Material Replacement and Fatigue Analysis of Nose Landing Gear's Shock Strut

Nishanth P[1], Prabakaran N[2], Akshay R Walikar[3]
Rakesh Ichangi[4], Ravishankar R N[5] & Vijay[6]
[1]Professor, [2]Assistant Professor, [3,4,5,6]Students
Department of Aeronautical Engineering
East West College of Engineering, Bengaluru, India
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Abstract - *Landing, take off are one of the most maneuvering occurring in aircraft. The landing gear is considered as a non-linear structure due to its complicate behavior during landing period large amount of impact forces transferred into nose gear and main landing gear. Nose landing gear bears approx.5% of aircraft's weight and is used for operations like landing, takeoff, as well as steering purpose. The cyclic loads acting on the landing gear which cause fatigue failure of landing gear or its parts. The current work includes the design of the nose landing gear which is retractable type of landing gear. During the ground operation of the aircraft, various types of loads will be encountered. Each of these loads will cause axial compression and tension on the wheels and strut of the landing gear.*

In this work the landing gear part we have chosen is shock strut which is one of the parts in landing gear on which most of the fatigue failures are observed is modeled using CATIA V5 Software. The analysis is carried out in ANSYS 20 R1.

***Keywords**: Non-Linear Structure, Impact Forces, Fatigue Loads, Shock Strut.*

I INTRODUCTION

Landing gear is a crucial component of an aircraft that enables it to take off and land safely. It refers to the system of wheels, struts, and other components that support the weight of the aircraft while it is on the ground, as well as during takeoff and landing [1].

The landing gear system is designed to absorb the shock of the aircraft's touchdown and distribute the resulting forces evenly throughout the structure of the aircraft. The landing gear is also responsible for providing stability and balance to the aircraft during taxiing, takeoff, and landing [2].

There are several types of landing gear systems, including fixed gear, retractable gear, and helicopter landing gear. The choice of landing gear system depends on the type of aircraft, its intended use, and other design considerations [3].

The development of landing gear technology has been a critical factor in the evolution of aviation, enabling aircraft to operate on a wide range of surfaces, including paved runways, grass fields, and water. Advanced landing gear systems have also contributed to the ability of aircraft to operate in challenging conditions, such as on short runways, in high winds, or on rough terrain [4].

Nose Landing Gear

In fighter aircraft, the nose landing gear is designed to be retractable to reduce drag and improve the aircraft's aerodynamic performance during high-speed flight. Fighter aircraft are typically designed for high maneuverability, so the landing gear must be lightweight and durable to withstand the stresses of high-G maneuvers [5].

The nose landing gear of a fighter aircraft is typically composed of a strut, shock absorber, and wheel assembly, similar to commercial airliners. However, it is often smaller and lighter in weight, and the wheel assembly is designed to be easily removable for maintenance and replacement [6].

To reduce drag during flight, the nose landing gear of a fighter aircraft is typically housed in a retractable bay in the aircraft's fuselage. The landing gear is deployed before landing and retracted after takeoff, allowing the aircraft to achieve higher speeds and maneuverability during flight [7].

Figure 1: Nose Landing Gear

Some fighter aircraft, such as the F-35 Lightning II, feature advanced nose landing gear technology, such as an electro-hydraulic actuator system, to improve reliability and reduce maintenance requirements. Additionally, some fighter aircraft may have a steerable nose landing gear to improve ground handling and maneuverability [8].

The nose landing gear of an aircraft is subject to various types of loads, including static loads, dynamic loads, and fatigue loads. Fatigue loads are caused by repeated stresses that occur over time and can cause damage to the landing gear system if not properly managed [9].

Shock Strut

The shock strut of a fighter aircraft's nose landing gear is a component that helps absorb the impact and shock of landing. It is located at the bottom of the nose landing gear and consists of a piston and cylinder arrangement filled with hydraulic fluid.

When the aircraft lands, the shock strut compresses, absorbing the impact of the landing and reducing the stress on the aircraft structure. The hydraulic fluid inside the shock strut helps to dampen the movement of the piston and cylinder, preventing oscillations and providing a smoother landing [10].

The shock strut is designed to be adjustable so that it can be set to different levels of stiffness depending on the weight of the aircraft and the speed of the landing. This helps to ensure that the aircraft lands safely and smoothly, even under different operating conditions.

Fatigue Loads on Landing Gear

Fatigue loads on the nose landing gear of an aircraft are primarily caused by the repeated stresses and strains that occur during takeoff and landing. These stresses are caused by the weight of the aircraft and the forces of the landing impact. The landing gear must be designed to withstand these loads for thousands of cycles over the lifespan of the aircraft [11].

To manage fatigue loads on the nose landing gear, aircraft designers and manufacturers use advanced materials, such as high-strength alloys and composites, to ensure that the landing gear is strong enough to withstand repeated stresses. Additionally, the landing gear is designed with specific features, such as shock absorbers and damping systems, to reduce the impact of landing forces and minimize the risk of fatigue damage.

During aircraft operation, regular inspections and maintenance are conducted to monitor and manage the fatigue loads on the nose landing gear. This includes visual inspections, non-destructive testing, and periodic overhauls and replacements of landing gear components [12].

The shock strut of a fighter aircraft's nose landing gear is subject to significant fatigue loads during operation. Fatigue loads occur when a component is subjected to repeated stress cycles over time, which can cause cracks to develop and propagate in the material.

During landing, the shock strut experiences significant compressive loads as it absorbs the impact of the aircraft touching down on the runway. These loads can be further increased if the landing is hard or the aircraft is heavy, putting additional stress on the shock strut.

In addition to landing loads, the shock strut can also be subject to fatigue loads during takeoff and taxiing. When the aircraft is on the ground, the shock strut is compressed due to the weight of the aircraft, and it experiences further compressive loads when the aircraft is accelerated during takeoff and decelerated during landing.

To prevent fatigue failure, the shock strut is designed and tested to withstand a certain number of stress cycles before needing to be inspected or replaced. Maintenance procedures typically include visual inspections, non-destructive testing, and replacement of the shock strut at specified intervals or when damage is detected.

Overall, managing fatigue loads on the shock strut of a fighter aircraft's nose landing gear is critical to ensure safe and reliable operation of the aircraft.

II OBJECTIVES

Project Overview

The following objectives are formulated for present work:

- To identify the problems in landing gear parts and analysis.
- To design a shock strut of a nose landing gear in CATIA V5.

- To carry out the fatigue analysis in ANSYS 2020R1.
- To propose a new material for shock strut with the goal of improving its performance during service.

The analysis of shock strut will be done by comparison with other Titanium alloys. The landing gear with Titanium alloy will be tested by applying a force during the landing gear under static structural analysis in ANSYS 2020 R1. The total deformation, fatigue life, damage, safety factor, equivalent stress and strain were calculated after applying boundary conditions and load.

Methodology

Problem Identification

Most of the fatigue failures occur in shock strut as per the case studies. This problem can be rectified by changing the material.

The improper material leads to the failure of parts. Steels material are heavy weighted and get easily corroded. On the other hand, titanium alloys are high strength materials. In this project we choose titanium alloy after comparing the properties with that of aluminum. Finally, we conclude with material properties of titanium with less stress, strain and deformation. From the literature it is observed that Ti-10Al-2Fe-3V has significant properties while, Ti-6AL-4V has better property when compared.

Design of Shock Strut

Design of the shock strut is carried in the CATIA- V5 software.

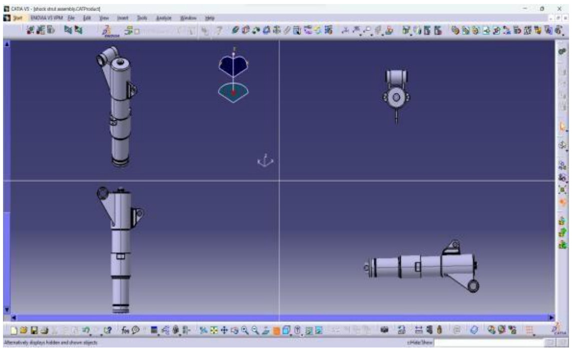

Figure 2: Design made using CATIA V5

Calculation of Load

To calculate the force in the nose landing gear, the aircraft is assumed to be ground taxing. the entire weight of the aircraft will be acting C.G. For our analysis we considered the Typhon aircraft and the maximum weight is 23,500 kilograms. By using the equilibrium equation of the weight.

$F_a L_n – (L_n + L_m) * F_{mg} = 0$

$F_{mg}=F_a*L_n/L_n-L_m$

$F_{mg} = (23000*8.5)/ (8.5-5.3)$ $F_{mg} = 61093.75$ N

Where,

L_n-Distance between nose landing gear from C.G point (m)
L_m-Distance between main landing gear from C.G point (m)
F_a-Total mass of the aircraft (N)
F_{mg}-Force on the nose landing gear (N)

Material Properties

Table 1: Properties of Ti-6Al-4V

Material Properties	Ti-6Al-4V
Density	4.4 g/cm^3
Co-efficient of thermal expansion	8.6E-06 K
Young's modulus	114GPa
Poisson's ratio	0.342
Strength co-efficient	12E+08MPa
Strength exponent	0.5
Cyclic strength co-efficient	6E+08MPa
Cyclic strain hardening exponent	0.15
Tensile yield strength	1000MPa
Tensile ultimate strength	1100MPa
Compressive ultimate strength	1000MPa
Alternating stress	450-660MPa

Above table refers to the properties of Ti-6Al-4V.

Table 2: Properties of Ti-10Al-2Fe-3V & Ti-6Al-6V-2Sn

Material Properties	Ti-10Al-2Fe-3V	Ti-6Al-6V-2Sn
Density (g/cm^3)	4.659	4.54
Poisson's ratio (µ)	0.32	0.32
Young's modulus (GPa)	110	110.3
Ultimate tensile strength (MPa)	1260	1050

Above table refers to the properties of Ti-10Al-2Fe-3V and Ti-6AL-6V-2Sn.

Static Structural Analysis

The static structural analysis calculates the stress, strain, deformation and forces in the structure caused by the load acting on it.

Meshing

Meshing is an important step in finite element analysis (FEA) that involves dividing a complex geometry into smaller and simpler elements to numerically solve the governing equations of the problem. ANSYS is a popular FEA software that provides various tools and options for meshing. In order to get accurate results, it is required to have high aspect ratios. The total 129087 Nodes and 76074 Elements were generated.

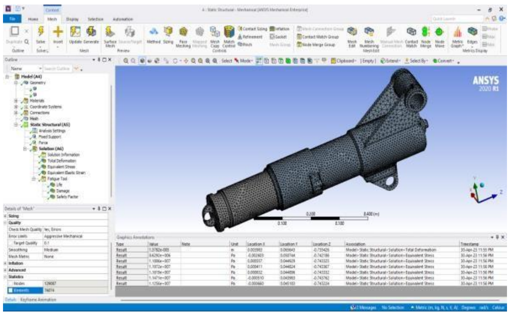

Figure 3: Meshing

Boundary Conditions

Two boundary conditions are applied. First, as fixed support the upper part of the shock strut is considered. Second, a force of 61093.75 N is applied at the bottom.

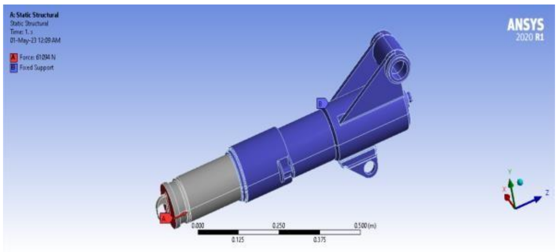

Figure 4: Boundary Condition

III RESULT

In this project, the shock strut is analyzed in static structural analysis method with Ti-6Al-4V. The vertical load applied to the designed shock strut is 61093.75N.

The analysis is completed and the results are obtained for stress, strain, deformation and life, deform, safety factor under fatigue tool which are shown below.

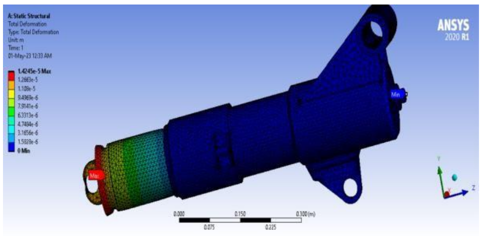

Figure 5: Total Deformation

The max deformation is 1.4223E-005 m.

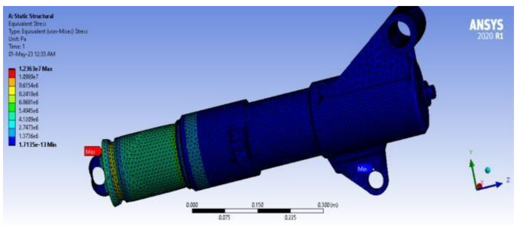

Figure 6: Stress

The max stress is 12.28 MPa.

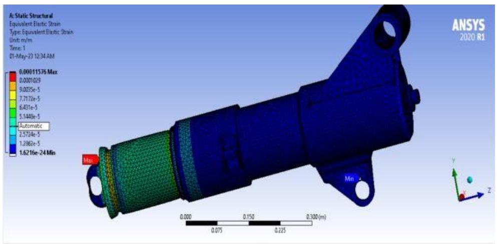

Figure 7: Strain

The max strain is 0.000115.

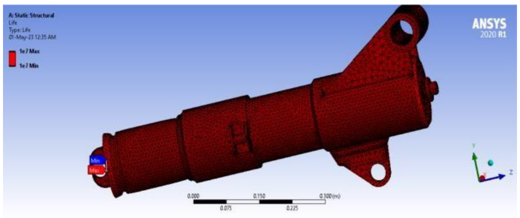

Figure 8: Fatigue Life

The total life is 1E+07 cycles.

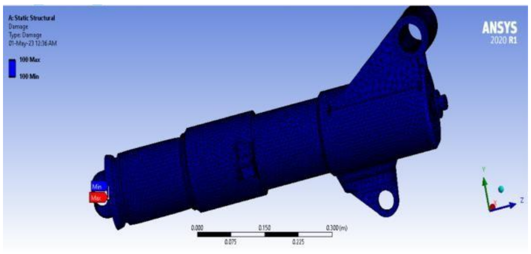

Figure 9: Damage

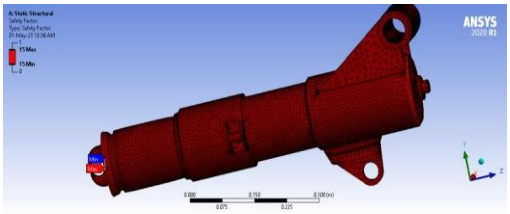

Figure 10: Safety Factor

Graphs

The result obtained is plotted in the graph namely:

- Von misses stresses
- Strain
- Deformation

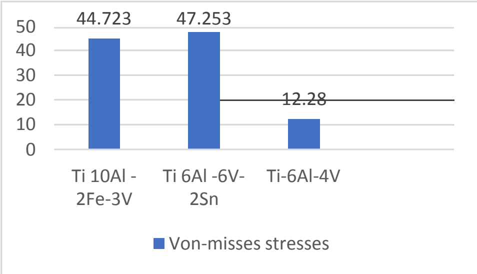

Figure 11: Von- Misses Stresses

Stresses acting over Ti-6Al-4V, Ti-10Al-2Fe-3V and Ti-6Al-6V-2Sn are 12.28 MPa,44.723MPa and 47.253 MPa respectively. By this we can conclude that Ti-6Al-4V is best.

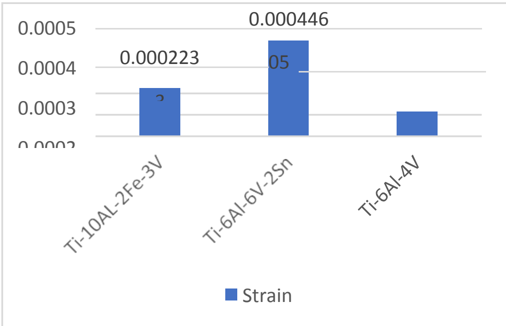

Figure 12: Strain

Strains over Ti-6Al-4V, Ti-10Al-2Fe-3V and Ti-6Al-6V-2Sn are 0.000115 ,0.000223 and 0.00044605 respectively. By this we can conclude that Ti-6Al-4V is best when considering strain factor.

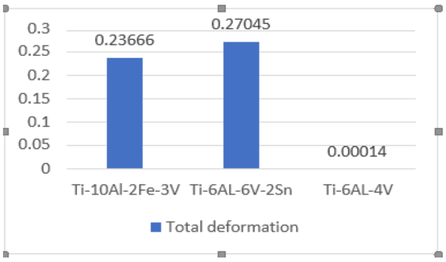

Figure 13: Total Deformation

Deformations of shock strut with Ti-6Al-4V, Ti-10Al-2Fe-3V and Ti-6Al-6V-2Sn are 0.00014 m,0.23666 m and 0.27045 m. We can observe deformation of Ti-6Al-4V is less.

IV CONCLUSION

We Understand that landing gear is an important part of an aircraft. In the above sections we saw that landing gear was impacted by fatigue failure. So, to understand this we designed a landing gear in Catia V5 software and the most affected part was shock strut. So, one method of rectifying this problem was changing the material from Ti-10Al-2Fe-3V to Ti-6Al-4V. The improved properties were observed.

The landing gear part is designed in using catia V5 software and is validated for the material Ti-6Al-4V. By considering the parameters like stresses, strains, deformations, under applied load.

It is observed that deformation of the material on certain load is 1.4223E-0.05 which is very less when compared with other two Titanium alloys.

The stress over TI-6Al-4V is observed 1.228e + 7= 12.28Mpa which is also less than other two materials.

The strain for the material under the conditions of load for Ti-6Al-4V is 1.15e-4 i.e., 0.000115 which is also less when compared with the other two materials.

It can be concluded that use of the material Ti-6Al-4V over Ti-10Al-2Fe-3V is better because of less deformation, stress and strain.

Hence Ti-6Al-4V withstands the load capacity as this composition has unique combination of material properties. Thus, this is the best suitable material for fighter aircraft landing gear as aircraft best results in static and model analysis.

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