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COMPUTATIONAL AND THEORETICAL STRESS ANALYSIS ON AIRCRAFT NOSE WHEEL COMPONENT

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ABSTRACT

This paper presents Load analysis on Aircraft Nose wheel landing gear to predict the deformation strength for three different materials. A simplified aircraft landing gear unit with all members and loads confined to one plane. The brace struts are pinned at each end. And the support C is of the roller type, thus no vertical reactions are produced by the support fitting at point C. the member at C can rotate on the roller but horizontal movement is prevented. A known load of 10000 lb. is applied to axle unit at A. The problem is to find the load in the brace struts and the reactions at B, C and D using ANSYS. The objective of this article is to develop a landing gear with suitable material which can withstand the impact loading. The landing gear is modeled using Finite Element Model method and the modeled component is analyzed using ANSYS to study its structural performance thereby replacing the material of the landing gear the same characters are studied in order to compare the result obtained by both the cases during the same landing conditions.

Keywords

Nose wheel, Load, Material properties, Element, Stress, taxiing, landing

1. INTRODUCTION

Landing gear is one of the most important airplane components to be used for aircraft takeoff, landing, taxiing, parking and steering on ground. Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. In order to verify the structural design loads and the structural strength, it is necessary to measure landing gear loads in flight tests. Generally, ground load calibration test is to remove the landing gear from the test aircraft, then fix it in specially designed test rig and apply loads to the landing gear. In this way, the connection stiffness between landing gear and rig cannot be fully simulated as the real connection stiffness with the aircraft. This will affect the accuracy of the result of loads measurement.

The design of the landing gear is one of the more fundamental aspects of aircraft design. The design & integration process encompasses numerous disciplines, e.g. structures, weights, runway design, and economics and has become sophisticated in the last few decades. The importance in the design of aircraft landing gear is structure. When aircraft is landed, landing gear is subjected to repeated stresses due to thrust acting on upper part. So due to repetitive stresses, landing gear may fail below yield point stresses. A collapse of a landing gear during the landing roll can have devastating effects on the aircraft. Therefore the gear must be able to withstand the shocks of landing.

Numerous configurations of landing gear types can be found. Additionally, combinations of two types of gear are common. Amphibious aircraft are designed with gear that allows landings to be made on water or dry land. The gear features pontoons for water landing with extendable wheels for landing on hard surface. A similar system is used to allow the use of skis and wheels on aircraft that operate on both slippery, frozen surfaces and dry runways. Typically, the skis are retractable to allow use of the wheels when needed.

2. LANDING GEAR LOADS AND SELECTION OF MATERIALS

Loads imposed on the various airframe components during landing and ground handling operation are of necessity dependent on characteristics of the airplane's landing gear. A conventional landing gear performs two basic functions. It dissipates the energy associated with vertical descent as the airplane contacts the ground; and, it provides a means of maneuvering the airplane on the ground (taxiing). Analysis of airplane behavior during the landing impact and during the taxiing operation is imperative in order that:

The landing gear and its attachment be designed to a proper strength level. Other components are investigated for every possible design consideration. It is apparent that landing impact loads are dependent on number of variables, which are airplane landing contact velocity (airplane design sink speed: 10ft/sec for transports and land based fighter except trainer 20ft/sec for carrier-based airplanes), airplane attitude, airplane mass, distribution of airplane mass to the various gears, and magnitude of lift acting on the airplane at time of impact. In addition to the variables contributing to vertical gear loads are those affecting gear drag loads, such as the friction coefficient between the tire and ground surface, and the spring function behavior of the entire gear in the fore and aft direction.

Landing gear experiences landing and ground maneuvering load cases. The different static and critical loads that act on under carriage are as follows:

i. Three-point landing spin-up load.
ii. Three-point landing spring back load.
iii. Three-point landing-impact load.
iv. Taxing load.
v. Pivoting load.
vi. Turning load.
vii. Towing load.
viii. Three point braked roll load.
ix. Unsymmetrical braking load.

To analyze fully all the possible gear loads, a number of landing scenarios must be examined. These include a level landing, a tail-down landing, a one-wheel landing, and a crabbed landing. For certification the aircraft may be subjected to drop tests, in which an actual aircraft is dropped from a height of somewhere between 9.2-18.7 in. The required drop distance typically will be 3.6 times the square root of the wing loading.

When the tires contact the ground they are not rotating. During the brief fraction of a second it takes for them to spin up, they exert a large rearward force by friction with the runway. This spin-up force can be as much as half the vertical force due to landing.

When the tire is rotating at the correct speed, the rearward force is relieved and the gear strut "springs back" forward, overshooting the original position and producing a "spring back" deflection load equal to or greater than the spin-up load. Another landing gear load, the braking load, can be estimated by assuming a braking coefficient of 0.8.

The load on the landing gear during retraction is usually based upon the air loads plus the assumption that the aircraft is in a 2-g turn. Other landing gear loads such as taxiing and turning are usually of lesser importance, but must be considered during detail design.

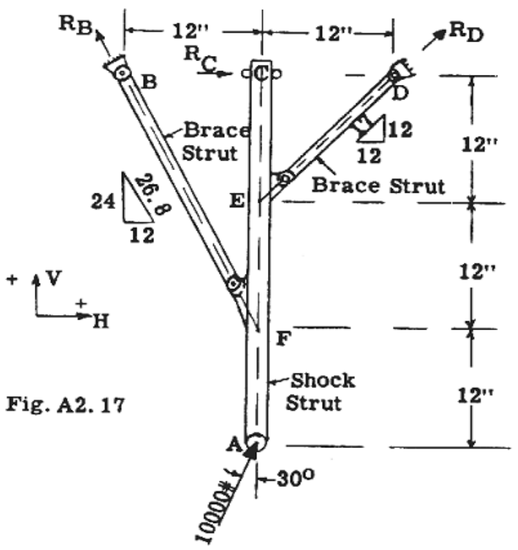

Fig. A2. 17

Another consideration in designing landing gear is material selection. Landing gear materials must be of high strength and stiffness, low cost and weight, and have good machinability, weldability, and forgeability. A list of selection criteria for materials are as follows:

i. Static Strength Efficiency
ii. Fatigue
iii. Fracture toughness and crack growth
iv. Corrosion and embrittlement
v. Environmental stability

Other criteria equally important are the criteria associated with producing the basic material in the forms required and fabricating the end product at a reasonable cost. These criteria are as follows:

i. Availability and Producibility
ii. Material costs
iii. Fabrication Characteristics

All of the criteria listed above are important to the selection of structural materials. In addition to these, the following are a few considerations that are more frequently related to specialized requirements:

i. Erosion and abrasion
ii. Wear characteristics
iii. Compatibility with other materials
iv. Thermal and electrical characteristics
v. Hard Coating to improve wear resistance
vi. Metallic plating to provide galvanic compatibility

Because of the stringent requirements, landing gear components are fabricated from forgings. Castings have not been acceptable for landing gear structures due to poor fatigue-related characteristics such as grain flow and porosity. The most widely used landing gear steel is 300M steel. It is heat treated to a 280,000-psi strength level. European equivalents to 300M are S155 and 35NCD16 steels. Recently developed Armlet 100 has the strength of 300M and substantially superior fracture toughness and stress corrosion thresholds. It is also five times the cost of 300M. When strength is not critical, but stiffness is, 180,000-psi 4340 steel is used. HP-9-4-30 and HY-TUF steel have 220,000-psi strength, but high fracture toughness, and have been widely used in naval gear. Among nonferrous alloys, the most widely used are high strength titanium alloys such as Ti-1OV-2Fe-3Al and Ti-6A1-6VlSn, and high-strength aluminum alloys such as 7075-T73 and 7175-T74. European equivalents are IMI1551 titanium and AZ74 aluminum.

3. FINITE ELEMENT ANALYSIS

The ANSYS product includes different modules like Structural, Thermal. Structure focuses on the structural integrity of your model. Thermal evaluates heat-transfer characteristics.

Structural Analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. For finite element analysis of Aircraft Landing Gear, Link 180, Beam 188 element has been used.

3.1 Standard Steps in Analysis:

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient, dynamic analysis. A typical ANSYS analysis has three distinct steps:

1. Pre Processing (Build the Model).
2. Processing (Apply Loads and obtain the solution).
3. Post Processing (Review the Results).

3.2 Finite Element Analysis of Nose Landing Gear:

The finite element is a numerical technique for solving a set of different simultaneous algebraic equations with imposed boundary conditions for analyzing structures and continua. Usually the problem addressed is too complicated to be solved satisfactorily by classical analysis method. The method was originally applied to the problems of structural mechanics, heat conduction, magnetic and electric fields, lubrication and others.

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4. COMPUTATIONAL RESULTS & DISCUSSIONS

Later Pre-processing and load application, the results obtained for landing gear made up of three different materials namely Steel, Titanium and Aluminium are as follows:

4.1 Stress distribution for Steel

For the landing gear made up of steel the maximum stress of 15.1797 N/mm2 is observed when a constant load of 10,000N is acting at the end of axle acting at the angle of 30 degrees.

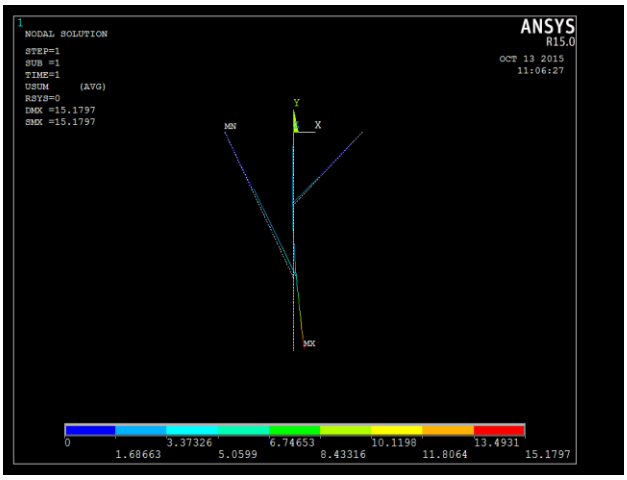

Figure: 4.1 contour plot for a deformed nose wheel with steel as material

4.2 Stress distribution for Titanium

For the landing gear made up of Titanium the maximum stress of 0.00414 N/mm2 is observed when a constant load of 10,000N is acting at the end of axle at an angle of 30 degrees.

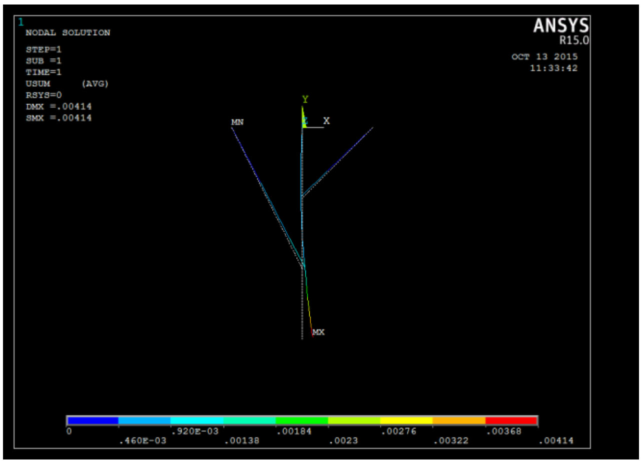

Figure: 4.2 contour plot for a deformed nose wheel with titanium as material

4.3 Stress distribution for Aluminium

For the landing gear made up of Aluminium the maximum stress of 0.0066 N/mm2 is observed when a constant load of 10,000N is acting at the end of the axle at an angle of 30 degrees.

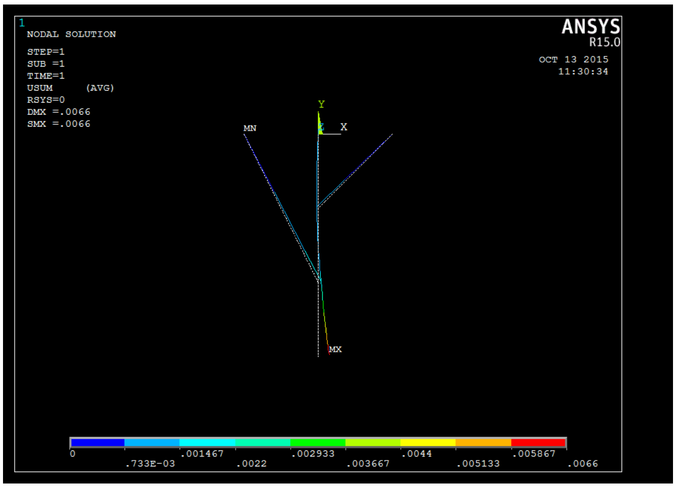

Figure: 4.3 contour plot for a deformed nose wheel with aluminium as material

5. THEORETICAL RESULTS AND DISCUSSIONS

5.1 Reaction Forces theoretical calculations

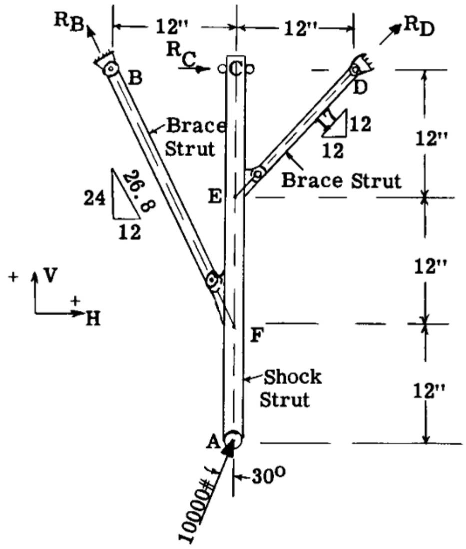

Figure 5.1: shows a simplified airplane landing gear unit with all members and loads

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To Find Reactions at D, RD take moments about point B:-

$\sum$ MB = -10000 sin 30 * 36 -1000 cos 30 * 12 – RD (12/17) 24 = 0

Hence, RD = -16750 N.

To Find Reactions at B, RB take $\sum$ FY = 0

$\sum$ FY = 10000 * cos 30 + (- 16750) (12/17) + RB (24/ 26.8) = 0

Hence, RB = 3540 N.

To Find Reactions at C, RC take $\sum$ H = 0

$\sum$ H = 10000 sin 30 – 3540 (12/26.8) + (-16750) (12/17) + RC = 0

Hence, RC = 8407 N.

5.2 Reaction Solutions from ANSYS

PRINT REACTION SOLUTIONS PER NODE

***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP= 1 SUBSTEP= 1

TIME= 1.0000 LOAD CASE= 0

The Following X, Y, Z Solutions Are In The Global Coordinate System

NODE	FX	FY	FZ	MX	MY	MZ
1	-1584.9	3169.9	0.000	0.000	0.000	0.000
3	-11830	-11830	0.000	0.000	0.000	0.000
5	8415.1					
TOTAL VALUES						
VALUE	-5000.0	-8660.3	0.000	0.000	0.000	0.000

Element	Theoretical solutions	ANSYS solutions
1	**3540**	**3169.9**
3	**-16750**	**-11830**
5	**8407**	**8415.1**

Table 5.2: Comparison among theoretical and Ansys solutions

5.3 Plots and Discussions

A graph is plotted between theoretical and ansys values of reaction forces by taking elements on X-axis and corresponding values on Y-axis.

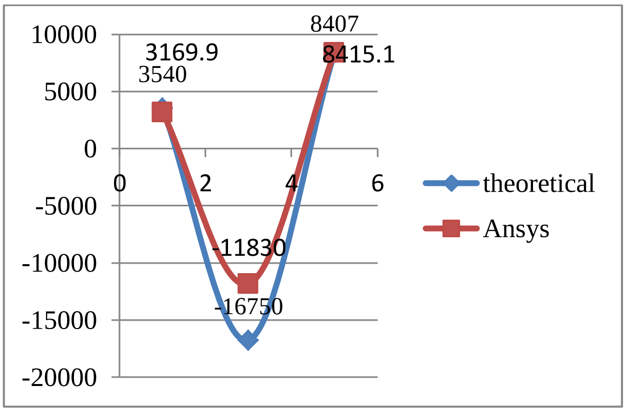
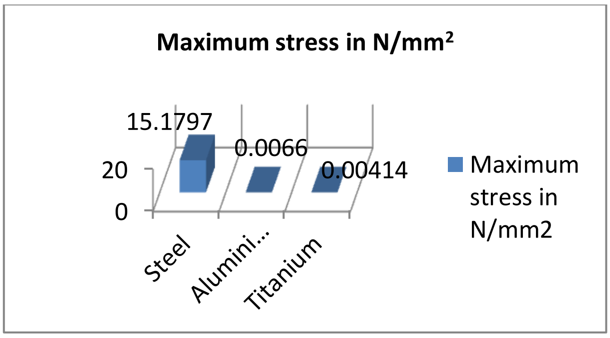


Figure 5.2: shows the comparison among theoretical and Ansys values for reaction forces.

5.4 Validations for Stress values with different strut materials

Material for wheel strut	Steel	Aluminium	Titanium
Maximum stress in N/mm^2	15.1797	0.0066	0.00414



6. CONCLUSIONS

It is clear from the above validation table and plots that the maximum stress distribution in the landing gear varies for different materials. For the landing gear made up of titanium is having the low maximum stress when compared to the steel and aluminium materials. Hence it is concluded that among the three materials the strut made of Titanium gives better strength for impact loading ie, when the load distributed is taken constant for all material considerations.

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