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Dynamic Response Analysis of Generic Nose Landing Gear as Two DOF System

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Abstract— Landing gear is a structural component of an aircraft to support the weight while it is on the ground and also to aid safe landing. A generic analytic model for linear dynamic analysis of landing gears, which captures responses of individual components, is seldom available in literature. In the present work an analytical model for the linear response analysis of landing gear is developed. The landing gear is modeled as a two DOF system. Dynamic responses are extracted using analytical methods two cases - smooth landing and base excitation. Modeling of two DOF model is done and transient responses are found using MATLAB. Further, numerical analysis is carried out using ANSYS software for the same configuration, whose results obtained are found to match well with that of analytical model.

Index Terms— Landing gear, Dynamic analysis, Two-DOF configuration.

1 INTRODUCTION

LANDING gear often referred as "the essential intermediary between the airplane and catastrophe", is a structural component of an aircraft to support the weight while it is on the ground and also to aid safe landing. It contains dedicated mechanism for absorbing the force of the landing in addition to plane's weight. A generic analytic model for linear dynamic analysis of landing gears, which captures responses of individual components, is seldom available in literature. In the present work an analytical model for the linear response analysis of landing gear is developed. The results are validated by numerical analysis. The response analysis is done for two cases - smooth landing and base excitation.

2 LANDING AS TWO OF SYSTEM

Fig 1. shows the schematic representation of landing gear. Aircraft fuselage is the interface between the plane and the gear chamber containing compressed nitrogen serves as a spring that carries the weight of a plane in ground operations. Main upper cylinder houses the compressed gas, hydraulic fluid, and within which the piston slides The orifice plate is essentially a circular plate with a hole in the center through which the hydraulic fluid flows, when the shock absorber piston is stroking along with the metering pin, which controls the damping. The metering pin is rigidly fixed to the piston. As the piston strokes, the changing size of the metering pin passes through the constant hole in the orifice plate, causing a variable effective orifice diameter, i.e. variable fluid damping. Snubber Orifice leads in to a small volume on the back side of the piston head called the rebound or snubber chamber. The purpose of the snubber is to provide damping when the shock absorber extends. Piston houses the metering pin and is also the rigid connection of the wheel axle. Tire adds stiffness characteristics to the overall performance of the gear.

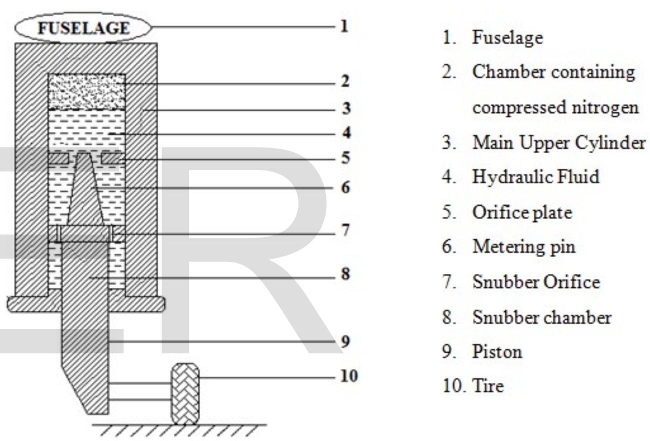

Fig. 1 Schematic Model of 2-DOF Landing Gear

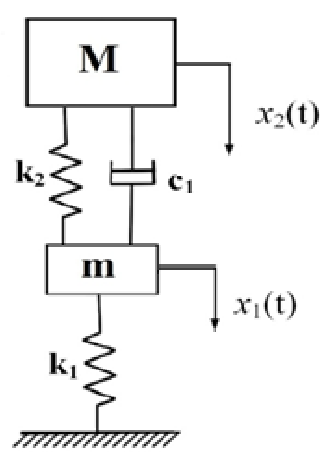

Fig. 2 Generalized Model of 2-DOF Landing Gear

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Equation of motion for landing gear four DOF system (Fig 2) is given by,

$$m\ddot{x}_1 + c_1(\dot{x}_1 - \dot{x}_2) + (k_1 + k_2)x_1 - k_2x_2 = 0 \qquad (1)$$

$$M\ddot{x}_2 + c_1(\dot{x}_2 - \dot{x}_1) - k_2x_1 + k_2x_2 = Mg \qquad (2)$$

On substituting the values [2]-[3],

M = 2000kg; m = 30kg

c_1 = 1110Ns/m

k_1 = 1750000N/m; k_2 = 651000N/m

Initial conditions,

$x_1(0) = x_2(0) = 0.1$m; $\dot{x}_1(0) = \dot{x}_2(0) = 0.2$m/s

2. 1 Analytical Modeling

The complete solution for the system of equation is given by,

$$x_1(t) = 0.0163e^{-0.15t}\cos(15.39t - 0.229) + 0.0731e^{-18.63t}\cos(282.42t - 0.0725) + 0.0112 \qquad (3)$$

$$x_2(t) = 0.06e^{-0.15t}\cos(15.39t - 0.229) + 0.00032e^{-18.63t}\cos(282.42t - 0.0725) + 0.0413 \qquad (4)$$

The responses are obtained using MATLAB and plots obtained are as follows.

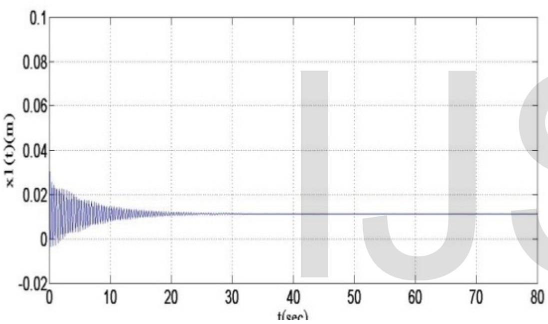

Fig. 3 Time Histories of the displacement x1(t) of landing gear two DOF system from the analytical method

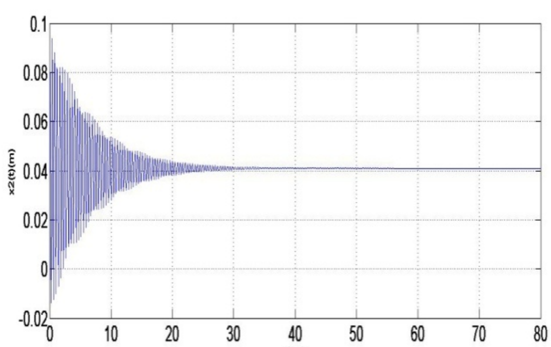

Fig. 4 Time Histories of the displacement x2(t) of landing gear two DOF system from the analytical method

2.2 Numerical Modeling

The landing gear is modeled in ANSYS using Structural Mass (3D mass 21) and Combination (Spring-damper 14). After the elements are chosen, the real constants and material properties are defined as given in the problem. As base excitation is not considered, all DOF's for the base node are set to zero. For other nodes, longitudinal motion is allowed. Initial conditions as specified in the analytical model are considered in addition to impact load at the fuselage end. Transient response analysis is done for the model and results are plotted using time-history post processor.

Fig. 5 Landing gear Two DOF system modeled in ANSYS

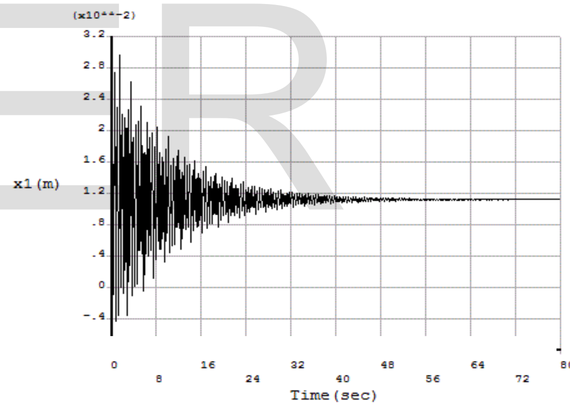

Fig. 6 Time Histories of the displacement x1(t) of landing gear two DOF system from the numerical method

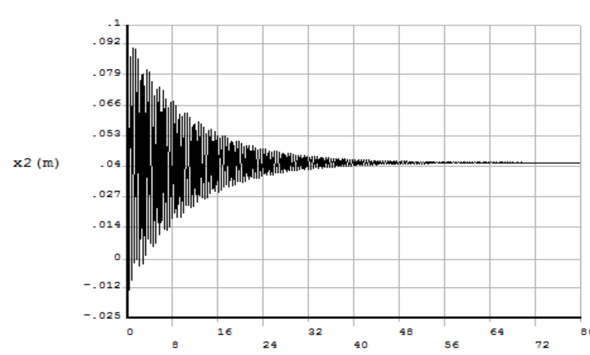

Fig. 7 Time Histories of the displacement x2(t) of landing gear two DOF system from the numerical method

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TABLE 1
COMPARISON OF RESULTS

Parameter	Analytical		Numerical	
	Min. Value	Max. value	Min. Value	Max. value
x_1	-0.004	0.3	-0.0045	0.3
x_2	-0.013	0.092	-0.013	0.092

The displacement-time plots for the two masses have been obtained by both numerical and analytical methods. Table 1 gives the comparison of analytically and numerically evaluated displacement components of two masses. It is clearly seen that the minimum and maximum values of displacement are closely matched in both the analytical and numerical methods.

3 LANDING GEAR TWO DOF SYSTEM WITH BASE EXCITATION

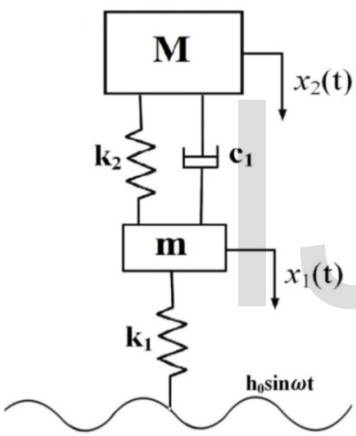

Fig. 8 Generalized Model of Landing Gear Two DOF with Base Excitation

Fig. 8 shows the generalized model of landing gear two DOF system with base excitation. All the parameters are same except at the generalized model of landing gear two DOF system subjected to harmonic force F(t) acts on the tire. Harmonic excitation refers to a sinusoidal external force of a single frequency applied to the system. Here the driving force F(t) is assumed to be of the form $h_0 \sin \omega t$, where h0 represents the magnitude, or maximum amplitude of the applied force and ω denotes the frequency of the applied force.

Equation of motion for landing gear two DOF system with base excitation (Fig 8) is given by,

$$m\ddot{x}_1 + c_1(\dot{x}_1 - \dot{x}_2) + (k_1 + k_2) - k_2 x_2 = h_0 \sin \omega t \quad (5)$$

$$M\ddot{x}_2 + c_1(\dot{x}_2 - \dot{x}_1) - k_2 x_1 + k_2 x_2 = Mg \quad (6)$$

The values are same as that of the above case and the harmonic excitation is assumed to be 0.2 sin10t.

The complete solution for the system of equation is given by,

$$x_1(t) = 0.06e^{-0.15t}\cos(15.39t - 0.229) + 0.0724e^{-18.63t} \cos(282.42t - 0.0725) + 0.19\sin 10t - 2.73\times 10^{-5} \cos 10t + 0.0112 \quad (7)$$

$$x_2(t) = 0.22e^{-0.15t}\cos(15.39t - 0.229) + 0.0003e^{-18.63t} \cos(282.42t - 0.0725) + 0.346\sin 10t - 3.14\times 10^{-5} \cos 10t + 0.0413 \quad (8)$$

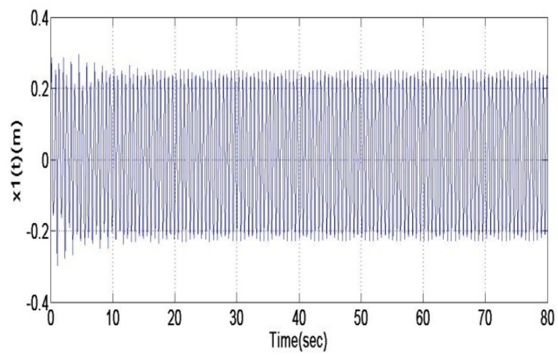

Fig. 9 Time histories of the displacement x1(t) of landing gear two DOF system with base excitation from the analytical method

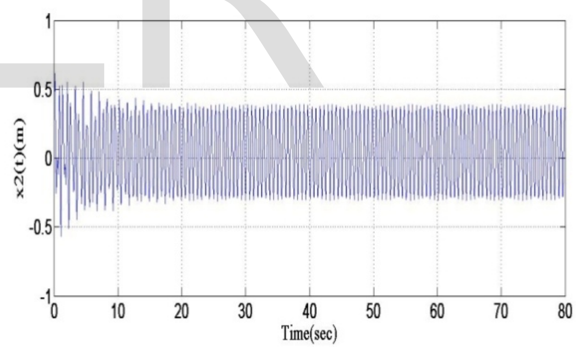

Fig. 10 Time histories of the displacement x2(t) of landing gear two DOF system with base excitation from the analytical method

3.1 NUMERICAL MODELING

For modeling two DOF landing gear system with base excitation displacement is defined as 0.2 sin10t using function editor. The responses obtained from numerical modeling are shown in Fig. 11 and Fig. 12.

Mass m is seen to be excited to a constant displacement throughout the period of analysis. Other mass M is observed to experience a logarithmic decrement in the displacement i.e. the excitation damps out by the time is 80sec. Table 2 shows the x displacement components of all two masses evaluated analytically and numerically.

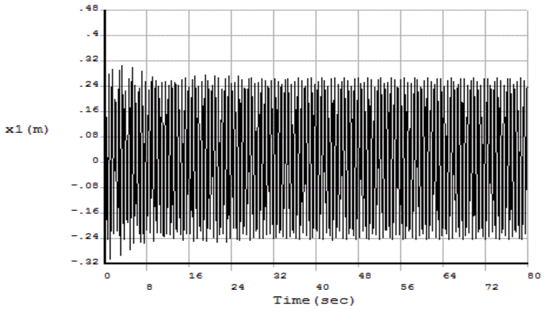

Fig. 1 Time histories of the displacement x1(t) of Landing Gear two DOF system with base excitation from the numerical method

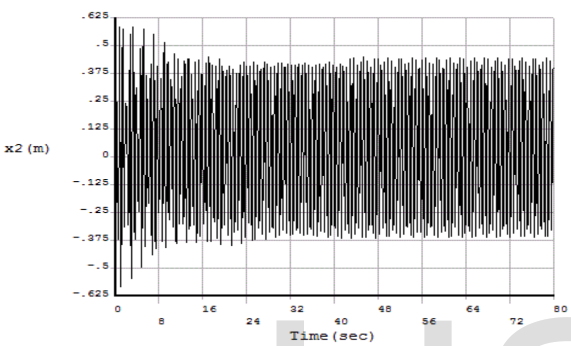

Fig.12 Time histories of the displacement x2(t) of Landing Gear two DOF system with base excitation from the numerical method

TABLE 2

COMPARISON OF RESULTS

Parameter	Analytical		Numerical	
	Min. Value	Max. value	Min. Value	Max. value
x_1	-0.3	0.3	-0.305	0.305
x_2	-0.58	0.58	-0.6	0.6

4 CONCLUSION

The responses obtained from numerical model are compared against that of analytical model. The results are found to be correlating well other than for initial conditions. This may be attributed to the non-linear behavior of the model in the initial stages. However, the above model presents to be a good approximation for investigators who conduct dynamic studies on landing gears.

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NOMENCLATURE

Symbol	Meaning	Unit
M, m	Mass of tire, collar, damper fluid & fuselage respectively	kg
k_1, k_2	Stiffness of various components	N/m
x_0	Initial displacement	m
v_0	Initial velocity	m/s
c_1	Damping coefficient of various components	N/m
Φ	Phase angle	rad
t	Time	s
g	Acceleration due to gravity	m/s^2
$x_1(t), x_2(t)$	Displacement of mass M, m	m