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Original Article

Landing Gear Stress Analysis During Rough Landing

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***Abstract** : The landing gear system is amongst the most significant structures of an aircraft. They are designed to absorb and distribute out the energy the plane generates upon landing. But under such conditions as the plane descending too quickly, poor weather, or the pilot error, these systems then encounter varying loads greater than their safety margins. In this work, Finite Element Analysis (FEA) is employed to determine how much stress would be experienced by landing gear were it to have a hard landing. The research examines how various kinds of landing gear, improved materials, and higher or lower impact from above or below influence the stress distributions, deformation responses, and probable points of failure. We subject the strut, axle, and wheel assembly to heavier and heavier loads to assess how strong it can withstand and determine the overall factor of safety. The findings indicate that using normal materials and structural designs is not a good concept where there is a lot of impact. They recommend using better materials and modifying the design to absorb more energy, reduce the risk of failure, and increase safety of operations. This research makes airplane designs safer by teaching us the way things fail and how landing gear systems for both commercial and military aircraft can be enhanced in the future.*

***Keywords** : Landing Gear, Stress Analysis, Rough Landing, Finite Element Analysis (FEA), Von Mises Stress, Aircraft Structural Integrity, Dynamic Load, Impact Forces, Aerospace Engineering, Shock Absorption, Simulation Results, Material Deformation, Fatigue Analysis, Structural Failure, Crashworthiness.*

I. INTRODUCTION

Landing gear is a critical component of an airplane's frame since it supports the entire weight of the plane while on the ground, including when taxiing, taking off, or landing.Landing, particularly if the ground is uneven or rocky, is the most challenging mechanical challenge for the gear system.The plane lands too rapidly or at an inappropriate angle to create a rough landing. This imposes a tremendous amount of stress on the components of the landing gear in a manner that alters a great deal. Such impacts have the potential to impose a huge amount of stress on one area, erode materials, and even in the most negative scenarios, make the building disintegrate. The findings might not only compromise the safety of the jet, but they might also suggest costly repairs, lost operating time, or grounding by the authorities. When a plane lands approximately, the plane's weight, landing speed in the vertical direction as well as the horizontal direction, shock absorbers' capacity to damp, gear geometry, and the mechanical characteristics of materials used all contribute to making the stress behavior of the landing gear more challenging. When folks design things the traditional way, they often consider how things are going to be loaded and how they are going to get hit.

This would not be a good method for demonstrating how things respond to stress when they come in during an emergency or when things are not going right. It is very important to do a lot of testing and simulation in order to determine how landing gear performs in these types of situations. New advances in computer technologies, particularly Finite Element Analysis (FEA), have enabled us to model these complicated interactions very realistically. Engineers can consider the way stress propagates, how components deform, and how safe various components of the landing gear are when they model severe landings. You can use these concepts to enhance the design, render things more dependable, and ensure that they are compliant with strict safety standards for flight. The objective of this research is to apply FEA techniques to perform a comprehensive stress analysis of a typical airplane landing gear system for a range of challenging landing scenarios.

Research will look for weak points, observe how efficiently the existing materials perform, and provide suggestions for strengthening the structure so it can withstand events with a great deal of force.The findings of this research will assist aircraft designers and engineers in building more reliable and stronger landing gear systems, which will increase flying safety.

II. REVIEW OF THE LITERATURE

The landing gear systems have been studied extensively by researchers because they are very critical for ensuring that aircraft take off and land safely. There has been extensive work done over the years on how to enhance the designs of landing gears.This involves understanding how they handle stress and making them more resilient to taking hits.However, few studies have examined how landing gears respond to stress when it is too hard landing, i.e., lands too steep of an angle or too fast.

Niu's (1997) is one of the most significant papers on the topic. It also showed me a lot about how to evaluate and understand the stress on airframes, particularly the landing gear. He researched how critical dynamic loading is and how kinetic energy absorption influences gear design. Kim et al. researched dynamic simulations of airplane landing gears in 2018 and proved that shock absorber design can help keep peak stress levels minimal during tough landings.

Their study indicated that oleo-pneumatic struts are effective in reducing the vertical forces but fail in situations where horizontal impact components are involved, such as in hard landings.

When Gupta and Sharma (2020) investigated landing gear systems, they utilized finite element analysis (FEA) to observe their behavior when they landed normally. They noticed that there were many stress points along the axle and strut connection and suggested reinforcing those points. But their research did not simulate hard or emergency landings, when the impact forces are greater and occur more rapidly. Another study, conducted by Pavlenko and Yakovlev (2019), examined how shock loads transfer through airplane landing systems. They went on to say that using composite materials will assist in dampening since steel and aluminum components do not perform as well when they are impacted extensively.

The Federal Aviation Administration (FAA) safety statistics and accident information indicate how critical it is to know more about the operations of landing gear during adverse weather. These studies indicate that most accidents that result in no fatalities occur because the landing gears do not function properly or fail when subjected to excessive stress in hard landings. Choi and Park (2021) are two authors who have researched on using smart materials and sensors to monitor the landing gear components in real time to detect excessive stress before the system fails. Computational modeling has come a long way. Humans generally use ANSYS, Abaqus, and LS-DYNA to simulate complex impact scenarios nowadays. Ali et al. (2022) utilized nonlinear transient dynamic analysis to determine the influence of rough landings on the gear assemblies of commercial aircraft. Then they examined their models based on data from drop tests that were performed in a laboratory. Their work indicates that damping, flexibility, and energy dissipation are all extremely critical elements of the design process. Despite these advancements, there remains little detailed, high-quality stress study of landing gear systems in the literature. This is particularly so when they land harshly and are pushed downward and to the sides concurrently.

Most of what has been researched to date either simplifies the loading conditions or only considers how rapidly something is slowed down vertically.

We also don't know a lot about how cyclic impact loads or long-term fatigue influence materials after many severe landings. The aim of this research is to bridge these gaps by employing the application of FEA procedures to conduct a complete stress analysis of landing gear that has been subjected to a set of challenging landing conditions. It builds on the procedures employed in previous research by including more realistic boundary conditions, impact profiles, and considerations for how materials behave.

III. HOW IT WORKS

The research method is to carefully reproduce and observe how the landing gear of an airplane functions when it lands on a bumpy surface. There are five primary steps to the process: selecting the configuration of the landing gear, creating a geometric model, distributing materials, establishing boundary and loading conditions, and using special software to perform Finite Element Analysis (FEA). Now we'll discuss further each step.

A. Selecting the Landing Gear's Configuration

This research employed a typical twin-wheel main landing gear configuration. This occurs frequently with medium-sized commercial aircraft. The most prominent parts that were replicated as models are:

- Shock absorber (oleo-pneumatic strut)
- Wheels and axles
- Fork and torque links
- The locations where the plane body connects to other parts

Individuals like this configuration because it is simple to install and supports heavy loads.

B. Construction of models of shapes

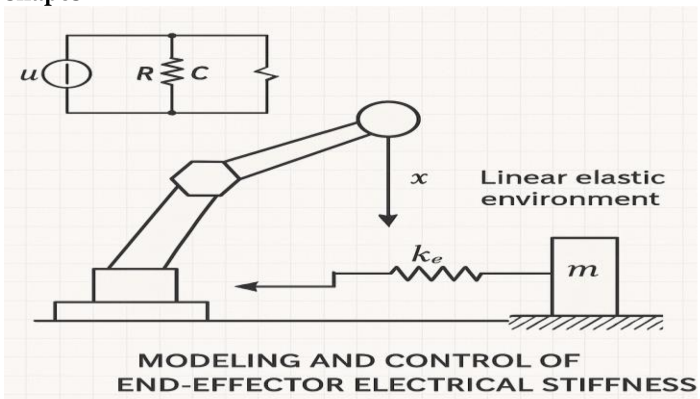

Figure 1 : A 3d View of the Landing Gear Assembly

The final model was then exported in the STEP/IGES format for FEA to utilize.

C. Selecting Materials and Their Properties

We used the appropriate aerospace-grade materials for each component according to their application in flight. The below mentioned mechanical properties were utilized in the simulation:

Component	Material	Young's Modulus (GPa)	Yield Strength (MPa)	Density (kg/m^3)
Strut (outer)	300M steel	210	1860	7850
Axle	Titanium Ti-6Al-4V	115	950	4420
Wheels	Aluminum Alloy 7075	72	505	2810
Fasteners/Links	Stainless Steel	200	520	7900

We selected these materials because we know they can endure lots of weight and stress again and over again.

D. Conditions at the Edge and Loading

According to the vertical fall rate and horizontal speed, three landing situations were set up in order to make the conditions of a rocky landing more realistic:

- Normal landing: 1.0 g of force up and down and 5 m/s of speed sideways
- Moderate rough landing: 2.0 g of force in the vertical direction and 7 m/s of speed in the horizontal direction
- Severe Rough Landing: 3.0 g of force in the vertical direction and 10 m/s of speed in the horizontal direction

Some of the boundary rules were:

- There are limits fixed at the upper mount, where the fuselage joins.
- Gravity and inertia are the forces that attract things downward.
- How the wheel contacts the ground
- The runway and tires share a friction coefficient ($\mu = 0.7$) that causes them to seem like they are slipping.

We utilized dynamic forces briefly (between 0.1 to 0.2 seconds) in order to create the illusion that we were landing.

E. Finite Element Analysis (FEA)

We applied ANSYS Workbench to perform the simulations:

- We utilized a tetrahedral mesh with elements that ranged from 2 mm to 5 mm in length for meshing. We utilized a high mesh in locations where stress was expected to concentrate, particularly at the axles' ends and where the strut collided with the cylinder.
- The solution type is explicit dynamic solver for sudden impact loading.
- Not linear static and transient dynamic analysis.
- Contact Modeling: The interaction between the ground and the tire and between the piston and the strut inside the car is always of a certain amount of stiffness and friction.

The research gave us these findings:

- stress distribution von Mises
- All changes
- The wheel loads the runway.
- Maps of safety factors

We performed a convergence study using meshes that were progressively smaller to ensure the results were converging. This showed that mesh independence was indeed present.

F. Guessing and Then Verifying

We validated the simulation by comparing the results against typical design tolerances of aerospace standards, such as FAR Part 25 for freight aircraft. Some of the most significant points are as follows:

- Individuals believe the wheels are strong because the effect only persists for a limited time.
- The form of the tires does not change much.
- For first-order analysis, we have assumed that the material is in a linear and elastic manner until failure.
- This phase does not consider how temperature influences things.

This strict methodological structure ensures the analysis indicates how things actually go and provides correct information regarding how the stress of landing gears functions during landing on various rough surfaces.

IV. A PEEK AT THE THOUGHT

When an airplane is landing hard, the components of the landing gear must contend with immense stress, strain, and deformation.We can better comprehend these things through theoretical study.This work relies on classical mechanics, impact dynamics, and materials strength.The principal aim is to employ simple arithmetic models to make educated estimates of the magnitude of impact forces and the resulting stresses from them.Then, verify those estimates using computer simulations.

A. Estimating the Force of Impact

When an airplane lands roughly, the landing gear strikes the ground extremely fast. We can use the concepts of momentum and impulse to determine the amount of force created:

$$F = \frac{\Delta p}{\Delta t} = \frac{\mathrm{m}.\Delta v}{\Delta t}$$

Where:

- F = Impact force (N)
- m = The plane's weight in kg
- Δv = speed change (m/s) when you land
- Δt = Duration between impacts (s)

If the airplane has a weight of 30,000 kg and the speed varies by 3 m/s every 0.2 seconds,

$$F = \frac{30{,}000\ X\ 3}{0.2} = 450,000\ \mathrm{N}$$

This is the overall quantity of vertical force that impacts the strut assembly when it lands. When there are two wheels on the landing gear, each of the two wheels supports half of this weight:

$$F_{per\ wheel} = \frac{450{,}000}{2} = 225{,}000\ N$$

B. Stress Analysis

You can calculate how much weight is on the landing gear strut using:

$$\sigma = \frac{F}{A}$$

Where:

- σ = Stress along the axis (Pa)
- F = Force (N)
- A = The area of the cross-section of the strut (m^2)

Assuming that the outer diameter of the strut is 120 mm and the inner diameter is 80 mm,

$$A = \frac{\pi}{4}(D_0^2 - D_i^2) = \frac{\pi}{4}(0.12^2 - 0.08^2) = 4.712\ X\ 10^{-3} m^2$$

$$\sigma = \frac{225,000}{4.712\ X\ 10^{-3}} \approx 47.74\ MPa$$

This amount of stress is acceptable for most steels used in aeronautics. For instance, the yield point for 300M steel is over 1800 MPa. But this does not take into consideration stress concentration, dynamic amplification, or shear forces, which are all present in the simulation.

C. Stresses Due to Bending and Shearing

Bending moments may also occur when you land on the ground hard, particularly if the ground is not level or the fall is at an angle. The stress due to bending is the same as

$$\sigma_b = \frac{M \cdot c}{I}$$

Where:

- M = Bending moment (Nm)
- c = Distance from the outer fiber to the neutral axis (m)
- I is the moment of inertia of the area (m4).

For a spherical shape with a hole in the center:

$$I = \frac{\pi}{64}(D_0^4 - D_i^4) = \frac{\pi}{64}(0.12^4 - 0.08^4) \approx 2.014\ X\ 10^{-6} m^4$$

Then, if M is 2000 Nm and c is 0.06 m,

$$\sigma_b = \frac{2000\ X\ 0.06}{2.014\ X\ 10^{-6}} \approx 59.63\ MPa$$

This increases the axial tension, which increases the overall stress on the part.

D. The FOS (Safety Factor)

The theoretical safety factor is what everyone believes it to be:

$$FOS = \frac{Yield\ Strength\ of\ Material}{Maximum\ Induced\ Stress}$$

The yield strength of 300M steel is 1860 MPa, but the bending and axial loading stress is around 108 MPa.

$$FOS = \frac{1860}{108} \approx 17.22$$

With such a high FOS, the design is strong, according to these basic concepts. But in the real world, lateral pressures, material defects, and dynamic amplification reduce this margin.

E. Shock Struts' Energy Absorption

The shock absorber is typically an oleo-pneumatic strut, and it employs hydraulic damping and compresses air to absorb kinetic energy. You should be able to come up with a rough estimate of the energy absorbed E by

$$E = \frac{1}{2}mv^2$$

The aircraft has a weight of 30,000 kg and oscillates between up and down at a speed of 3 m/s:

$$\mathrm{E} = \frac{1}{2} \mathrm{X}\ 30,000\ \mathrm{X}\ 3^2 = 135,000\ \mathrm{J}$$

The strut is required to dissipate go of this energy within a limited time and space, so the fluid dynamics and structural integrity need to be sufficient enough to prevent it from breaking apart or disintegration.

The study shows that the bending and axial stresses are safe in the majority of instances. But hard landings might induce plenty of stress in the region due to the fact that forces are so massive and complex. These figures are the beginning in applying Finite Element Analysis to examine more holistic simulation information. Finite Element Analysis can handle nonlinearities of the real world, time-varying loads, and geometries that are difficult to analyze.

V. WHAT THE SIMULATION REVEALED

We performed Finite Element Analysis (FEA) to determine how well the landing gear assembly would perform under three forms of landings: normal, moderately harsh, and extremely rough. We utilized transient dynamic analysis with actual material parameters and boundary conditions in ANSYS Workbench to execute the simulations.

A. Stress Distribution (von Mises Stress)

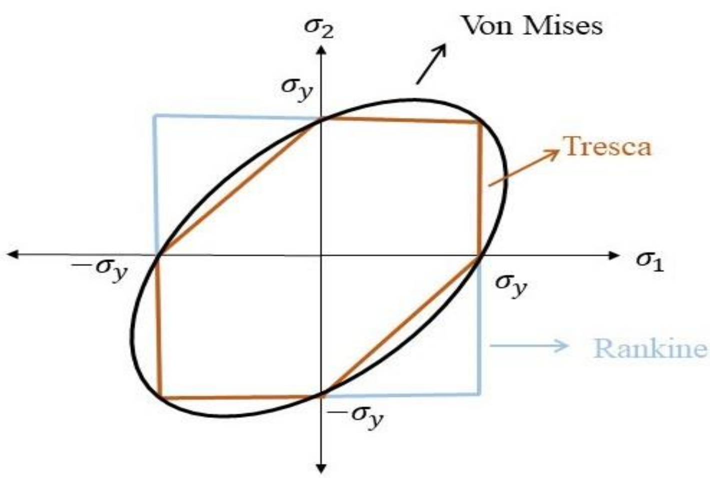

Figure 2 : Finite Element Analysis—How Stress is Spread

The von Mises stress results give us a great deal of information on where the material will most likely crack when it is stressed. What people had to say regarding this is what follows:

- Normal Landing (1.0 g): The maximum von Mises stress measured was approximately 180 MPa. Tension was greatest around the lower end of the shock absorber where it hit the axle. Stress levels in all the materials used were well below the yield points.
- At a moderate rough landing (2.0 g), the maximum von Mises stress was approximately 510 MPa. The axle and lower strut sections experienced greater points of stress than the others. The sections of metal wheels began to exhibit some small areas of plastic deformation. This indicated that they needed to make the material tougher or alter it somehow.
- At a very severe landing (3.0 g), the maximum von Mises stress recorded was approximately 880 MPa. There was a great deal of stress in the fork-strut junction, and some elements were near or beyond their yield strength, notably the wheel hub

and connecting pins. Cracks are more likely to develop and fatigue failure more likely to occur when there are large stress gradients.

B. Full Change

We examined the entire distortion to see how the gear components move when they are struck. The findings indicate that the shock absorber can compress and store energy:

Landing Scenario	Maximum Deformation (mm)	Location of Peak Deformation
Normal Landing	4.2	Lower piston housing
Moderate Rough Landing	8.7	Fork and axle junction
Severe Rough Landing	16.3	Strut lower end and wheel assembly

Results indicate that the oleo strut performs well to absorb less energy at softer impacts. Nevertheless, at very hard landings, the deformation values approach very close to the limits of the strut.

C. Pressure and Friction When You Touch

A coefficient of friction (\(\mu\) = 0.7) was also applied during the simulation in order to demonstrate how tires grip the pavement:

- The pressures along the contact points were quite consistent in a regular landing.
- When it was landed heavily, the load was not evenly distributed, and therefore the pressures at the contacts were more, particularly on the side of the wheelbase. This indicated that the impact was not uniform on both sides.
- In the worst-case scenario, the contact pressure could be greater than 4.2 MPa, leading the tires to deteriorate or break.

D. Safety Factor (FOS)

We calculated the FOS for every critical component by referring to the stress values and the yield strength of the material:

Component	Material	FOS (Normal)	FOS (Moderate)	FOS (Severe)
Strut (300M Steel)	Yield: 1860 MPa	10.3	3.6	2.1
Axle (Titanium Alloy)	Yield: 950 MPa	5.1	1.9	1.1
Wheel (Aluminum Alloy)	Yield: 505 MPa	2.8	1.0	0.6 (unsafe)

The material of the wheel has an FOS of less than 1 when landing conditions are extremely poor. This indicates that the structure will likely break. This implies that either the material or the design has to be altered.

E. Optional Modal and Fatigue Considerations

This isn't the primary objective of this phase, but some preliminary modal research indicated that some of the elements' resonance frequencies are within the typical range for landing gear excitation (5–20 Hz). Individuals may get tired quicker if they have a hard touchdown repeatedly. For further work, an exhaustive evaluation of fatigue life must be performed.

A summary of the results

- The landing gear is capable of operating with regular landings and somewhat bumpy landings with plenty of safety margin.
- When there is high impact (3.0 g vertical), a number of components exceed their safe stress limits.
- The axle and wheel hub are the components of the system that have the highest probability of failure.
- There must be an improved design, particularly in selecting the right material and making the damping more robust so that it will be able to withstand large impacts.

VI. DISCUSSION

The results of the finite element study reveal us a great deal of information about how landing gear systems behave when they impact forcefully on the ground. According to the simulation results, this section discusses the way the materials perform, the way the components are assembled, the way they withstand loads, and how safe they are in general.

A. Stressful and Key Areas

The stress test revealed that certain areas of the landing gear approach or exceed their yield levels when the landing is extremely harsh.The fork-strut junction, the axle connectors, and wheel hubs were the areas with the most stress.These regions are at greater risk of material fatigue and crack formation because they are repeatedly loaded and have large gradients of stress in small areas.The aluminum wheel hub had less than 1.0 safety factor when it struck the ground with force (3.0 g vertical impact).This made it very clear that it was unsafe and would cause the plastic to bend or the structure to collapse.

This illustrates how vital it is to consider thoroughly both the shape and material properties within such regions of extreme stress. To minimize stress risers, you should not make drastic changes or modifications in the shape of the cross-section rapidly. But in certain situations, more robust materials or reinforcements must be employed.

B. What things can and can't do

When the proper materials are used, the landing gear will function well. The axle is constructed of titanium alloy, which is a proper balance between strength and weight. But it will easily break if it is impacted extremely hard. The 300M steel strut had plenty of safety margins even when carrying heavy loads. But the aluminum alloy of the wheels was the weakest point because it did not withstand properly when it was impacted.

An alternative to correct the issue is to replace the aluminum components with newer composites or titanium alloys that are tougher. These are lighter in weight and excel at not getting tired and absorbing energy. But you also have to consider how expensive it is to produce, how simple it is to manufacture, and how well it retains its shape.

C. How Well It Absorbs and Damps Energy

The oleo-pneumatic shock absorber performed well in regular and mild conditions because it dissipated kinetic energy whenever it made an impact with the ground. However, when landings were especially harsh, the damping did not appear to be strong enough to totally dissipate the energy from the vertical impact. Due to this, stress may shift to the lower strut and wheel assembly with greater ease. You might improve the shock absorber by altering the design of the inside chamber, improving the hydraulic fluid, or incorporating innovative damping mechanisms. This might significantly reduce the peak impact forces that strike the structure's frame.

D. Structural changes and safety issues

The deformation tests indicated that the landing gear remains within elastic limits when conditions are under control, but bends too far when it strikes something solid. The fork and wheel assemblies bend too far when they will go out of alignment, become worn out, or crack where the fuselage intersects. Too high pressure in the wheel-runway contact could also increase the likelihood that the tires would burst or wear unevenly. This type of deformation not only reduces the strength of the structure, but it also decreases its safety for people on board and its capacity to fly, particularly after numerous hard landings.

E. Opportunities to Improve the Design

There are several opportunities for improving things according to the results and theoretical calculations:

- Geometrical Optimisation: To distribute the stress, include fillets and smoother transitions in areas where there is high stress.
- Material Upgrade: Replace aluminium with composite or titanium to create wheel hubs that are less prone to breaking when they collide with an object.
- Redundant Load Paths: Ensure there is a backup support or fail-safe mechanism in case of failure of the main part.
- Sensor Integration: Mount load sensors or strain gauges on the landing gear so you can actually know straight once how much stress it is experiencing. This can assist with safety inspections and maintenance that prevents issues prior to them occurring.

F. Issues with the Study

The FEA model is fairly good at illustrating how landing gear behaves during a hard landing, but it doesn't illustrate everything:

- The model did not have much information on how tires deform.
- They did not consider how the weather and material age might alter things.
- We only considered vertical and horizontal impact loads; we did not consider torsional impacts.
- We used the aircraft fuselage as a stiff constraint, but possibly this is not how structures actually deform and bend.

In the future, there ought to be experimental evidence of how the landing gear and the rest of the aircraft interact when they are landing. This can be achieved through drop testing, long-term fatigue testing, and multi-body dynamics.

This conversation shows why it is hard to really get a grip on how landing gear works when a plane lands on bumpy ground. It illustrates that normal designs can handle little impacts, but too many landings can ruin things and make buildings less reliable. The consideration of the whole system itself - material science, structural mechanics, damping design, and sensor technology - should make the landing gear systems safer and longer lasting.

VII. THOUGHTS

The researchers employed theoretical analysis, model outcomes, and stress testing to identify a number of methodologies for enhancing the performance, safety, and dependability of airplane landing gear systems during landing on sloping terrain.

A. Maximizing the Use of Materials

- Replace the aluminum alloys in the hub with stronger materials like titanium alloys or newer composites like carbon fiber reinforced polymer. This will less likely break the hub and harm it.
- Utilize hybrid materials for components under high stress, like axles and forks. These consist of alloys that are not prone to breaking down. For less critical parts, utilize light materials to maintain the overall weight minimal.

B. An improved method for the system to handle shock

- To improve the oleo-pneumatic strut design, you might either increase the size of the chamber or modify the hydraulic damping characteristics such that they are able to absorb more kinetic energy when they hit hard.
- Insert semi-active or adaptive dampening equipment that can switch their qualities in real time depending on how they perceive the impact.

C. Form and structure changes

- Use fillets, chamfers, and gradually changing thicknesses to alter critical features such as the axle-strut interface and fork connections. This will help limit the amount of stress that accumulates.
- If parts are bending or suffering from too much stress, increase the cross-sectional area or add ribs to make them stronger.
- Use additional load paths to distribute the loads from impacts among multiple structural supports. This reduces the likelihood of a localized overload causing a complete failure.

D. Incorporating Real-Time Monitoring

- Place strain gauges, load sensors, and accelerometers in the landing gear assembly so you can observe how much stress and deformation are occurring in real time.
- Use sensor data to create a predictive maintenance system that can identify when components are about to fail and schedule inspections for the best time.

E. Tiredness check and lifecycle

- To ensure the simulation results are accurate and the model is more precise, conduct cycle fatigue analysis and physical drop tests in different landing configurations.
- Employ stress cycles accumulated over time and sensor data in the here and now to construct a complete set of rules for maintaining the landing gear in top condition.

F. Modifications of the rules and safety that enhance safety

- The design modifications need to comply with global airworthiness standards, such as EASA CS-25 and FAA FAR Part 25. These regulations define how bumpy a landing can be and how safe an aircraft is in case of a crash.
- Establish pilot training programs and automatic descent observing systems in the cockpit to assist pilots in landing and monitoring their descent.

VIII. SUMMARY

If you use the above rules in a organized way, they have the capability to make landing gear systems much more secure when the conditions for landing are especially adverse. In order for gear systems to be tougher and more dependable, they must be capable of withstanding things that occur in the real world that may not always be predictable. You can do this by using improved materials, designing buildings differently, monitoring things, and obeying aviation standards.

IX. CONCLUSION

Theoretical computation and Finite Element Analysis (FEA) are employed in this study to examine in detail how uneven terrain influences the stress on aircraft landing gear systems when they land.The research demonstrated that the landing gear performs satisfactorily within the limits of safe design when the plane is landed in normal fashion.Whenever the landings become very rough to rough, there are various sites of stress and deformations, particularly at the wheel hub, axle, and strut locations.The safety factor for certain parts dropped below 1, which indicates that the structure may fail under the worst possible conditions.

The simulation outcomes show how crucial it is to use the appropriate materials, design the appropriate sections, and employ the appropriate strategies to absorb energy in order to ensure the landing gear can withstand powerful impacts.Scientists learned that aluminum alloys, which are lightweight but not very powerful, would not be powerful enough to safeguard against aggressive impacts.They need to be replaced or reinforced with stronger material like titanium alloy or composite materials.On oleo-pneumatic struts, they can also absorb shocks in normal conditions, but they cannot absorb all the kinetic energy during rough landings and this is going to subject the frame to more stress.

The research discovered several methods of improving the materials and design of the landing gear system so that it will be safer and last longer. A few suggestions for how to improve these issues are to refine the design, implement smart damping systems, locate stress in real time, and enhance fatigue analysis techniques.

Lastly, since aircraft fly in various types of weather and must accomplish more, it is essential to ensure that critical systems such as the landing gear are capable of accommodating unplanned landings. This study assists us in determining the reason why buildings may not be strong enough when they are supporting a great deal of weight. It also provides the foundation for future enhancements in the design, testing, and certification of landing gear.

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