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Multi-Physics Based Simulations of a Shock Absorber Sub-System

A. V. Hari Babu
Department of Mechanical Engineering
SVR Engineering College, Nandyal, Andhra Pradesh, India

Nirmala
Department of Mechanical Engineering
SVR Engineering College, Nandyal, Andhra Pradesh, India

Abstract

Landing gear failure is a high concern in the aviation industries. As per the Federal Aviation Administration reports, most of the aircraft failures take place at the time of take-off and landing of aircraft. Generally aircraft failures are related to its improper maintenance of landing gear and health monitoring check-ups. In this project work a tri-cycle landing gear shock absorber system model is selected and analyzed it in multi-physics domain, using AMESim software package. AMESim stands for Advanced Modeling Environment for performing Simulation of engineering systems. The software package provides a 1D simulation suite to model and analyze multi-domain intelligent systems, and to predict their multi-disciplinary performance. The various multi-physics domains considered in modeling are mechanical, pneumatic, and hydraulic. Each of the sub-components of these domains are modeled and checked for their output variables. Under the dynamic simulation, vertical loads, strut displacements and efficiency curves of the shock absorber are plotted for various sink velocities. MATLAB programming package is used to perform the mathematical functions to find the efficiency of shock absorber with the help of load and displacement curve plots. In the multi-physics dynamic simulation vertical loads with respect to time and strut displacement with respect to time are plotted. For the validation purpose these plots are tallied with an experimental plots and the plots are well matched. If there is any further iteration is going to conduct on the same model or similar model instead of doing experimental test one can do software analysis to get the results.
Keywords: landing gear, AMESim Software, MAT LAB

I. Introduction

The Landing Gears (LG) of an aircraft are the critical components in an aircraft body, as it carries almost the whole weight of an aircraft [1]. In the process of landing an aircraft, the undercarriage component will come across the mighty quantity of force that must and should reduce to a certain limit so that it will decrease the vandalize of the aero structure. Aircraft vibrations and dynamic loads following from high landing collision, from runway while taxi strip unevenness are validate as the significant factors in creating dynamic stress, fatigue damage on the structure, discomfort to crew and passenger, and depletion of pilot's skill to aircraft control in the process of ground operations. Literature divulge that no. of an unfortunate incidents are recorded are due to failure of landing gear. About 60% aircraft unfortunate incidents [2] arises due to undercarriage component failures therefore vibration and stress analysis of landing gear is very necessary. Main Landing Gear* (MLG) is used to digest the horizontal and upstanding energy caused by the landing of aircraft. MLG is the prime source of shock absorption at landing. It prevents vandalize to the aircraft. Thus highly care to be taken at the time of designing the MLG. Landing gear component materials must and should be of high stiffness and strength, low weight and cost, and have good weld-ability, machinability and forge-ability. They also must and should be resistant to corrosion, stress corrosion, and crack begins commencing and breed. Landing gear modeling and design become sophisticated, since it includes many different engineering disciplines structures, weights, economics and runway design.

Undercarriage structure supports an airplane on ground operation and allows flight, land and taxi. Tricycle is the most widely used undercarriage configuration. The MLG wheels lies at much close to the airplane C.G and bears much of the aircraft load and weight. Two MLG wheels are lies at the equal span from C.G. position. The front gear carries much smaller load as it lies far from C.G the MLG carries usually 80% of aircrafts total weight and nose gear carries about 20% of the total weight. All along of flight landing gear is a dead weight. Therefore its weight and shape should be least as possible. To avoid the exterior aerodynamic drag the Undercarriage in modish aircraft are retractable one, which requires complex retraction and lowering mechanism.

II. Objectives and Methodology

A. *Objectives of the Project*

The intend of this project is to model and analyze the landing gear shock absorber system in multi-physics domain software, using AMESim package and integrate with the structural analysis. The various multi-physics domains considered in modeling are mechanical, pneumatic, and hydraulic. Each of the sub-components of these domains are modeled and checked for their output variables. Under the dynamic simulation, vertical loads, strut displacements and efficiency curves of the shock absorber are plotted for various sink velocities. MATLAB programming package is used to perform the mathematical functions to find the efficiency of shock absorber with the help of load and displacement curve plots.

B. Methodology

A multi-physics domain shock strut model is prepared by utilizing mechanical, hydraulic and pneumatic components in the sketch mode of the AMESim package and the submodel mode each component connections and its working conditions are verified. The design and user parameters of the each components are assigned in the parameter mode. This all the thing will be done in the modeling module only. Simulation mode the simulation will be executed. The desired outcome of the simulation is plotted by selecting the parameters. The outcome of the efficiency curves are fed to the MATLAB for to calculate efficiency of the shock absorber.

III. SIMULATION AND ANALYSIS

A. Multi-Physics Domain Simulation

Multi-physics domain simulations that includes multiple physical phase or multiple simultaneous physical phenomena. Examples just like, combining gases kinetics and Mechanics of Fluid or combining Finite Elements with molecular dynamics. Partial Differential equations are involved in solving Multi-physics typically including coupled structures. Huge number of real world problems need multi-physics examination tools. Examples, Solidification problems- Solder joints and Flutter in aircraft wings - Fluid-Structure synergy. Ensuring two side coupling

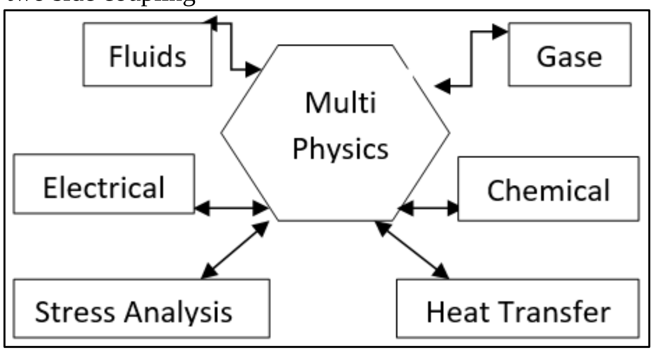

Fig. 1: Multi-Physics Domain

AMESim package is based on spontaneous graphical connector in which the system is displayed throughout the simulation process. This package gives a one dimensional simulation environment to model and analyze multi-domain intelligent systems, and also predict their multi-disciplinary operational ability.

B. Landing Gear System

A shock strut is constructed of two telescoping cylinders or tubes that are closed on the external ends shown in Fig 2. The top cylinder is fixed to the airplane and does not transfer. The bottom cylinder is termed the piston and is free to slide in and out of the top cylinder. Two chambers are formed. The lower chamber is always filled with hydraulic lubricant and the top chamber is filled with compressed natural gas or nitrogen. A passage located between the both cylinders provides a passage for the lubricant from the lower chamber to enter the upper cylinder chamber when the strut is compressed.

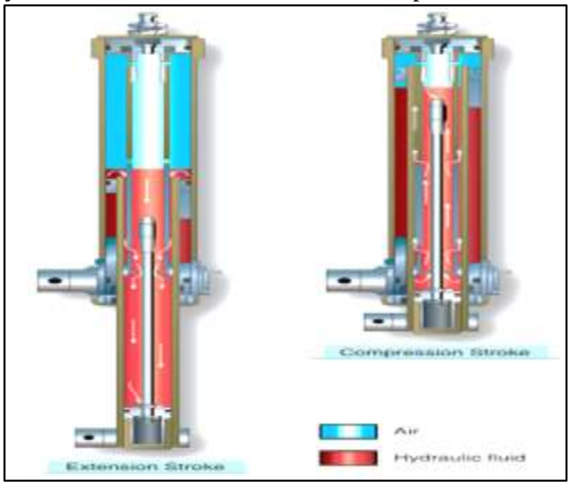

Fig. 2: Cut section View of Shock Strut

Arrows indicates the fluid motion at the time compression and elongation of the strut. Shock strut compression phase begins as the aircraft wheels touch the deck. As the air craft center of mass moves downward, the shock strut compresses, and the bottom cylinder or piston is forced upside into the top cylinder. The metering pin is therefore moved up through the orifice. Pin taperness regulates the fluid flow from the lower cylinder to the upper cylinder at all points during the compression phase. In this way, the huge quantity of heat is vanish through the walls of the cylinder. At the end of the downward stroke, the compressed gas in the top cylinder is furthermore compressed which bounds the compression phase of the strut with minimal collision.

MILWITZKY presented two degrees of freedom system to explain the combination of airplane and undercarriage in the 1950s [6]. This system motion was divided into two phases: one is before the deflection phase of shock-strut and second is telescope phase of shock-strut. The total amount of axial force existed of hydraulic force, pneumatic force, and internal friction force. The hydraulic force was computed with constant orifice area and constant discharge coefficient and without taking snubber orifice hydraulic force into account. The pneumatic force was simply the multiplication of the pneumatic area and the pressure. The addition of all friction forces given by each of the bearings was the internal friction force.

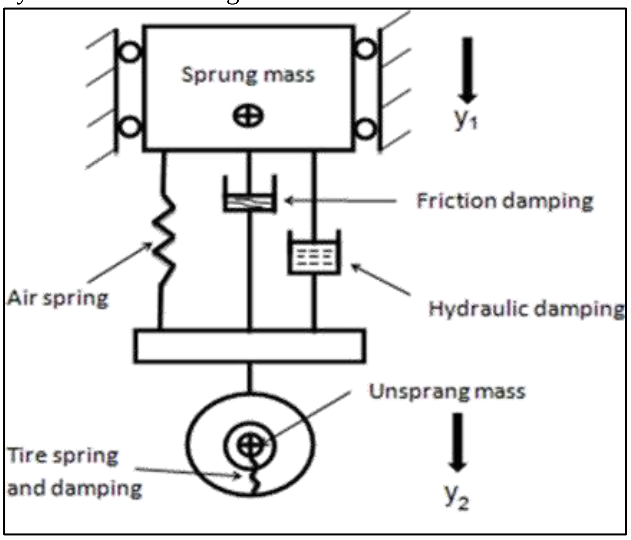

Fig. 3: Two Degrees of Freedom System

C. *Modeling of Two Chamber Shock Absorber in Multi-Physics Domain*

AMESim package is utilized to model a two chamber shock absorber in multi-physics domain. AMESim model narrates standard shock absorber (OLEO Pneumatic) that can be modeled using Hydraulic Component Design library. This verification is twofold, it is levelheaded of two simulation on the same shock absorber. The current one verifies the simulation of dynamic loading on the shock absorber. The complete system is modeled within AMESim using the Thermo-Hydraulic and Pneumatic Component Design (THCD and PCD) to assess the sizing for each part of the device:

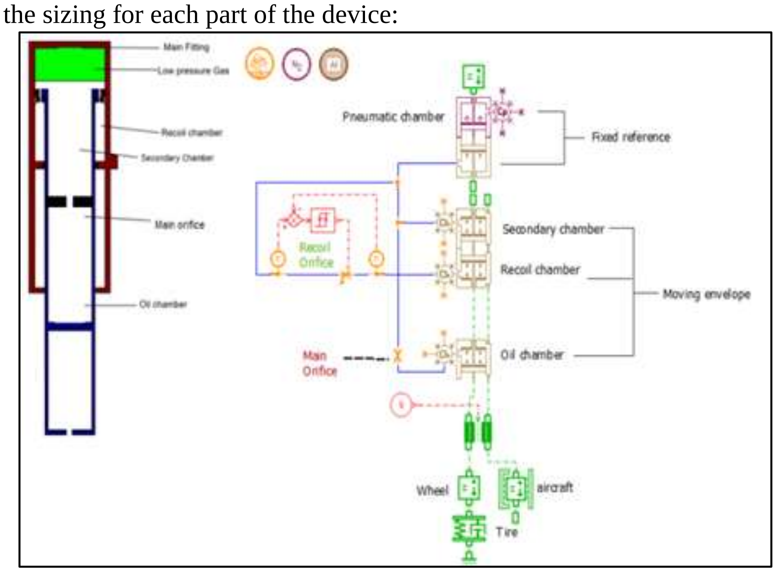

Fig. 4: Principle Scheme & AMESim Model

This model is the characterization for a two chambers OLEO pneumatic shock absorbers. The OLEO pneumatic shock absorbers are focusing at absorbing the vertical kinetic energy during the landing of the aircraft; this kinetic energy is dissolute in a laminar flow between the two chambers of the OLEO. Based on the compression/expansion phase a moveable component is either allowing or restraining the oil to go in or out the recoil chamber. Design and user parameters of dynamic simulation of Nose Landing Gear.

IV. Results

A. AMESim Package Simulation Results of Elementary Landing Gear Model

At the aircraft landing stage the undercarriage under goes an impact force from the deck. A multi-physics domain model is utilized to simulate and compute the deck impact forces on the undercarriage when it is landed at different sink velocities. This multi-physics domain model consist of hydraulic, pneumatic and mechanical components which helps to model a perfect replica of landing gear.

When reaching the ground, their induced relative displacements compress the fluid inside the chamber, through the accumulator that is designed to damp the oscillations. An inclination +90 degree is imposed to M1 and M2 to represent the aircraft going towards the ground. At 0 sec time, the wheel reaches the ground and that results in an important wheel/ground contact force. At this time, the wheel keeps a position around 0.075 m while the aircraft continues to go down. The contact force increases.

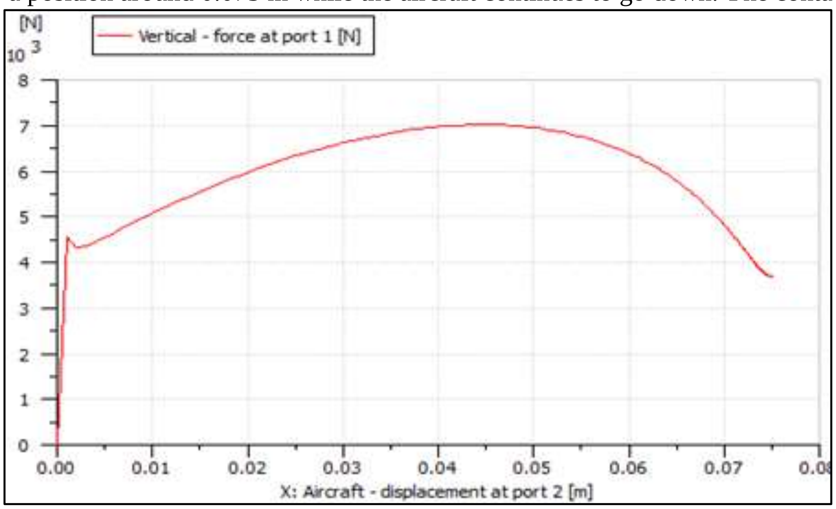

Fig. 5: is Load/Stroke Curve

When the gap or clearance of the elastic contact (gap) is 0 mm. The area under curve will give the efficiency of a shock absorber. The area under the curve will give the efficiency of the shock absorber.

B. MATLAB Code For To Find the Area under the Curve

```
%# Table format: 1D
%# table unit = N
%# axis1_unit = null
%compute area under the curve
dum=[%insert graph data%];
lodi=[%insert graph data%];
xv=lodi(:,1);
yv=lodi(:,2);
plot(xv,yv);
area_Under_the_curve=trapz(xv,yv)
```

%efficiency=(Actual wave o/p)/(square wave o/p) * 100% [$n = \int_0^x f\, ds / (f_{max} X S_{max})$] Where f = force, S= displacement

```
max_displacement=max(xv)
max_load=max(yv)
max_area=max_displacement*max_load
eff=(area_Under_the_curve/max_area)*100
xlabel('Displacement, mm','Fontsize',12)
ylabel('Load, kN','Fontsize',12)
```

1) Matlab Out Put

1) area_Under_the_curve = 380.2033
2) max_displacement = 0.0752m
3) max_load = 7.0189e+003 N
4) max_area = 527.8617

5) Efficiency = 83.75%

C. AMESim Package Simulation Results of Two Chamber Landing Gear Model Numerical and Experimental Results Correlation MLG

The correlation of numerical and experimental results of the maximum vertical force and the maximum strut deflection are plotted when the aircraft lands at 3.05 m/s sink velocity They are shown in Fig 6, Fig 7.

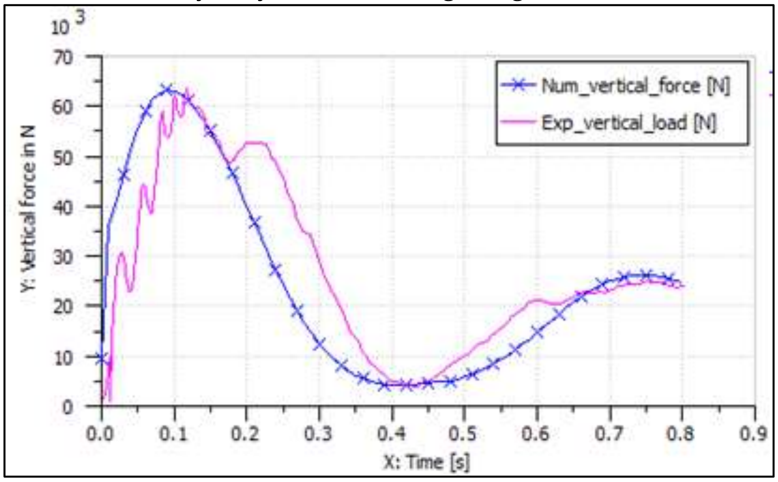

Fig. 6: Vertical Force Vs Time Curves of MLG Comparison

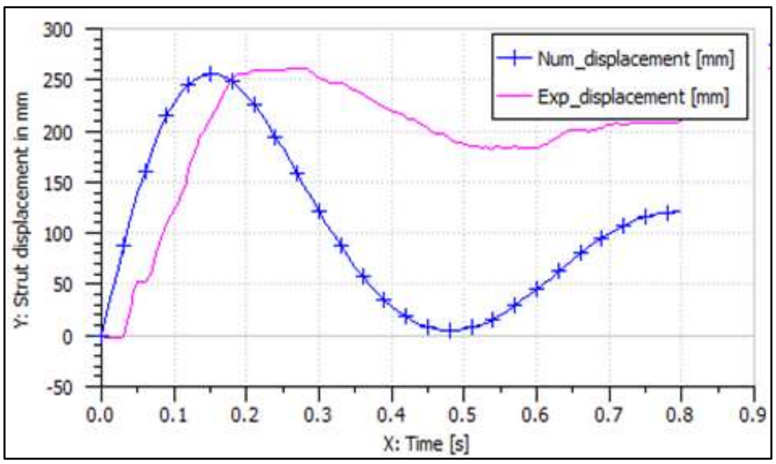

Fig. 7: Strut Displacement Vs Time Curve of MLG Comparison

From the plots it is observed that the experimental curve is not smooth. It is mainly due to the consideration of a small time interval which is about 0.0001 sec where as in numerical method, it is about 0.01sec. Figure also shows that the experimental plot has been deviated from the origin which is mainly due to late impact of landing gear on the deck. Table 5.1 shows the vertical force and strut deflection for different sink velocities. It has been observed that vertical force as well as strut deflection increases.

Table - 1
Numerical and Experimental Values of MLG

Sl. no	*Sink velocity m/s*	*Max Vertical force, N*		*Max Strut deflection, mm*	
		Numerical	*Experimental*	*Numerical*	*Experimental*
1	*1*	*32545*	*-----------------*	*128*	*-----------------*
2	*2*	*46356*	*-----------------*	*177*	*-----------------*
3	*3.05*	*63099*	*63544*	*234*	*260*

D. AMESim Package Simulation Results of Nose Landing Gear

1) Numerical and Experimental results correlation NLG

The correlation of numerical and experimental results of the maximum vertical force and the maximum strut deflection are plotted when the aircraft lands at 3.05 m/s sink velocity They are shown in Fig 5.25 and Fig 5.26.

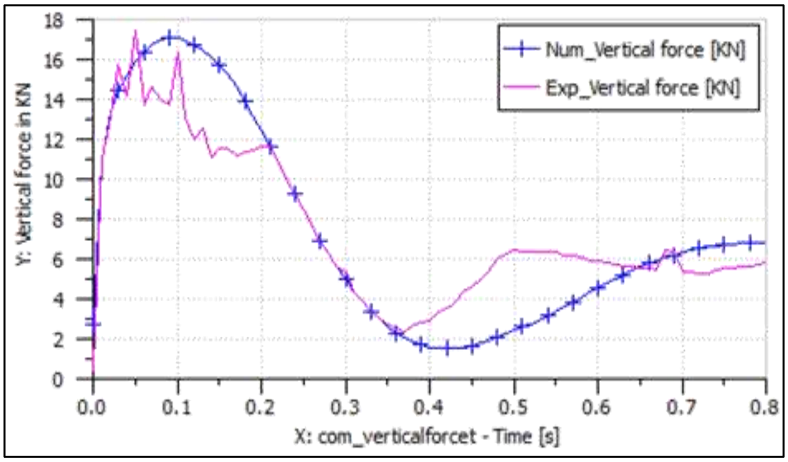

Fig. 8: Vertical Force Vs Time Curve of NLG Comparison

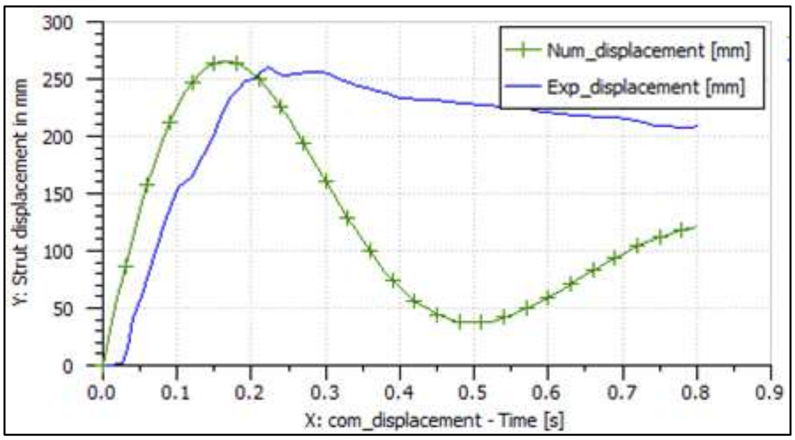

Fig. 9: Strut Displacement Vs Time Curve of NLG Comparison

From the plots it is observed that the experimental curve is not smooth. It is mainly due to the consideration of a small time interval which is about 0.0001 sec where as in numerical method, it is about 0.01sec. Figure also shows that the experimental plot has been deviated from the origin which is mainly due to late impact of landing gear on the deck. Table 5.2 shows the vertical force and strut deflection for different sink velocities. It has been observed that vertical force as well as strut deflection increases.

Table – 2
Numerical and Experimental values of NLG

Sl. no	*Sink velocity m/s*	*Max Vertical force , N*		*Max Strut deflection, mm*	
		Numerical	*Experimental*	*Numerical*	*Experimental*
1	*1*	*9065*	----------------	*146*	-----------------
2	*2*	*12505*	----------------	*203*	-----------------
3	*3.05*	*17053*	*17486*	*257*	*263*

V. CONCLUSION

In this project work, AMESim software was used to prepare a multi-physics domain landing gear model. This multi-physics model was utilized to compute the vertical loads and the strut displacement.
Following points can be concluded from this work

1) By utilizing multi-physics domain model one can perform dynamic simulation of landing gear easily and effectively in AMESim software.
2) In AMESim software, it is easy to understand the relative work between mechanical, pneumatic and hydraulic physical domains.
3) The outcome plots of the multi-physics dynamic simulation are well matched with the experimental plots of the vertical load vs time and the strut displacement vs time. From this, we can conclude that AMESim software can be used for the analysis of any type of landing gear parts which consists multi-physics domains

VI. FUTURE SCOPE OF WORK

The following improvements can be made in future

1) For the Landing Gear model, multi physics domain simulation can be carried out by adding a metering pin in oil chamber which is used for controlling the oil flow.
2) Structural analysis can be carried out on Landing gear model with wheels
3) We can perform dynamic analysis on landing gear model using FE package.
4) The analysis carried out in this project can be applied to the landing gear of any type of tri-cycle air-craft

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