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CONCEPTUAL DESIGN AND OPTIMIZATION OF AIRCRAFT LANDING GEAR SYSTEMS BY USING ANSYS SOFTWARE

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Abstract: *Landing gear is a vital structural unit of an aircraft which enables to take off and land safely on the ground. A variety of landing gear arrangements are used depending on the type and size of an aircraft. Even during a normal landing operation heavy load are to be absorbed by the landing gear. In turn joints are to be provided such that such heavy concentrated loads are first received by the airframe and subsequently diffused to the surrounding areas. Normally heavy concentrated loads are received through a lug joint. Therefore, design of a lug joint against failure under static and fatigue loading conditions assumes importance in the development of an aircraft structure. This project deals with the design and analysis of a typical lug joint representative of a landing gear attachment of a small airplane. The design will provide safety against failure of the lug, and failure of the pin in Catia. A typical landing load case will be assumed for which structural analysis will be carried out. The landing gear space structure will be idealized as a statically determinate structure and a stress analysis will be performed using strength of Material approach. The stresses developed because of all three types of loading on the structural members of the landing gear will be calculated. A finite element model of the landing gear structure will be developed and analyzed in Ansys. The FEA stress and deformation results will be compared. These stresses and internal loads can then be used for the design of various structural members of the landing gear unit. Fatigue life to crack initiation will be estimated for a critical lug of the landing gear unit by considering the constant amplitude landing cycles.*

I- INTRODUCTION

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear has wheels to facilitate operation to and from hard surfaces, such as airport runways. Other gear feature skids for this purpose, such as those found on helicopters, balloon gondolas, and in the tail area of some tail dragger aircraft. Aircraft that operate to and from frozen lakes and snowy areas may be equipped with landing gear that have skis. Aircraft that operate to and from the surface of water have pontoon-type landing gear. Regardless of the type of landing gear utilized, shock absorbing equipment, brakes, retraction mechanisms, controls, warning devices, cowling, fairings, and structural members necessary to attach the gear to the aircraft are considered parts of the landing gear system.

Landing Gear Arrangement

Three basic arrangements of landing gear are used: tail wheel type landing gear (also known as conventional gear), tandem landing gear, and tricycle-type landing gear.

Tail Wheel-Type Landing Gear

Tail wheel-type landing gear is also known as conventional gear because many early aircraft use this type of arrangement. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly. A few early aircraft designs use a skid rather than a tail wheel. This helps slow the aircraft upon landing and provides directional stability. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design. The increased clearance of the forward fuselage offered by tail wheel-type landing gear is also advantageous when operating in and out of non-paved runways.

Tandem Landing Gear

Few aircraft are designed with tandem landing gear. As the name implies, this type of landing gear has the main gear and tail gear aligned on the longitudinal axis of the aircraft. Sailplanes commonly use tandem gear, although many only have one actual gear forward on the fuselage with a skid under the tail. A few military bombers, such as the B-47 and the B-52, have tandem gear, as does the U2 spy plane. The VTOL Harrier has tandem gear but uses small outrigger gear under the wings for support. Generally, placing the gear only under the fuselage facilitates the use of very flexible wings. 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.

Adjusting Landing Gear Latches

The adjustment of various latches is a primary concern to the aircraft technician. Latches are generally used in landing gear systems to hold the gear up or down and/or to hold the gear doors open or closed. Despite numerous variations, all latches are designed to do the same thing. They must operate automatically at the proper time, and they must hold the unit in the desired position. A typical landing gear door latch is examined below. Many gears up latches operate similarly.

Clearances and dimensional measurements of rollers, shafts, bushings, pins, bolts, etc., are common. On this particular aircraft, the landing gear door is held closed by two latches. To have the door locked securely, both latches must grip and hold the door tightly against the aircraft structure. The principle components of each latch mechanism are a hydraulic latch cylinder, a latch hook, a spring-loaded crank-and-lever linkage with sector, and the latch hook. When hydraulic pressure is applied, the cylinder operates the linkage to engage (or disengage) the hook with (or from) the roller on the gear door. In the gear-down sequence, the hook is disengaged by the spring load on the linkage. In the gear-up sequence, when the closing door is in contact with the latch hook, the cylinder operates the linkage to engage the latch hook with the door roller.

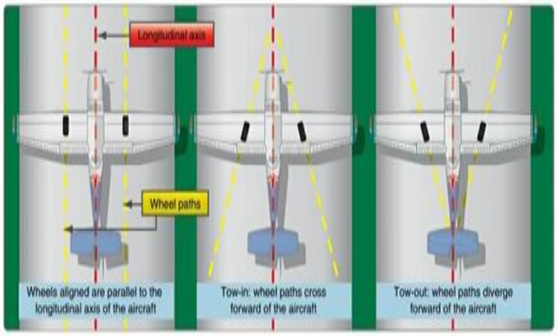
II- LITERATURE SURVEY

Alignment system of Landing Gear

As previously mentioned, a torque arm or torque links assembly keeps the lower strut cylinder from rotating out of alignment with the longitudinal axis of the aircraft. In some strut assemblies, it is the sole means of retaining the piston in the upper strut cylinder. The link ends are attached to the fixed upper cylinder and the moving lower cylinder with a hinge pin in the center to allow the strut to extend and compress. Alignment of the wheels of an aircraft is also a consideration. Normally, this is set by the manufacturer and only requires occasional attention such as after a hard landing. The aircraft's main wheels must be inspected and adjusted, if necessary, to maintain the proper tow-in or two-out and the correct camber. Tow-in and tow-out refer to the path a main wheel would take in relation to the airframe longitudinal axis or centerline if the wheel was free to roll forward.

Three possibilities exist. The wheel would roll either:
1) Parallel to the longitudinal axis (aligned)
2) Converge on the longitudinal axis (tow-in)
3) Veer away from the longitudinal axis (tow-out)

The manufacturer's maintenance instructions give the procedure for checking and adjusting tow-in or tow-out. A general procedure for checking alignment on a light aircraft follows. To ensure that the landing gear settle properly for a tow-in/tow-out test, especially on spring steel strut aircraft, two aluminum plates separated with grease are put under each wheel. Gently rock the aircraft on the plates to cause the gear to find the at rest position preferred for alignment checks.



A straight edge is held across the front of the main wheel tires just below axle height. A carpenter's square placed against the straight edge creates a perpendicular that is parallel to the longitudinal axis of the aircraft. Slide the square against the wheel assembly to see if the forward and aft sections of the tire touch the square. A gap in front indicates the wheel is towed-in. A gap in the rear indicates the wheel is towed out. Camber is the alignment of a main wheel in the vertical plain. It can be checked with a bubble protractor held against the wheel assembly. The wheel camber is said to be positive if the top of the wheel tilts outward from vertical. Camber is negative if the top of the wheel tilts inward.

Small Aircraft Retraction System

As the speed of a light aircraft increases, there reaches a point where the parasite drag created by the landing gear in the wind is greater than the induced drag caused by the added weight of a retractable landing gear system. Thus, many light aircraft have retractable landing gear. There are many unique designs. The simplest contains a lever in the flight deck mechanically linked to the gear. Through mechanical advantage, the pilot extends and retracts the landing gear by operating the lever. Use of a roller chain, sprockets, and a hand crank to decrease the required force is common.

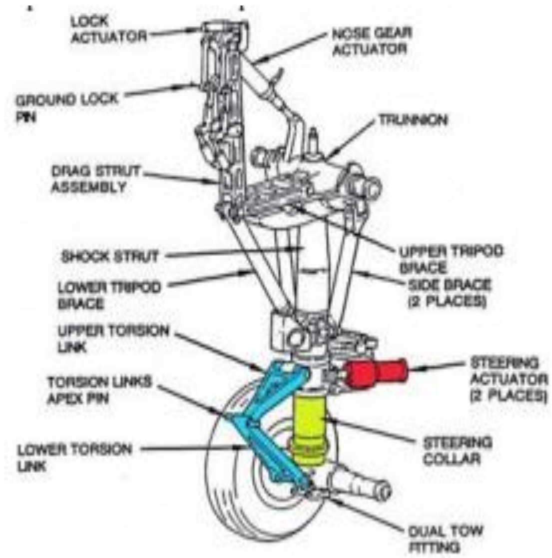


Fig: Steering system of nose wheel

Large Aircraft Retraction System

Large aircraft retraction systems are nearly always powered by hydraulics. Typically, the hydraulic pump is driven off of the engine accessory drive. Auxiliary electric hydraulic pumps are also common. Other devices used in a hydraulically-operated retraction system include actuating cylinders, selector valves, up locks, down locks, sequence valves, priority valves, tubing, and other conventional hydraulic system components. These units are interconnected so that they permit properly sequenced retraction and extension of the landing gear and the landing gear doors.

Nose wheel steering system

The nose wheel on most aircraft is steerable from the flight deck via a nose wheel steering system. This allows the aircraft to be directed during ground operation. A few simple aircraft have nose wheel assemblies that caster. Such aircraft are steered during taxi by differential braking. Most small aircraft have steering capabilities through the use of a simple system of mechanical linkages connected to the rudder pedals. Push-pull tubes are connected to pedal horns on the lower strut cylinder.

As the pedals are depressed, the movement is transferred to the strut piston axle and wheel assembly which rotates to the left or right. Due to their mass and the need for positive control, large aircraft utilize a power source for nose wheel steering.

III - OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully develop a design of an Aircraft Landing Gear. The mechanism is to be reliable, simple, cost-effective and practically feasible. The aim of this Landing Gear mechanism is to provide Baring conditions to the aircraft on runways, so as to enable added threshold speed on curves in comparison with non stresses. This system is also supposed to enhance aircraft and passenger comfort as the side force felt during landing taking on the runway comparatively more or less.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and time in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the design was adopted from an existing landing gear and minor changes were made to suite our purpose, the landing mechanism first devised was based on using driven by engine for lifting and lowering mechanism. This mechanism was later dropped in testing phase due to following disadvantages.

3.1 Summary of capabilities

Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product. Catia Elements is a software application within the CAID/CAD/CAM/CAE category, along with other similar products currently on the market.

Catia Elements is a parametric, feature-based modeling architecture incorporated into a single database philosophy with advanced rule-based design capabilities. The capabilities of the product can be split into the three main heading of Engineering Design, Analysis and Manufacturing. This data is then documented in a standard 2D production drawing or the 3D drawing standard ASME Y14.41-2003.

3.2 Engineering Design

Catia Elements offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

3.3 Analysis

Ansys Elements has numerous analysis tools available and covers thermal, static, dynamic and fatigue FEA analysis along with other tools all designed to help with the development of the product. These tools include human factors, manufacturing tolerance, mould flow and design optimization. The design optimization can be used at a geometry level to obtain the optimum design dimensions and in conjunction with the FEA analysis.

III- WORKING METHODOLOGY

Landing gear is the undercarriage of an aircraft or spacecraft and may be used for either takeoff or landing. For aircraft it is generally both. It was also formerly called alighting gear.

For aircraft, the landing gear 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 fold away during flight to reduce air resistance or drag.

IV- DESCRIPTION OF PROJECT

Aircraft Wheels

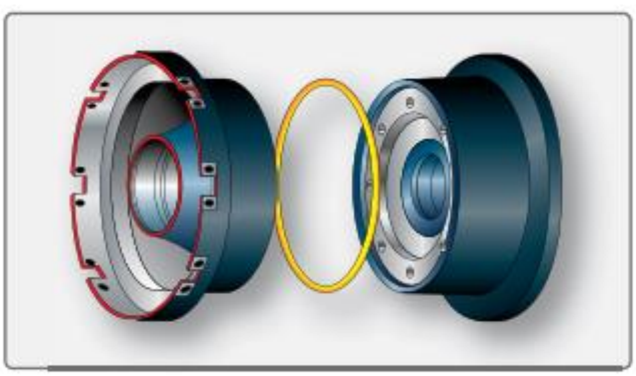
Aircraft wheels are an important component of a landing gear system. With tires mounted upon them, they support the entire weight of the aircraft during taxi, takeoff, and landing. The typical aircraft wheel is lightweight, strong, and made from aluminum alloy. Some magnesium alloy wheels also exist. Early aircraft wheels were of single piece construction, much the same as the modern automobile wheel. As aircraft tires were improved for the purpose they serve, they were made stiffer to better absorb the forces of landing without blowing out or separating from the rim. Stretching such a tire over a single piece wheel rim was not possible. A two-piece wheel was developed. Early two-piece aircraft wheels were essentially one-piece wheels with a removable rim to allow mounting access for the tire. These are still found on older aircraft. Later, wheels with two nearly symmetrical halves were developed. Nearly all modern aircraft wheels are of this two-piece construction.

Wheel Construction

The typical modern two-piece aircraft wheel is cast or forged from aluminum or magnesium alloy. The halves are bolted together and contain a groove at the mating surface for an o-ring, which seals the rim since most modern aircraft utilize tubeless tires.

Outboard Wheel Half

The outboard wheel half bolts to the inboard wheel half to make up the wheel assembly upon which the tire is mounted. The center boss is constructed to receive a bearing cup and bearing assembly as it does on the inboard wheel half. The outer bearing and end of the axle is capped to prevent contaminants from entering this area. Aircraft with anti-skid brake systems typically mount the wheel-spin transducer here. It is sealed and may also serve as a hub cap.



Two-piece split-wheel aircraft wheels found on modern light aircraft

Wheel Inspection

An aircraft wheel assembly is inspected while on the aircraft as often as possible. A more detailed inspection and any testing or repairs may be accomplished with the wheel assembly removed from the aircraft. On Aircraft Inspection, The general condition of the aircraft wheel assemblies can be inspected while on the aircraft. Any signs of suspected damage that may require removal of the wheel assembly from the aircraft should be investigated. Proper Installation The landing gear area is such a hostile environment that the technician should inspect the landing gear including the wheels, tires, and brakes whenever possible. Proper installation of the wheels should not be taken for granted.

V-DESIGN METHODLOGY OF AIRCRAFT LANDING GEAR

5.1 Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

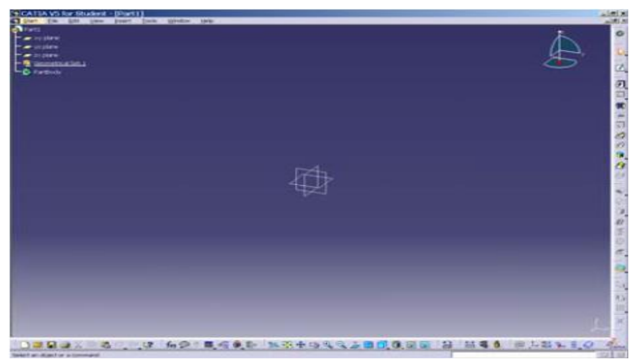


Fig: Home Page of CatiaV5

5.2 History

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software to develop Dassault's Mirage fighter jet, and then was adopted in the aerospace, automotive, shipbuilding, and other industries. Initially named CATIA (Conception Assisted Tridimensional Interactive — French for Interactive Aided Three-dimensional Design) — it was renamed CATIA in 1981, when Dassault created a subsidiary to develop and sell the software, and signed a non-exclusive distribution agreement with IBM.

5.3 Scope of Application

Commonly referred to as 3D Product Lifecycle

Management software suite, CATIA supports multiple stages of product development (CAx), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, equipment and systems engineering. CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances, as well as kinematics definition.

5.4 Modeling of Aircraft Landing Gear in Catia V5

This **aircraft landing gear** is designed using Catia v5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design. The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

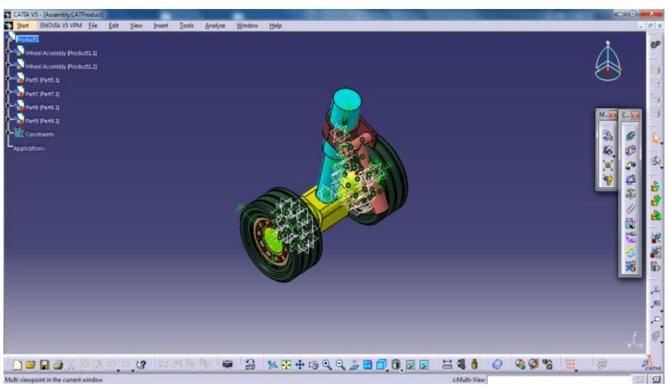


Fig: Model design in CATIA-V5

5.4.1 Machinery Parts and their Designs

Theory

In this chapter, the introduction of Aircraft Landing Gear is presented alongside machinery parts with their function and effects on rotating moment and failure types along with their reasons. Also shown is deformation in its parts during the working stage and the effect of tools and its parameters.

5.4.3 Assembly Modeling of Aircraft Landing Gear

In this modeling each and every component get assembled together with the means of constraints, coincidence, contact, offset, angle, fix component, flexible, manipulate, etc.

VI - ANALYSIS OF AIRCRAFT LANDING GEAR

6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the components is done using ANSYS. For motor and attached system is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of the components.

6.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

File Menu > Import> STEP > Click ok for the popped-up dialog box > Click

Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

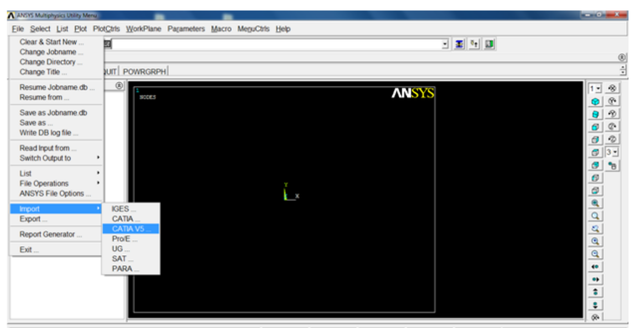


Fig: Import panel in Ansys.

6.3 Analysis procedure of Aircraft Landing Gear model:

Tetrahedral element that has a quadratic displacement behavior and is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element also has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

VII- DISCUSSION ON ANALYSIS RESULT

7.1 Results of Displacement analysis:

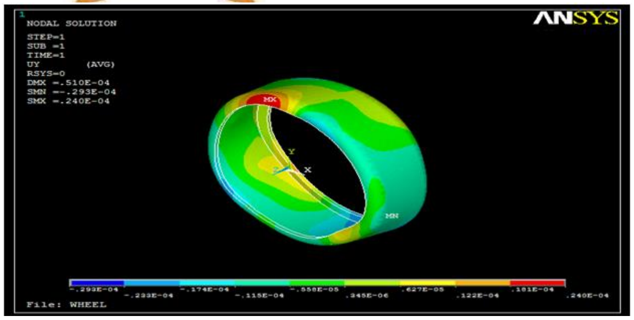


Fig: Wheel Displacement

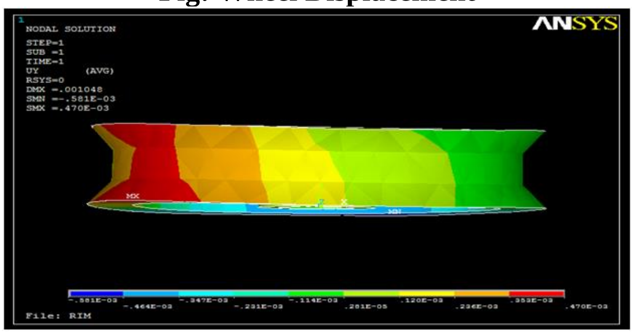


Fig: Rim Displacement

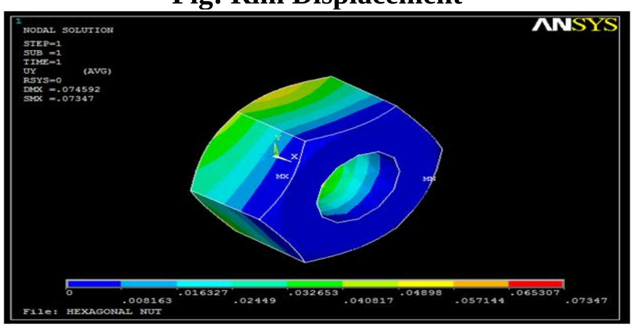


Fig: Hexagonal Nut Displacement

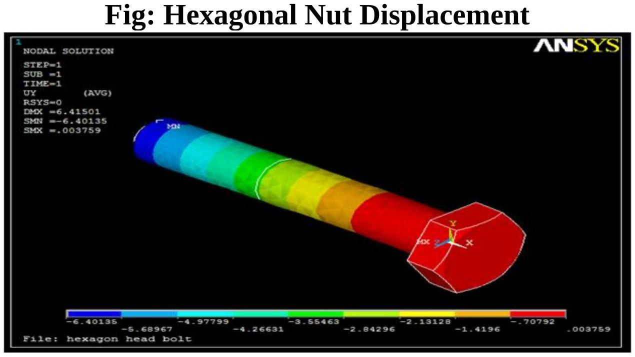


Fig: Hexagonal Bolt Displacement

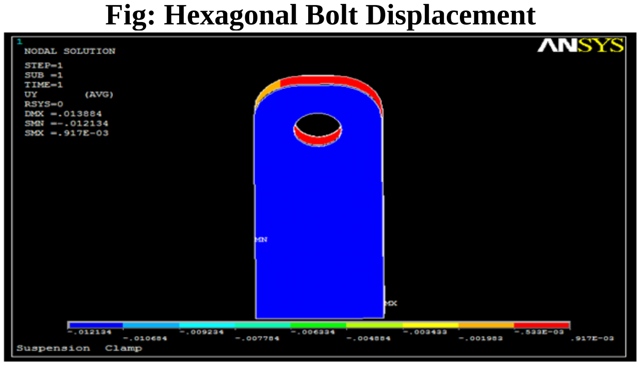


Fig: Suspension Clamp Displacement

7.2 Results of Stress analysis:

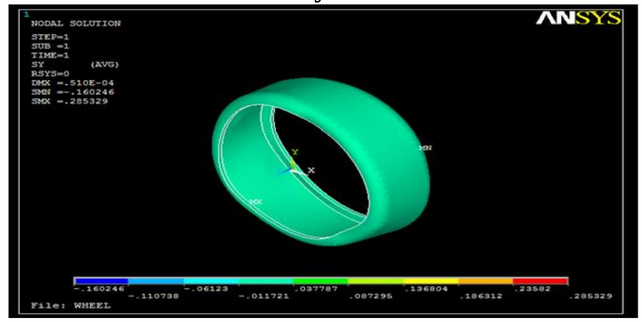


Fig: Wheel Stress

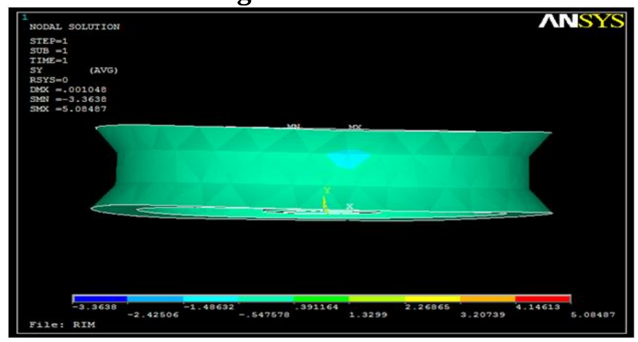


Fig: Rim Stress

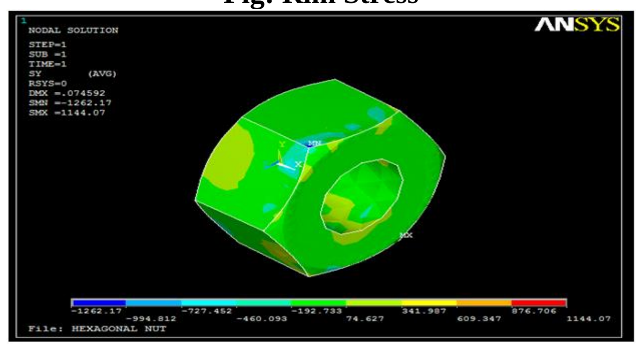


Fig: Hexagonal Nut Stress

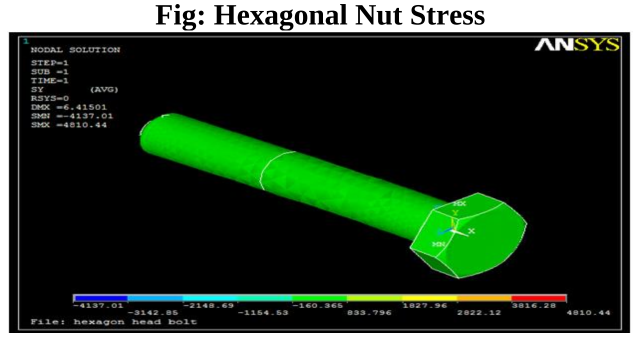


Fig: Hexagonal Bolt Stress

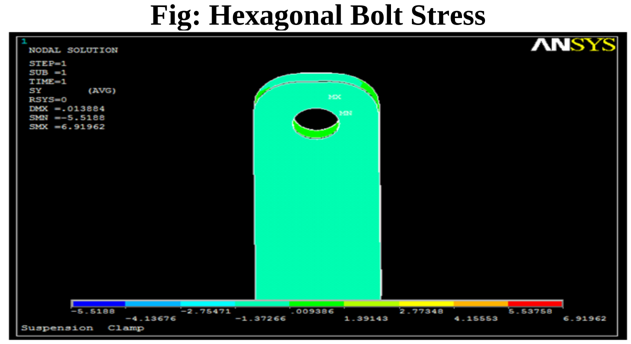


Fig: Suspension Clamp Stress

7.3 Results of Strain analysis:

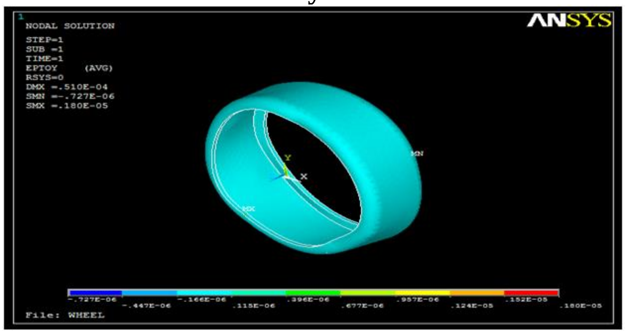


Fig: Wheel Strain

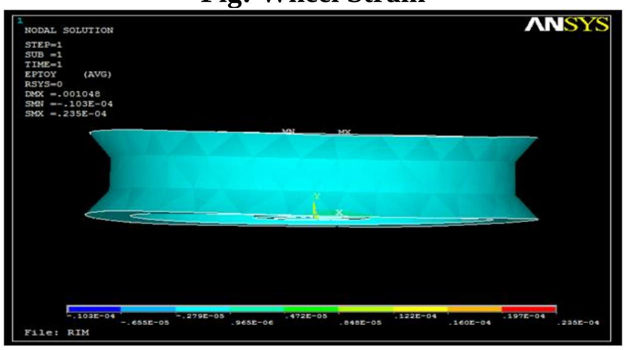


Fig: Rim Strain

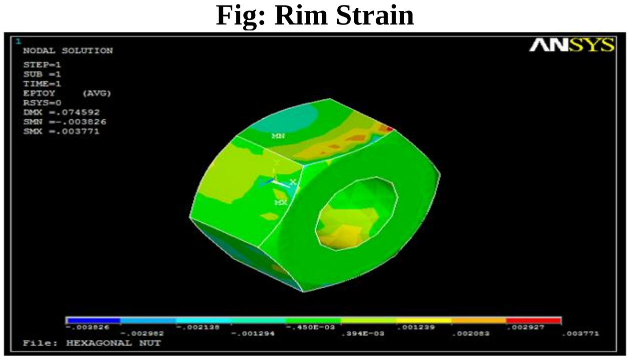


Fig: Hexagonal Nut Strain

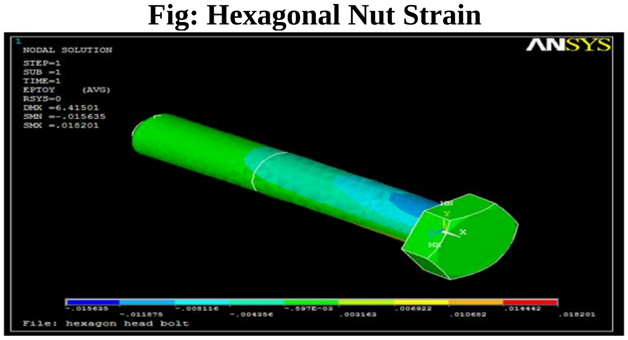


Fig: Hexagonal Bolt Strain

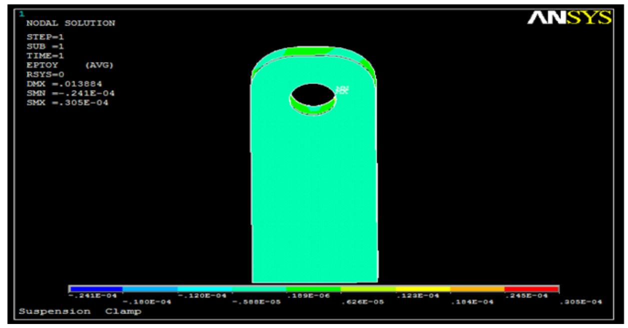


Fig: Suspension Clamp Strain

VIII - CONCLUSION

The project "Aircraft Landing Gear" has been successfully designed and tested. Presence of every module has been reasoned out and designed and analyzed carefully thus contributing to the best working of the unit.

Secondly, the trend towards low power hand held transceivers increases all of these challenges. Keeping all the above parameters in view we have designed a low-cost integrated system for monitoring the different types of parameters between systems.

As shown above figures, the displacement of the suspension clamp design is meshed and solved using Ansys and displacement is 0.917E-03mm, which is very less. This is showing us that clearly each component in assembly is having minor displacement.

Stress is at the fixing location (Minimum Stress which is acceptable), stress value is 6.91962Mpa. The value which is very less compared to yield value of Structural Steel; this is below the yield point. The maximum strain is 0.305E-04MPa, this solution solving with the help of Ansys software so that the maximum strain is less. So, we can conclude our design parameters are approximately correct.

This process may be incremental but the overall concept requires a shift in the way we think about mechanization for machines that is based more on needs and novel ways of meeting them rather than modifying existing techniques. Finally, we conclude that Industrial Aviation System is an emerging field and there is a huge scope for research and development.

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