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Dynamic Modeling of Landing Impact Isolator for Aeroplane

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Abstract—*Endeavor of this work is to investigate the dynamic forces acting on tires and landing impact isolator of an aircraft. Due to constraints associated with reality this study has been confined to the transverse forces and will, not include the influence of the drag force that applies on the tires during turn-up instance. Within the constraints impressed by this restraint, an endeavor is made to evolve a technique for analytical calculations which, it is thought of, will be handy in realistic design work. The landing impact isolator which is being widely used and which has achieved a good amount of excellence shows a rather complex link between the force, the stroke, and the rate of stroke. For practical needs, it is vital to state this representation in mathematical model and to evolve a technique for the analytical key of the resulting differential equations. Same has been accomplished with the aid of MATLAB software. Yet it is sometimes helpful to include a highly idealistic landing impact isolator which has linear differential equations. Although such a representation will never accurately simulate the details of the actual landing impact, it accepts of simple analytical handling and accepts study of queries of a more common nature. This has been done in the current work and the applicability of the outcome obtained there falls in the truth that they do not depend on the more or less supplementary particulars of practical landing isolators.*

Keywords: *Isolator, Model, Matlab*

1. INTRODUCTION

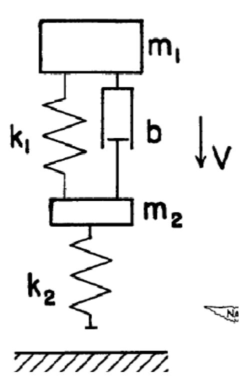

Fig. 1: Spring-damper model

Essentially, a landing impact isolator consists of an isolator and a tire. The impact isolator may be compressed significantly. It resists this motion with an elastic force rising with rising deformation and with a damping force which depends on the rate of displacement and which, converts mechanical energy into some other form. This impact isolator can be idealized as a spring-damper model as shown in Fig. 1.

2. LITERATURE REVIEW

Literature is reviewed to get the feel of what is happening in and around the world so as to identify the lacunas associated with the field of problem and solve them accordingly.

Hydro-pneumatic impact isolators of air suspension were mentioned [1] which can alter their damping forces in related to air pressure in air springs. Due to the option of improving dynamic characteristics of all vehicles that use the pneumatic suspension were evolved. An impact isolator is a mechanical installation configured to damp down impact impulse, and transform kinetic energy [2]. The impact isolator's responsibility is to take up or dissipate energy. In a vehicle, it minimizes the effect of passing over rough road, causing to enhance ride quality, and escalation in comfort due to considerably reduced amplitude of excitation. Design of an active suspension system that reduces the vertical vibrations of the vehicle's body in spite of versatile road conditions was discussed [3]. A group of five modules were designed to accomplish this goal. This process was adopted through the use of electromagnetic circuitry. Design and manufacturing possibility of a damper tailored to a Formula SAE style vehicle has been included [4]. Investigation into the evolution of dampers, racing dampers and the idea of the damper in Formula SAE style vehicles, dictates the direction of the novel design. An electric impact isolator that transforms the kinetic energy of an oscillating object into electric energy was discussed [5]. 3D CAD model of the planned design was evolved according to the design goals spelt out by the numerical models. This kinetic energy was usually deserted in a form of thermal energy in a straight, mechanical impact isolator. The main objective of the work is to design and analyze the working of an electric impact isolator. Shock absorbers are vital subsystem of a suspension system, joining the vehicle to its tyres [6]. The necessities for dampers comes into play as roll and pitch related to vehicle maneuvering, and from the waviness of roads. In nineteenth century, road condition was generally extremely bad. A physical and analytical model was evolved for a twin-tube hydraulic shock absorber, employing oil as the working means [7]. To analyze the model, various types of numerical integration were adopted. The influence of the amplitude and frequency of the disturbance, as well as the parameters narrating the flow rate of oil through the valves, were investigated. A shock absorber is a mechanical appliance designed to reduce or damp down shock impulse, and convert kinetic energy [8]. Basic duty of the shock absorber is to absorb or dissipate energy. Present methodologies for the prediction of wear of an automotive shock absorber, with the objective of developing an approach for a fast and useful diagnostic method that could be carried out in any revamp facility [9]. In vehicles trouble occurs while moving on speed breakers on road [10]. The aim of this project is to design and analyze the concert of Shock absorber by changing the wire size of the coil spring. The Shock absorber is designed to cater for shock load and dissipate kinetic energy.

This survey brings out a fact that so far no endeavor has been put up in establishing dynamic modeling of impact isolator.

3. MATHEMATICAL MODELING

The tire is for the current needs a spring whose deformation is nearly proportional to the force acting on it. Mass of the tyre is sandwiched in between these two deformable rudiments, considering subsystems of the impact isolator which contribute in the movement of tire. Aircraft mass lies on top of the whole impact isolator, portion of which i.e. m_1 which belongs to the impact isolator under study. During landing of aircraft, this structure reaches the ground with a significant velocity. Transverse component 'V' of this velocity is of attention as long as the turning up of the wheels is excluded. The impact commences when the bottom end of the landing isoaltor approaches the ground. This instance is assigned as t = 0, and the oscillations of the masses m_1 and m_2 are investigated which follow for t > 0 when the deformation of the bottom end of the spring-mass system is abruptly stopped.

Linear differential equations are acquired when the impact isolator is represented by a spring and a damper and when the tire is implicit to be a linear spring. There may also be a linear damper joined with the tire but, compared with the isolator damping, the role of the tire to damping is so less that it is not so significant to consider it in the equations.

Fig. 2 shows the system in two instances, one for t = 0 and the other for some soon after time.

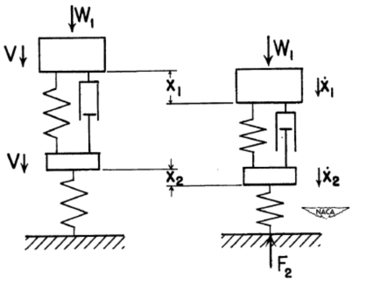

Fig. 2: System in two positions

Displacements of the masses m_1 and m_2, measured from their instances at t = 0 and are designated as x_l and x_2 respectively. Their difference

$x_l - x_2$

is the stroke of impact isolator.

If k_2 and is the stiffness of the tire, then the force transformed from the ground to the unsprung mass m_2 and is

$F2 = k_2\, x_2$

On contrary, force in impact isolator is the addition of an elastic force $k_l x$ and damping force which in general will be proportional to the velocity

$$\dot{x} = \frac{dx}{dt}$$

With which masses m_l and m_2 loom each other:

$$F_1 = k_1 x + \mathrm{b}\dot{x}$$

Next is the load W_1 which acts as outside force on mass m_l. It is nothing but lift induced by wing subtracted from weight of aircraft.

The three forces W_l, F_l and F_2 calculate the displacement of masses m_l and m_2, according to the equations

$$m_1\ddot{x}_1 = W_1 - F_1$$
$$m_2\ddot{x}_2 = F_1 - F_2$$

When F_1 and F_2 are uttered by x_l and x_2 according to above mentioned equations, the governing differential equations of the impact isolator are obtained as follows.

$$m_1\ddot{x}_1 + b(\dot{x}_1 - \dot{x}_2) + k_1(x_1 - x_2) = W_1$$
$$m_2\ddot{x}_2 - b(\dot{x}_1 - \dot{x}_2) - k_1(x_1 - x_2) + k_2 x_2 = 0$$

4. SENSITIVITY ANALYSIS

As mentioned in earlier section, an endeavor is made to evolve a technique for analytical calculations which will be handy in realistic design work. This has been accomplished through sensitivity analysis where in the influence of the following parameters on impact force has been extracted.

- Mass acting on isolator
- Damping of isolator
- Stiffness of isolator and tire

Solution of the above mentioned equations have been worked out in dimensionless form so as to meet the above said requirement.

An allusion length is needed for displacements x_l and x_2 and stroke x and when they are graphically expressed as function of time an allusion time is required. As the deflections commence from '0' at t = 0 and reach asymptotically distinct values, the static deflections, it would be rationale to implement static deflection of the mass m_l as a benchmark of length:

$$\delta = m_1 g\left(\frac{1}{k_1}+\frac{1}{k_2}\right)$$

A straightforward time benchmark may be found in the period of the vibrations which the mass m_l can make on the springs k_l and $k_2$in the lack of damping.

$$T = \sqrt{\frac{\delta}{g}} = \sqrt{\frac{m_1(k_1+k_2)}{k_1 k_2}}$$

For forces F1 and F2 the load W_1 can be considered as benchmark; but, as W_l depends on in plane velocity of the aircraft and on the angle of attack of its wings, it may have somewhat dissimilar values for dissimilar landing cases of the same aircraft. Hence it would be rationale to take it granted m_1g as an allusion value.

Apart from these variables there exists a group of constants which effect the impact. They are the masses m_1 and m_2, the spring constants k_l and k_2 damping b of the isolator, net load W_1 and transverse velocity V of the aircraft. These constants can be clubbed to arrive at the following dimensionless quantities.

$\frac{m_2}{m_1}$	$\frac{k_1}{k_1+k_2}$	$\frac{bT}{m_1}$	$\frac{W_1}{m_1 g}$	$\frac{VT}{\delta}$

4.1 Influence of mass acting on isolator

The following values are chosen for various parameters.

Table 1: Values of parameters

$\frac{m_2}{m_1}$	0 and 0.05
$\frac{k_1}{k_1+k_2}$	0.25
$\frac{bT}{m_1}$	0.5
$\frac{W_1}{m_1 g}$	0.2
$\frac{VT}{\delta}$	2.0

Fig. 3 shows variation of impact force for two different values of mass ratios.

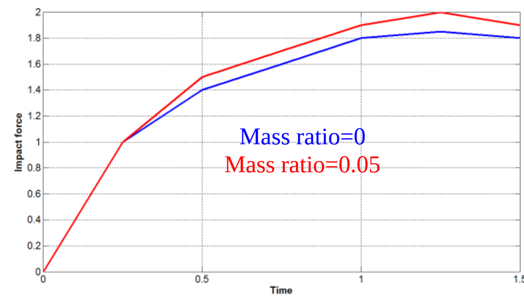

Fig. 3: Variation of impact force with time

- In the beginning there exists clear cut difference exists.
- The mass absorbs the first impact and the impact isolator force increases slowly; a slight overshoot follows; and then the curves are really parallel, the gap between them corresponding to the sum of the tire mass m_2 to the total mass $m_1 + m_2$ which must be decelerated.
- The above mentioned phenomenon ascertains the idea that the maximum of the impact isolator force is not much effected by the mass and that one may assume $m_2 = 0$ when this leads to a simplification of analytical work.

4.2 Influence of damping of isolator

The following values are chosen for various parameters.

Table 2: Values of parameters

$\frac{m_2}{m_1}$	0.025
$\frac{k_1}{k_1+k_2}$	0.25
$\frac{bT}{m_1}$	0.5 and 1
$\frac{W_1}{m_1 g}$	0.2
$\frac{VT}{\delta}$	2.0

Fig. 4 shows variation of impact force for two different values of damping.

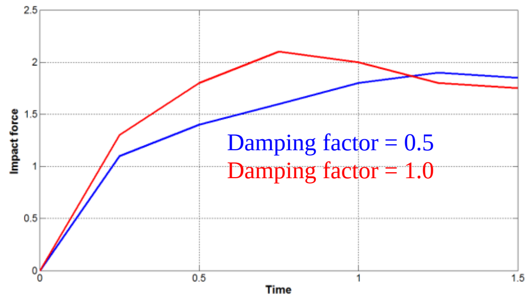

Fig. 4: Variation of impact force with time

- At start there is less difference between the two curves, since the impact is taken by the tire, but then the increase is rapid for the case of higher damping
- Highest is reached rapidly but it is only 7% more than that for the case with half as much damping.

4.2 Influence of stiffness of isolator

The following values are chosen for various parameters.

Table 3: Values of parameters

$\frac{m_2}{m_1}$	**0.025**
$\frac{k_1}{k_1+k_2}$	**0.15 and 0.25**
$\frac{bT}{m_1}$	**0.5**
$\frac{W_1}{m_1 g}$	**0.2**
$\frac{VT}{\delta}$	**2.0**

Fig. 5 shows variation of impact force for two different values of stiffness.

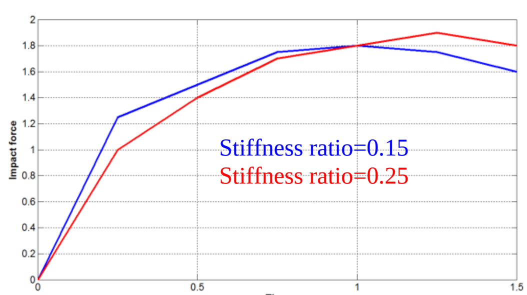

Fig. 5: Variation of impact force with time

- Increase of stiffness ratio implies that the impact isolator is made stiffer and the tire softer
- As a result, significant part of the total deformation will occur in the tire, and since due to lack of damping the impact force will develop more slowly.

5. CONCLUSION

An attempt has been made to evolve a technique for analytical calculations which will be handy in realistic design work. This has been accomplished through sensitivity analysis where in the influence of the various parameters on impact force has been extracted.

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