Engineering Notes

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Optimization of an Oleo-Pneumatic Shock Absorber of an Aircraft during Landing

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Introduction

IN optimum design of aircraft landing gear, consideration must be given to minimizing both dynamic loading on the structure during landing impact and fatigue damage caused by landing and taxiing loads. This Note is an outcome of a procedure adopted for the optimum design of landing gears of the oleo-pneumatic type as applied to three different aircraft. In such a system, the peak ground load can be limited by a proper choice of the area of orifice in the shock absorber. The orifice considered in all these cases is a simple orifice without a metering pin. Studies reveal that the response curve of the ground load with time has two distinct peaks that vary with the damping constant (orifice area) of the shock obsorber. For the minimum peak load design, these two peaks are observed to have nearly the same values.

Mathematical Model

For a good estimation of landing loads transmitted to the airframe, a mathematical model is formed on the lines suggested by Yff[1] incorporating the aircraft's rigid-body vertical translation and pitch and the first three coupled elastic modes of vibration of the wing.

Peak ground load is chosen as the performance index for optimization. The constraint is on the stroke of the shock absorber, while the variable is the diameter of the orifice in the shock absorber; all the other parameters are held constant. Since the performance index is not an explicit function of the variable, the direct search technique due to Powell is used for optimization.[2]

A computer program is written for the above mathematical model and checked with the available results.[1,3] The aircraft considered for this study are 1) a typical jet trainer aircraft,[4] 2) the aircraft given in Refs. 3 and 5, and 3) the aircraft taken for the study by Yff.[1]

Results

The transients of the ground reaction, shock absorber stroke, and stroke velocity are shown in Figs. 1, 2, and 3, relating to an aircraft of the 5000-lb class. The particular set of conditions imposed on this aircraft for carrying out optimization are as follows: velocity of descent 8.86 fps, zero forward velocity, and only rigid-body vertical translation mode.[3,5]

It is observed from the transient of the ground load that there are two peaks in the response. For large damping constants, the first peak value is greater than the second, whereas for small damping constants, the second is larger. However, the two peaks are nearly equal for the optimal case. This is an important observation from all three aircraft considered in this study.

Another significant observation is that the first peak occurs after the instant the shock absorber stroke velocity has reached its maximum and the second peak occurs at the time when the stroke velocity is nearing zero (Fig. 1 and 3).

Physical Interpretation

The total force in the shock absorber is the sum of the forces due to airspring, orifice damping, and friction. The first two components contribute a major part of the total force. The airspring force is directly proportional to the shock absorber stroke, whereas that due to the orifice damping is a function of the stroke velocity. It is seen from the transient of

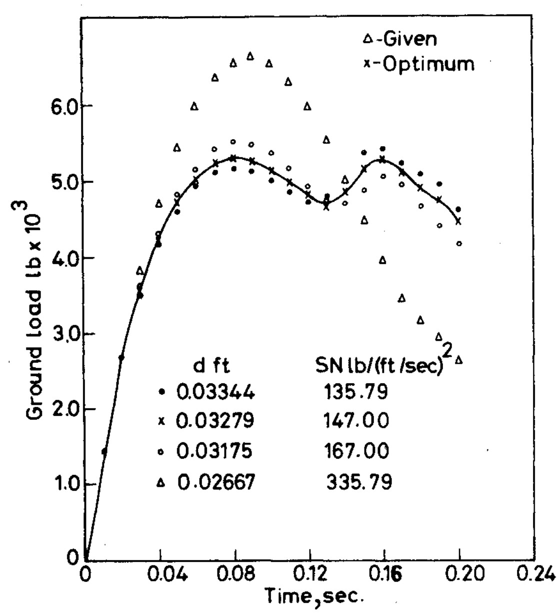

Fig. 1 Ground load vs time. SN = damping constant in the shock absorber. d = diameter of the orifice in the shock absorber.

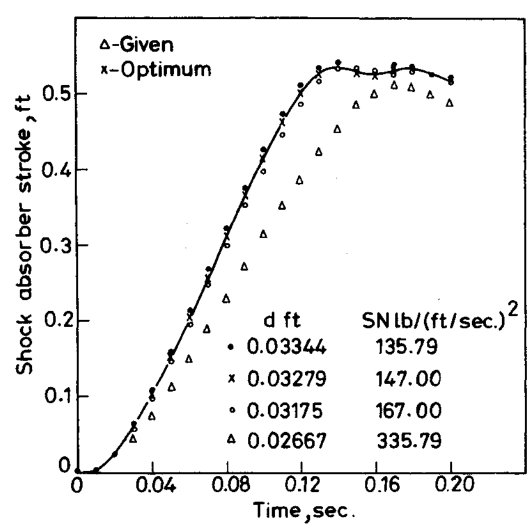

Fig. 2 Shock absorber stroke vs time. For symbols, see Fig. 1.

Received Dec. 13, 1976; revision received March 28, 1977.
Index categories: Landing Dynamics; Subsystem Design.
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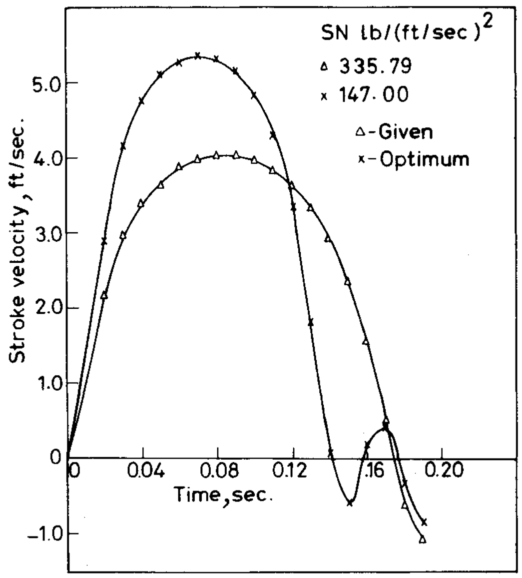

Fig. 3 Stroke velocity vs time. For symbols, see Fig. 1.

the stroke velocity that the velocity increases to a maximum in a small interval of time, drops down to zero, and then changes its sign. Until the stroke velocity reaches its maximum, both the airspring and damping forces increase. Beyond this maximum velocity, airspring force increases at a slower rate, but the damping force decreases. Hence the load keeps on increasing until the stroke velocity reaches its maximum, and then the load decreases. The time of occurrence of peak load depends on the relative magnitudes of the two forces.

At the end of the stroke, when the stroke velocity is zero, the damping force is also zero. Now, only the airspring force is in action trying to extend the shock absorber. Therefore, the load decreases after that instant. The valley in between the two peaks is determined by the magnitudes of the airspring force that is increasing and the damping force that is decreasing.

Conclusion

In the transient of the ground load of an aircraft, there are two peaks, the relative magnitudes of which depend on the damping constant of the shock absorber. In the optimum damping case, the magnitudes of the peaks are almost the same.

Hence, by looking at the transient response of the ground load of an aircraft while landing, we can judge whether the damping constant of the shock absorber is optimal. If the first peak value is greater than the second peak value, decrease the damping constant (by increasing the area of the orifice) to reach the optimum; if the second peak value is greater, increase the damping constant (by decreasing the area of the orifice) to obtain the optimum. The extent of the required change in the orifice area depends on the relative magnitudes of the two peaks. In the opinion of the author, the above result could be used as a rule of thumb for the optimum design of an aircraft undercarriage.

Acknowledgment

The author wishes to thank A. K. Rao and R. Krishnan of the Indian Institute of Science, Bangalore, and R. Sankaranarayanan and V. T. Nagaraj of Hindustan Aeronautics Limited, Bangalore, for their guidance and support in carrying out this work.

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Evaluation of Flight Spoilers for Vortex Alleviation

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Nomenclature

$C_{L,\text{trim}}$ = trimmed lift coefficient of generating model
$C_{l,TW}$ = trailing wing rolling-moment coefficient

$$\frac{\text{trailing wing rolling moment}}{qS_{TW}b_{TW}}$$

q = dynamic pressure at trailing wing location
S_{TW} = area of trailing wing
b_{TW} = span of trailing wing

Introduction

THE strong vortex wakes generated by large transport aircraft are a potential hazard to smaller aircraft, and so NASA is involved in a program of model tests, flight tests, and theoretical studies to determine the feasibility of reducing this hazard by aerodynamic means.

The magnitude of the vortex-wake hazard is influenced greatly by the direction of the flight of the aircraft which is penetrating the trailed vortices. A cross-track penetration at right angles to the trailing vortices tends to cause pitching and vertical motion and to produce vertical loads on the penetrating airplane in a manner similar to that of a gust encounter. Also, an along-track penetration, parallel to and between the wingtip vortices, can occur in both the takeoff climbout and the landing approach. This type of penetration may cause settling or, at least, may reduce the rate of climb of the penetrating aircraft. However, an along-track penertration through the vortex center is considered to be the most hazardous encounter since such penetration induces a rolling motion to the penetrating aircraft that could result in an upset.

The approach being used by NASA to evaluate the effectiveness of vortex-alleviation devices in ground-based facilities is to simulate an airplane flying in the trailing vortex of another larger airplane and to make direct measurements of rolling moments induced on the trailing model by the vortex generated by the forward model. From flight tests, the pilot's qualitative separation requirement is determined from the separation distance where the vortex-induced upset would cause a missed approach during an IFR landing.

This Note briefly summarizes the results obtained to date from wind-tunnel and full-scale flight investigations of the flight spoilers that exist on the wide-bodied transport jet aircraft when used as trailing vortex hazard alleviation devices. All of the data presented herein were obtained with

Received Jan. 14, 1977; revision received Feb. 24, 1977.

Index categories: Aerodynamics; Flight Operations; Jets, Wakes, and Viscid-Inviscid Flow Interactions.

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