component and sub system were designed and analysed 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%.

The 747-8 landing gear is made up of 18 wheels. This many are needed to spread the plane's enormous weight on the runway. Two are positioned beneath the nose. The other 16, consisting of four four-wheeled carriages, or bogies, are arranged with one under each of the wings and two on the underside of the fuselage. The impact of landing is absorbed evenly by all four bogies through their shock absorbers. The main gear tyres are 1.3 metres (4.3 feet) in diameter, filled with nitrogen gas and fitted with anti-skid brakes. The main landing gear folds sideways under the wings after take-off.
The nose landing gear has two wheels positioned side by side. After take-off, they retract in a forward direction into the nose of the fuselage, powered by hydraulic jacks. Hinged doors close behind them.

2. LANDING GEAR LITERATURE SURVEY

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.

2.1 Material trends for landing gear:

Titanium 6-4 (Ti 6Al 4V) is the workhorse of the industry and still accounts for nearly 60% of the production volume. However, new materials have reached the market in recent years. The introduction of ***AerMet100*** and ***AF1410*** has made inroads in the steel section and replaced some of the ***300M*** and ***4340*** materials used on landing gear, while the appearance of titanium alloys such as ***Ti 10-2-3 (Ti 10V 2Fe 2Al)*** and most notably ***Ti 5-5-5-3 (Ti 5 Va 5Mo 5Al 3Cr)*** recently has transformed the landing gear materials application especially on the new generations of wide-body aircraft. With these materials come new machining challenges and requirements for optimised tooling.

2.2 Machining:

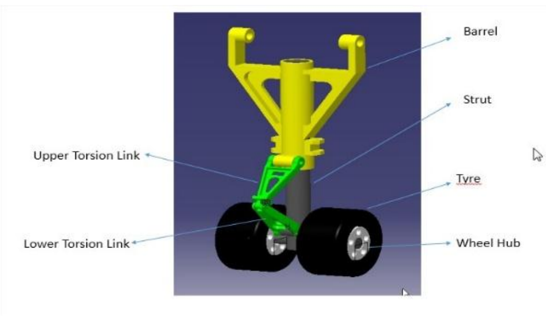
1. Aluminium Alloy:

High-efficiency processes are essential to machine components from blocks of material. These machining processes can sometimes reduce more than 90% of the solid material into chips to leave the final shape required. Recently, cutting tools capable of machining components at a speed of 5,000m/min (300km/h) have been commercialised. The chip evacuation rate of these processes can be up to 10,000cm^3 per minute.

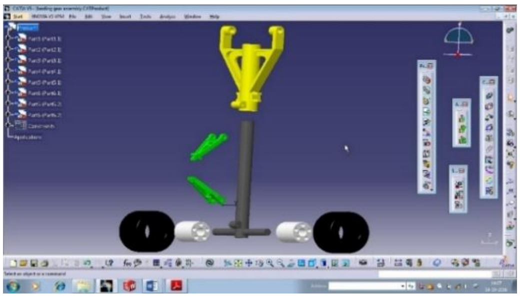
2. Titanium Alloy:

Titanium alloy has the highest specific strength (strength/weight ratio) of all metallic materials under 400 deg.C, it is also light, strong and corrosion resistant. New passenger jets are using an increasing ratio of Titanium alloy Ti- 6Al-4V, this material is used for aircraft components that require high strength, such as wing joints and landing gear. High efficiency machining of Titanium alloy is a challenge because its low thermal conductivity causes machining heat to concentrate on the edge of the cutting tool.

3. DESIGN MODEL



(a)

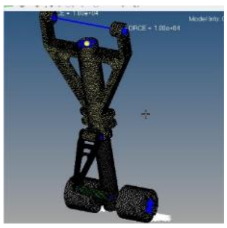


(b)

Fig 1(a) above shows the complete model of nose landing gear which was made in Catia v5 r21 software which is widely used in automobile and aerospace industries Fig 1(b) shows the exploded view of the assembly. A typical nose landing gear consist of six elements those are:
Barrel or Cylinder Brace, Upper Torsion Link, Wheel Hub, Strut, Lower Torsion Link and Tyre.
Firstly all the six parts are made separately and then assembled to form a complete model. In nose landing gear, barrel, upper torsion link and lower torsion link are complex parts and wheel hub, tyre and strut are easy parts. By using the dimensions and approximation firstly a strut is made, than barrel is made taking reference of strut and similarly every component was made.

4. FINITE ELEMENT MODELLING

4.1 Meshing



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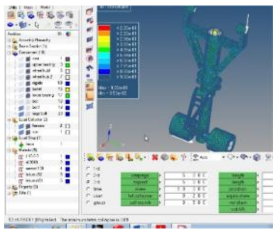

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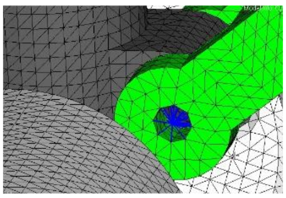

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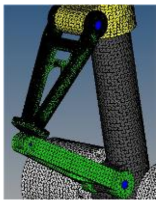


(d)

- **Fig 2**(a) above shows the complete meshed model having 3d and 1d elements, for 3d meshing firstly 2d meshing is done.
- After that quality of mesh has been checked by check elems option, in check elem for 3d mesh tet collapse has been checked. After click on it , it will show how many elements are not having tet collapse more than 0.2.

- In fig 2(b) tet collapse had to be checked for knowing the quality of mesh as it gives the value of no. of elements failing.
- The fig 2(c) shows 1d meshing, rbe3s were made in every hole where bolt will be given this has been done so that the centre load will distribute the load to all the nodes of the hole.
- The fig 2(d) shows the bolts which were made in 1d meshing by declaring hyperbeam and bars. Also we can see that there are three bolts given in which two are same and one is different as described in cad design.

4.2 Material selection

Three type of materials are used for obtaining the best results. The three materials are:
STEEL ALLOY
ALUMINIUM ALLOY
TITANIUM ALLOY

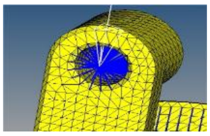
These three are widely used in aerospace industries to make various sub systems and components.
The four figures below shows the mechanical properties of these three alloys. In steel alloys, ferrium m54 turns out to be a good material to use but also ferrium s53 and aermet 100 were also tested. The results shows that these three are not so different in results but ferrium m54 is somewhat better than other two so ferium m54 was selected as steel alloy.
In aluminium alloys, al 2040 is used as it is used in aerospace widely. In titanium alloys, ti 10-2-3 is used as it is better than ti 6Al-4V. So by this way ferrium s53, ti 10-2-3 and al 2040 were used to obtain results of deformation and stresses.
Mass of meshed model:

Titanium alloy: 123 Kg
Aluminium alloy: 83 Kg
Steel alloy: 190 Kg

Table 1- Material Properties

S N o.	MATERIAL	TENSILE STRENGTH (Mpa)	DENSITY (g/cm3)	POISSION'S RATIO	YOUNG'S MODULUS (Gpa)	FRACTURE TOUGHNESS (ksi in1/2)
1	FERRIUM S53	1985	7.98	0.29	204	65
2	FERRIUM M54	2020	7.98	0.29	196	115
3	AERMET 100	1965	7.89	0.28	195	115
4	Ti 10-2-3	1260	4.65	0.32	107	100
5	Ti 6Al-4V	1200	4.512	0.31	119	107
6	Al 2040	469	2.78	0.33	73.1	33.7

4.3 APPLYING BOUNDARY CONDITIONS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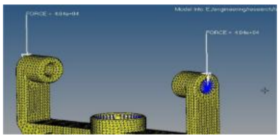
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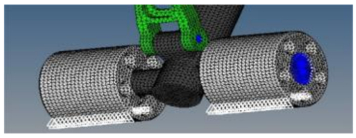

(g)

After giving material and properties to every component boundary conditions have to be applied for analysis.
In boundary conditions, a load and a constraint is needed for static linear analysis. Fig 2(e) shows the rbe3 made for applying force to the centre node and for distribution of the force to each nose of the hole.

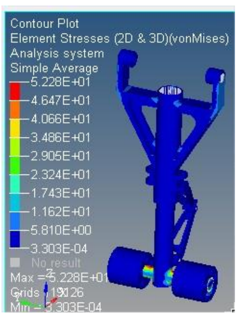
Table 2- specifications of Boeing 747-8

SNo.	NAME	WEIGHT (Kg)
1	Maximum take-off weight	440000
2	Maximum landing weight	306200
3	Operating empty weight	211900
4	Maximum zero fuel weight	288000

Taking maximum take-off weight into account a static load of 80850 N has been chosen.
Max take-off weight is 440000 kg and nose landing gear feels 5% of total weight which is 22000 kg so a 215600 N as the weight of whole design was 190 kg and actual nose landing gear have 1500 kg weight, the weight taken is eight times lighter so 215600/8 *3 = 80850 N (taken F.O.S = 3).
Fig 2(f) shows a total force of 80850 N is applied to both sides centre nodes 40425 N each and Fig2(g) shows the bottom line of the wheel hubs which are given constraints in all the direction.

5. EXPERIMENTAL RESULTS

5.1 Deformation and Stress Results of Aluminium Alloy (Al 2040)



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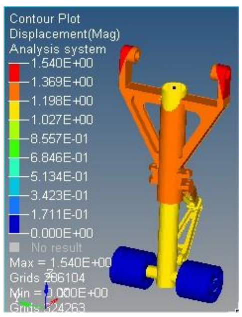

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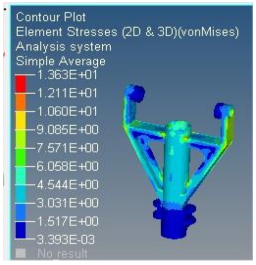

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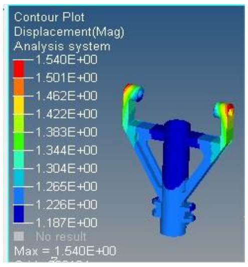
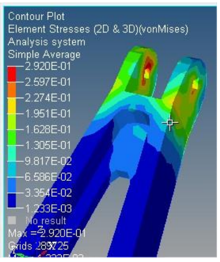


(d)

fig 3(a) shows the stress induced in the whole assembly having maximum stress of 52 mpa in the centre of both sides of the strut's shaft Fig 3(b) shows the deformation of the assembly, we can see a deformation of 1.5 mm is the maximum deformation induced on the barrel Fig3(c) shows the stresses on the barrel Fig3(d) shows the deformation of barrel.



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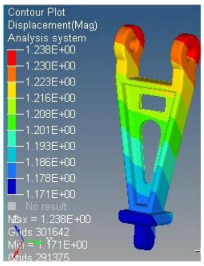

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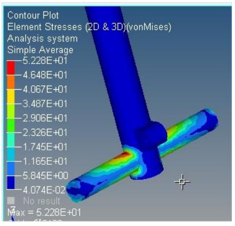

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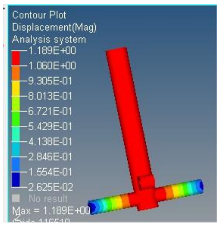
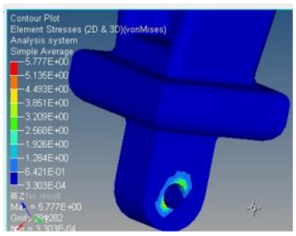


(h)

Fig3(e) shows the stresses on lower torsion link which is maximum at smaller holes Fig3(f) shows the deformation of lower torsion link having maximum at the smaller holes Fig3 (g) shows the stresses induced on the strut Fig3 (h) shows the deformation of strut which is maximum at the top having 1.24 mm value.



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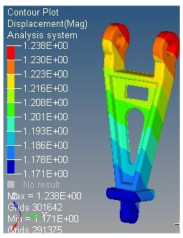

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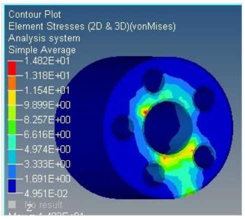

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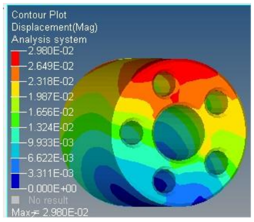
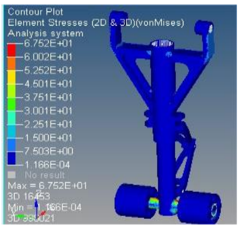


(l)

Fig3 (i) shows the stresses induced on the upper torsion link which is maximum at smaller holes Fig3(j) shows the deformation of upper torsion link having maximum deformation of 1.23 mm Fig3(k) shows the stresses induced on the wheel hub Fig3(l) shows the deformation of the wheel hub.

5.2 Deformation and Stress Results of Steel Alloy (Ferrium M54)



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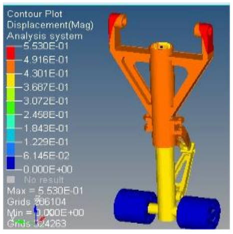

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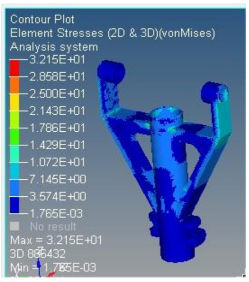

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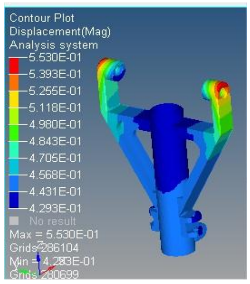
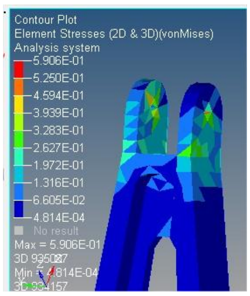


(d)

Fig 4(a) shows the stress induced in the whole assembly having maximum stress of 67.5 mpa Fig 4(b) shows the deformation of the assembly, we can see a deformation of 0.553 mm is the maximum deformation induced on the barrel Fig 4(c) shows the stresses on the barrel Fig 4(d) shows the deformation of barrel.



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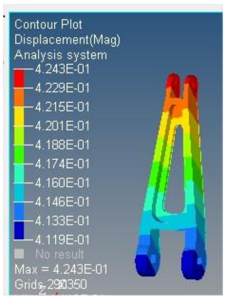

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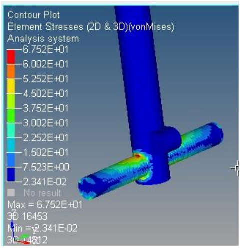
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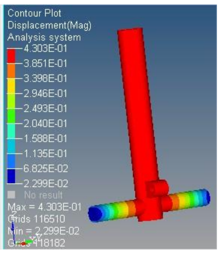
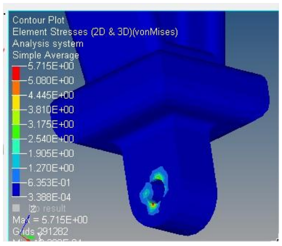

(h)

Fig 4(e) shows the stresses on lower torsion link which is maximum at smaller holes Fig 4(f) shows the deformation of lower torsion link having maximum at the smaller holes Fig 4(g) shows the stresses induced on the strut Fig 4(h) shows the deformation of strut which is maximum at the top having 0.43 mm value.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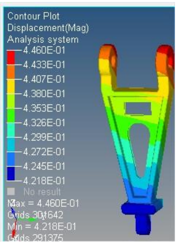
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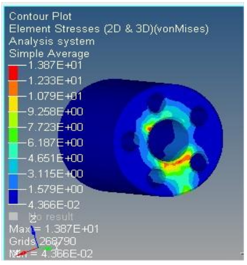
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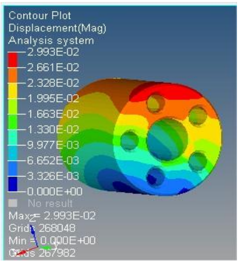
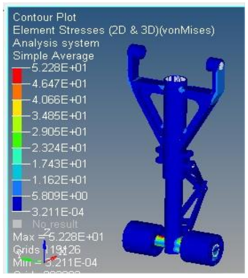

(l)

Fig 4(i) shows the stresses induced on the upper torsion link which is maximum at smaller holes Fig 4(j) shows the deformation of upper torsion link having maximum deformation of 0.446 mm Fig 4(k) shows the stresses induced on the wheel hub Fig 4(l) shows the deformation of the wheel hub.

5.3 Deformation and Stress Results of Titanium Alloy (Ti 10-2-3)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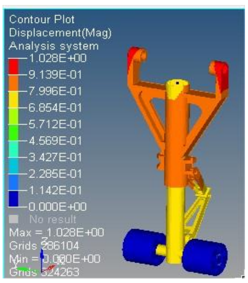
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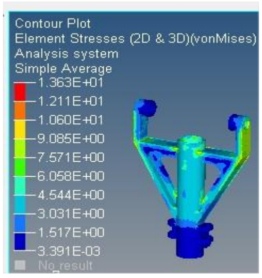
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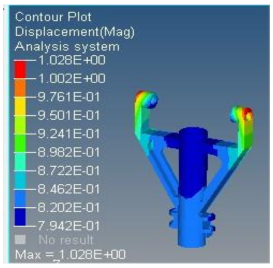
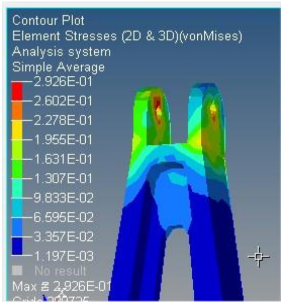

(d)

Fig 5(a) shows the stress induced in the whole assembly having maximum stress of 52.2 mpa Fig 5(b) shows the deformation of the assembly, we can see a deformation of 1.02 mm is the maximum deformation induced on the barrel Fig 5(c) shows the stresses on the barrel Fig 5(d) shows the deformation of barrel.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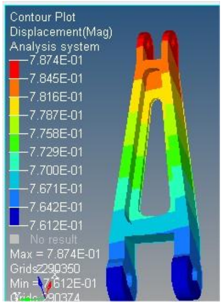
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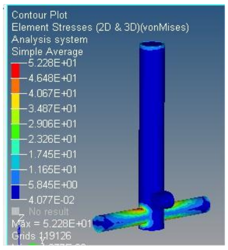
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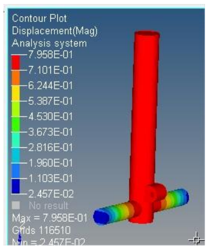
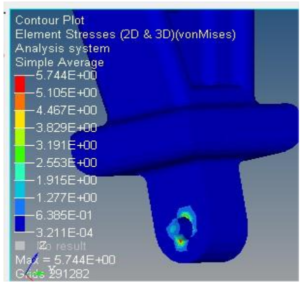

(h)

Fig 5(e) shows the stresses on lower torsion link, maximum at smaller holes Fig 5(f) shows the deformation of lower torsion link, maximum at the smaller holes Fig 5 (g) shows the stresses induced on the strut Fig 5(h) shows the deformation of strut.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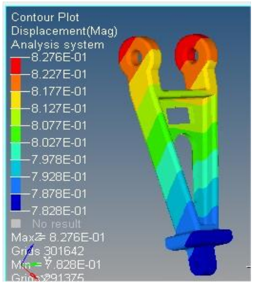
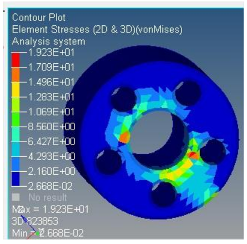
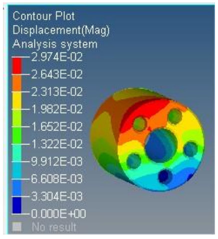

(j)



(k)



(l)

Fig 5 (i) shows the stresses induced on the upper torsion link which is maximum at smaller holes Fig 5 (j) shows the deformation of upper torsion link Fig 5 (k) shows the stresses induced on the wheel hub Fig 5 (l) shows the deformation of the wheel hub.

Table 3- Material v/s Results

SNo.	MATERIAL	MAX. DEFORMATION (mm)	MAX. VON MISE STRESS (Mpa)
1	Steel alloy (Ferrium m54)	0.553	67.5
2	Titanium alloy (Ti 10-2-3)	1.02	52.2
3	Aluminium alloy (A2040)	1.5	52

TABLE 4- FACTORS V/S MATERIALS

SNo.	FACTORS	STEEL ALLOY	TTITANIUM ALLOY	ALUMINIUM ALLOY
1	COST	MEDIUM	HIGH	LOW
2	WEIGHT	HIGH	MEDIUM	LOW
3	MACHINABILITY	LOW	MEDIUM	HIGH
4	STRENGTH	HIGH	MEDIUM	LOW
5	STIFFNESS	HIGH	MEDIUM	LOW

6. CONCLUSION

After evaluating all the results and tables a conclusion is made that a single material should not be used for every component as the role of every component is different. So it is decided that the strut which is having the highest stress allocation should be made of steel alloy, as per results maximum stress is generated in steel alloy but the strut needs to be strong enough to handle all the loads so for strength steel alloy should be used, steel alloy is more is weight but for strength we have to compromise the weight in case of strut.

For barrel again titanium alloy is selected as the highest deformation is seen their and a good stiff material is needed to reduce deformation though steel alloy has lesser deformation but steel alloy weights too much approx. 66% more so titanium alloy is selected. The upper and lower torsion links are having a good amount of stress and deformation on the area surrounding the small holes so titanium alloy should be used and wheel hub should be made of aluminium alloy.

For nut and bolts though a stronger material is needed so steel alloy can be used for that application.

6. FUTURE WORK

- Non-linear, fatigue and impact analysis can also be done to know the phenomenon of the landing gear.
- Hydraulics and tyres should be taken for best results.
- Some other materials can also be tested.
- Topology optimization can also be done to reduce the weight and a combination of reduced weight design and steel alloy can probably do the job and can be made in less cost.

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