Modeling and Analysis of Aircraft Landing Gear: Experimental Approach

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Abstract: ***The main objective of this paper to present prototype of aircraft landing gear using higher end CAD software to study the behavior of landing gear as per actual working condition and to perform structural analysis to study the landing gear behavior for cyclic loading (fatigue loading). Computer modeling (CAD) and finite element analysis will be explored to analyze stresses developed while landing. It also includes displacement analysis. For modeling purpose PROE-WILDFIRE software & for analysis ANASYS V-8 software is used.***

Keywords: Modeling, stress analysis

1. Introduction

The design of the landing gear is one of the more fundamental aspects of aircraft design. The design & integration process encompasses numerous displines, e.g. structures, weights, runway design, and economics, and has become sophisticated in the last few decades. The importance of 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.

2. Principles of Flight

An airplane in flight is the center of a continuous tug of war between four forces: lift, gravity force or weight, thrust, and drag. Lift and Drag are considered aerodynamic forces because they exist due to the movement of the aircraft through the air. The weight pulls down on the plane opposing the lift created by air flowing over the wing. Thrust is generated by the propeller and opposes drag caused by air resistance to the frontal area of the airplane. During takeoff, thrust must overcome drag and lift must overcome the weight before the airplane can become airborne. In level flight at constant speed, thrust exactly equals drag and lift exactly equals the weight or gravity force. For landings thrust must be reduced below the level of drag and lift below the level of the gravity force or weight landing thrust must be less than drag, and lift must be less than weight

3. Landing Gear Concept Selection

The design and positioning of the landing gear are determined by the unique characteristics associated with each aircraft, i.e., geometry, weight, and mission requirements. Given the weight and cg range of the aircraft, suitable configurations are identified and reviewed to determine how well they match the airframe structure, flotation, and operational requirements. The essential features, e.g., the number and size of tires and wheels, brakes, and shock absorption mechanism, must be selected in accordance with industry and federal standards before an aircraft design progresses past the concept formulation phase, after which it is often very difficult and expensive to change the design.

Based on the design considerations, algorithms were developed to establish constraint boundaries for use in positioning the landing gear, as well as to determine whether the design characteristics violate the specified requirements. The considerations include stability at takeoff/touchdown and during taxiing, braking and steering qualities, gear length, attachment scheme, and ground maneuvers.

3.1 Configuration Selection

The nose wheel tricycle undercarriage has long been the preferred configuration for passenger transports. It leads to a nearly level fuselage and consequently the cabin floor when the aircraft is on the ground. The most attractive feature of this type of undercarriages is the improved stability during braking and ground maneuvers. Though the tricycle arrangement may be most popular today that was not always the case. The tail wheel undercarriage dominated aircraft design for the first four decades of flight and is still used on many small piston-engine planes. The tail dragger arrangement consists of two main gear located near the center of gravity that support the majority of the plane's weight. A much smaller support is also located at the rear of the fuselage.

3.2 Design Considerations

Several design considerations that must be addressed are briefly discussed to illustrate the complexity involved in the development of such a methodology. The list is made up of an ever-increasing, and sometimes conflicting, number of requirements, e.g., component maximum strength, minimum weight, high reliability, low cost, overall aircraft integration, airfield compatibility, etc., and truly reflect the multidisciplinary nature of the task. The weight of the landing gear, which typically ranges from three to six percent of the maximum aircraft takeoff weight, is also a design consideration. With advances in flight Science technologies, which result in reduced structural and mission fuel weights, the landing gear may become an increasingly large weight fraction in future large aircraft.

The location of the aircraft center of gravity (cg) is critical in the design and location of the landing gear. The nose and main assemblies must be located within specific distances from the aircraft cg, in both the longitudinal and lateral directions. Another issue to be considered is the distribution of the aircraft weight, which is dependent on the distances between the aircraft cg and the nose and main assembly.

Airfield compatibility has become one of the primary considerations in the design of landing gears due to the high cost associated with infrastructure modification, e.g., pavement reinforcement and runway and taxiway expansion. Pavement bearing strength, which varies from one airport to another due to variations in sub grade materials, dictates the number and arrangement of tires needed to produce the required flotation characteristics. Flotation is defined as the capability of the runway pavement and other surfaces, e.g., taxiway and apron, to support the aircraft. In addition, the disposition of the landing gear is constrained by the runway and taxiway geometry as found at the airports to be served. Since the ground track is dependent on the dimensions of the wheelbase and track, an increase in these dimensions could bring the aircraft over the edge of the pavement during certain maneuvers, e.g., a 180-degree turn and centerline-tracing taxiing, and cause the aircraft to bog down in soft soil.

The soundness of a landing gear concept depends on the efficiency of overall system integration. Ground clearance, particularly between the engine nacelle and the static ground line, plays a key role in determining the length of the landing gear and the permissible takeoff rotation angle. Insufficient allowance can result in costly modifications.

3.3 Factor Considered in landing Gear Design

- Weight of the landing gear
- Component maximum strength,
- Aircraft integration,
- Airfield compatibility,
- Minimum weight,
- Aircraft center of gravity

3.4 Landing Gear Disposition

The positioning of the landing gear is based primarily on stability considerations during taxiing, liftoff and touchdown.

3.4.1 Angles of Pitch and Roll during Takeoff and Landing

The available pitch angle at liftoff and touchdown must be equal, or preferably exceed, the requirements imposed by performance or flight characteristics. A geometric limitation to the pitch angle is detrimental to the liftoff speed and hence to the takeoff field length. Similarly, a geometric limitation to the roll angle. It could result in undesirable operational limit under cross-wind landing condition. For a given aircraft geometry and gear height, the limit for the takeoff landing pitch angle follows directly. The roll angle at which the tip of the wing just touches the ground is calculated using the expression.

$$\tan\phi = \tan\Gamma + \frac{2h_g}{s-t} - \tan\theta \tan\Lambda$$

In this case, it taken as the dihedral angle, s is the wing span; t is the wheel track, and the wing sweep. Similar conditions may be deduced for other parts of the aircraft, except that s in Eq. must be replaced with appropriate value.

3.4.2 Pitch Angle Required for Liftoff

The takeoff rotation angle is prescribed in preliminary design, and then estimated. The final values are found as detailed performance characteristics of the aircraft become available. The pitch angle at liftoff is calculated using the expression

$$\theta_{LOF} = \alpha_{LOF} + \frac{d\theta}{dt}\left(\frac{2l_1}{V_{LOF}} + \sqrt{\frac{l_2}{g}\frac{C_{LLOF}}{dC_L/d\alpha}}\right)$$

Where α_{LOF} is the highest angle of attack anticipated for normal operational use, V_{LOF} is the liftoff speed, g is the gravitational acceleration C_{LLOF} is the lift coefficient. As shown in following fig.2, the dimension of l_1 and l_2 are defined by the line connecting the tire-ground contact point upon touchdown and the location of the tail bumper

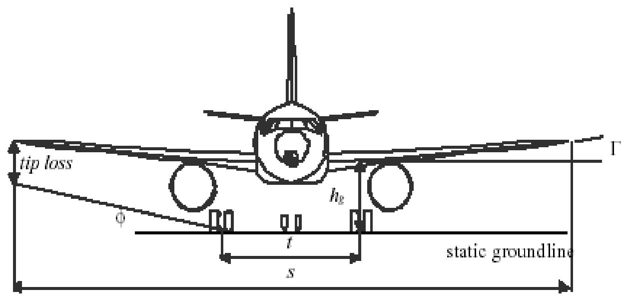

Figure 1: Front View

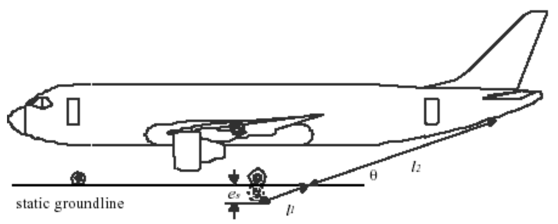

Figure 2: Side View

3.5 Pitch and Roll Angles during Landing

With the flaps in the fully-deflected position, the critical angle of attack of the wing during landing is smaller than in takeoff. Consequently, the pitch angle during landing is generally less than that during takeoff. In the absence of detailed information, the pitch angle on touchdown may be assumed equal to. As for the roll angle upon touchdown, an upper limit of between five and eight degrees is generally applied to large transport

3.6 Sideways Turnover Angle

Forces acting sideways on the airplane in cross-wind landing condition or a high-speed turn during taxiing could cause the aircraft to turnover on its side. It is thus desirable to keep the turnover angle (Ψ) as small as possible. The angle is determined using the expression

$$\tan\psi = \frac{h_{cg}}{l_n \sin\delta}$$

$$\tan\delta = \frac{t}{2(l_m + l_n)}$$

and is defined as the angle between the aircraft centerline and the line connecting the center of the nose and main assembly. The dimensions used in the above equations are given in Fig. For land-based aircraft, either the maximum allowable overturn angle of 63 degrees or the stability considerations at takeoff and touchdown and during taxiing, whichever is the most critical, determines the lower limit for the track of the main assembly.

3.7 Ground Operation Characteristics

Besides ground stability and controllability considerations, the high costs associated with airside infrastructure improvements, e.g., runway and taxiway extensions and pavement reinforcements have made airfield compatibility issues one of the primary considerations in the design of the landing gear. In particular, the aircraft must be able to maneuver within a pre-defined space as it taxies between the runway and passenger terminal. For large aircraft, this requirement effectively places an upper limit on the dimension of the wheelbase and track.

3.8 Shock Absorber Design

The basic function of the shock absorber is to absorb and dissipate the impact kinetic energy to the extent that accelerations imposed upon the airframe are reduced to a tolerable level. Existing shock absorbers can be divided into two classes based on the type of the spring being used: those using a solid spring made of steel or rubber and those using a fluid spring with gas or oil, or a mixture of the two that is generally referred to as oleo-pneumatic. The high gear and weight efficiencies associated with the oleo-pneumatic shock absorber make it the preferred design for commercial transports. Based on the analysis procedure as outlined in this chapter, algorithms were developed to determine the required stroke and piston length to meet the given design conditions, as well as the energy absorption capacity of the shock absorber.

4. Modeling of Landing Gear

4.1 CAD Software's for Landing gear design

- PRO/E – For 3D Component Design.
- Pro/Assembly- For Assembling Components of landing gear
- PRO/Mechanism – For Mechanism

Pro/ENGINEER is a parametric, feature based, solid modeling System. It is the only menu driven higher end software. Pro/ENGINEER provides mechanical engineers with an approach to mechanical design automation based on solid modeling technology and the following features

5. Finite Element Analysis

The finite element method has become a powerful for the numerical solution of a wide range of engineering problems

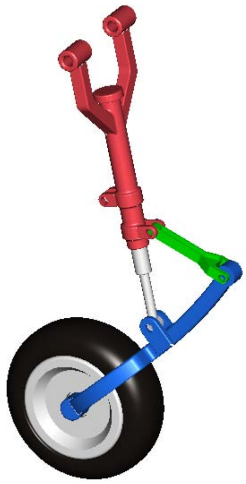

Figure 3: Model of Aircraft landing gear

Applications range from deformation and stress analysis of automotive, aircraft, building and bridge structures to field analysis of heat flux, fluid flow, magnetic flux, seepage and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modeled with relative ease. In this method of analysis, a complex region defining a continuum is descretized into simple geometric shapes called finite elements. The material properties and the governing relationships are considered over these elements and expressed in terms of unknown values at element corners. An assembly process, duly considering the loading and constraints, results in a set of equations. Solution of these equations gives us the approximate behavior of the continuum.

5.1 ANSYS

ANSYS is a multi-discipline CAE (Computer Aided Engineering) tool that enables you to simulate the physical behavior of a model and to understand and improve the mechanical performance of your design. You can directly calculate stresses, deflections, frequencies, heat transfer paths, and other factors, showing you how your model will behave in a test lab or in the real world.

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, SOLID92-Tetrahedral element has been used

5.2 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. Preprocessing (Build the model).
2. Processing (Apply loads and obtain the solution).
3. Post Processing (Review the results).

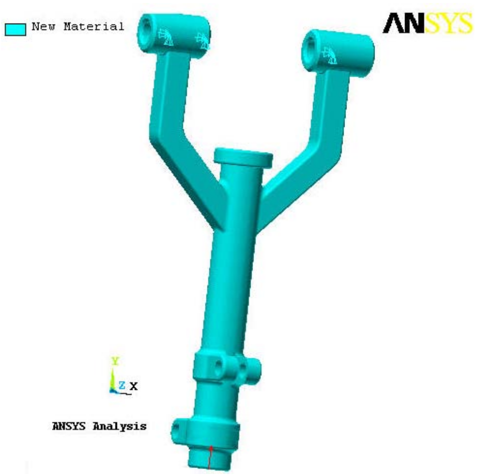

Figure 4: Boundary condition

6. Conclusion

The design of the landing gear is one of the more fundamental aspects of aircraft design. When aircraft is landed, landing gear is subjected to repeated stresses due to thrust acting on upper part.

Figure 5: Meshing

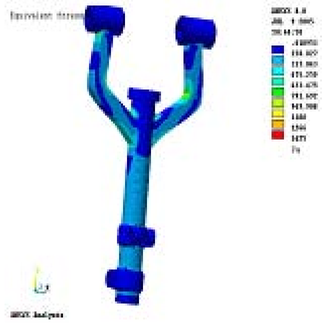

Figure 6: Displacement analysis

So due to repetitive stresses, landing gear may fail below yield point stresses. A collapse of landing roll can have devastating effects on the aircraft. Therefore the gear must be able to withstand the shocks of landing. So it is necessary to calculate maximum stress induced.

So in this project prototype of Aircraft (Joint strike fighter F-35) Landing gear is created & maximum stress and maximum displacement is calculated.

- The maximum equivalent stress is 1424.6 N / m2 which is less than 600 N / mm2 (Yield stress) So design model is safe under given working condition
- The maximum displacement is 5.86756E-08 m

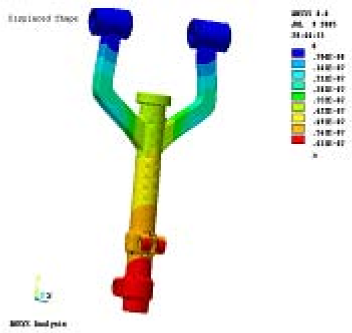

Figure7: Stress Analysis

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