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SUMMARY

Aircraft dynamic loads and vibrations resulting from landing impact and from runway and taxiway unevenness are recognized as significant factors in causing fatigue damage, dynamic stress on the airframe, crew and passenger discomfort, and reduction of the pilot's ability to control the aircraft during ground operations. One potential method for improving operational characteristics of aircraft on the ground is the application of active-control technology to the landing gears to reduce ground loads applied to the airframe.

An experimental investigation was conducted on series-hydraulic active control nose gear. The experiments involved testing the gear in both passive and active control modes. Results of this investigation show that a series-hydraulic active-control gear is feasible and that such a gear is effective in reducing the loads transmitted by the gear to the airframe during ground operations.

INTRODUCTION

Aircraft dynamic loads and vibrations resulting from landing impact and from runway and taxiway unevenness are recognized as significant factors in causing fatigue damage, dynamic stress on the airframe, crew and passenger discomfort, and reduction of the pilot's ability to control the aircraft during ground operations. The ground-induced structural vibrations on large, flexible airplanes can reduce the pilot's capability to control the airplane during high-speed ground operations. These ground-induced dynamic loads and vibrations are magnified for supersonic-cruise aircraft because of the increased structural flexibility inherent in these slender-body, thin-wing designs. Such operational problems with supersonic-cruise airplanes have occurred at high take-off and landing speeds on some runways which are only marginally acceptable for most subsonic commercial airplanes. One potential method for improving operational characteristics of such airplanes on the ground is the application of active-control technology to the landing gears to reduce the ground loads applied to the airframe.

Previous analytical studies (references 1 and 2) have been conducted to determine the feasibility and potential benefits of applying active load control to the airplane main landing gear to limit the ground loads applied to the airframe. The results reported in reference 2 indicate that a shock strut incorporating a hydraulically controlled actuator in series with the passive elements of a conventional shock strut have acceptable properties and would be quite feasible to implement. Based on the results of reference 2, a modified version of the series-hydraulic active gear which eliminated the actuator and effected control by using a servovalve to remove or add hydraulic fluid to the shock-strut piston (lower cylinder) was analytically and experimentally investigated in references 3 through 6. Based on the results described in these references, the gear from a F-106B was modified for drop tests. The purpose of this paper is to present the results of passive and active drop tests of the F-106B nose gear.

SERIES-HYDRAULIC ACTIVE-CONTROL GEAR

Control Concept

The series-hydraulic control concept limits the gear force applied to the airframe by regulating the damping force (hydraulic pressure) in the piston of the oleo-pneumatic shock strut. To incorporate this active control concept into a conventional gear requires a modification to the gear to control the flow of fluid in or out of the shock-strut with a servovalve. A schematic drawing of a series-hydraulic landing gear that has been fabricated to permit experimental verification of the concept is shown in figure 1. The gear represented is a simple generic oleo-pneumatic shock strut without a metering pin. The control concept is designated series-hydraulic because the control servovalve is in series with the shock-strut piston and hydraulic fluid is removed from or added to the piston to provide force regulation.

The actual gear selected for inclusion of the active control concept was the nose gear of the F-106B with no metering pin. The gear was modified to accommodate the control by adding a three-tube arrangement to the orifice as shown in figure 2. A collection chamber at the top of the 3 tubes connects the fluid in the shock-strut piston to one side of the secondary piston. The other side of the secondary piston is connected to the servovalve. The purpose of the secondary piston is to mechanically limit the amount of fluid that can be taken out or added to the shock strut for flight safety.

The control hardware required for the active gear test program included a 200 GPM (0.76 m^3/min) servovalve, a low-pressure (atmospheric) reservoir, a 9 GPM (0.04 m^3/min) hydraulic pump, a high-pressure (3000 psi (20.7 MPa)) accumulator, an electronic controller, and feedback transducers. The isolation valve allowed isolation of the gear from the control hardware to permit passive gear testing.

System Operation

System operation is briefly described as follows. The electronic controller determines the operational mode (take-off or landing), and implements the control laws. The control laws programmed into the controller are based on the following logic. At touchdown, the controller receives a signal from a transducer to measure the instantaneous sink rate. Assuming a constant mass, the present energy is then calculated. An integration of the acceleration is also begun at this time so that the gear upper mass velocity is known at all subsequent times. As the gear compresses, the remaining work capability of the shock strut is calculated using the instantaneous values of acceleration (or force) and stroke remaining. This remaining work capability is then compared with the present energy of the upper mass calculated using the instantaneous upper mass velocity. When the remaining work capability equals or exceeds the present energy of the upper mass the controller stores in memory the instantaneous value of the scaled acceleration (wing-gear interface force) for use as the impact limit force and activates the servovalve control loop. The controller attempts to maintain this force by removal or addition of hydraulic fluid from or to the oleo-pneumatic shock strut lower chamber. Feedback from the accelerometer provides the controller with a means of determining the difference between the present and the desired force. The slope of the accelerometer output is also used for rate feedback in the control laws, so that if the force is not at the proper level but is tending to return to it on its own, the magnitude of the servo command would be reduced by some amount. Likewise, force trends away from the desired level provoke servo commands larger than would be generated if using force difference alone in the control laws. When the upper mass energy has been dissipated and the sink velocity is nearly zero, the controller linearly transitions the impact limit force to a value of zero for rollout control. During rollout and taxi the controller maintains the wing-gear interface force within a designed tolerance (deadband of ±1750 lbf (±7.8 kN) for these tests) about the static normal force. After control initiation at touchdown, the controller continuously operates with a long-time constant (5 seconds) control to return the gear stroke to the designed static equilibrium position.

EXPERIMENTAL INVESTIGATION

Landing simulation tests (passive and active) with the nose gear from a F-106B fighter interceptor airplane (fig. 3) were conducted at the NASA Langley Research Center to demonstrate the feasibility and the potential of the active gear for reducing ground loads transmitted to the airframe. The vertical drop tests simulated touchdown impact with and without lift.

Drop Tests

A photograph of the test apparatus for conducting the vertical drop tests of the nose gear is shown in figure 4. Additional details of the gear and apparatus are shown in figure 5. Using the drop test apparatus, the nose gear was dropped vertically with simulated lift at 4.5 fps (1.37 m/s) in both the passive and active modes. A 1-g lift simulation was obtained by using crushable aluminum honeycomb to stop the drop carriage (upper mass) vertical acceleration. The chosen test condition is representative of the airplane being derotated at a high pitch rate. A second test of the gear was also conducted at a vertical speed of 2.5 fps (0.76 m/s) without lift. Without lift applied, vertical speeds higher than about 2.5 fps (0.76 m/s) would cause the gear to bottom out. Such a drop test is representative of losing pitch control during derotation.

A comparison of the measured upper mass acceleration for the active versus passive gear without lift is shown in figure 6. Significant events such as drop carriage release, free fall, tire impact, and control activation are indicated in the figure. A 47% decrease in upper mass acceleration was obtained with the active control gear. The decrease in acceleration translates to a 47% decrease in the amplitude of forces transmitted to the airframe. For the 2.5 fps (0.76 m/s) vertical drop without lift, the passive gear stroke shown in figure 7 nearly bottomed out; consequently, the active gear stroke was essentially the same as for the passive gear case. Upper mass acceleration data for a 4.5 fps (1.37 m/s) drop with lift are shown in figure 8. A 36% decrease in the transmitted force was obtained with the active gear. As shown in figure 9, there was a 10% increase in the strut stroke associated with the active control.

CONCLUDING REMARKS

A potential method for improving the operational characteristics of aircraft on the ground by the application of active-control technology to the landing gears to reduce ground loads applied to the airframe has been investigated. An experimental program was conducted on a series-hydraulic active-control nose landing gear from a F-106B fighter interceptor aircraft involving both passive and active control modes. Results of the investigation show: (a) That such a concept can be achieved through modification of existing hardware, and (b) that the concept is effective in significantly reducing the loads transmitted by the gear to the airframe during landing and ground operations.

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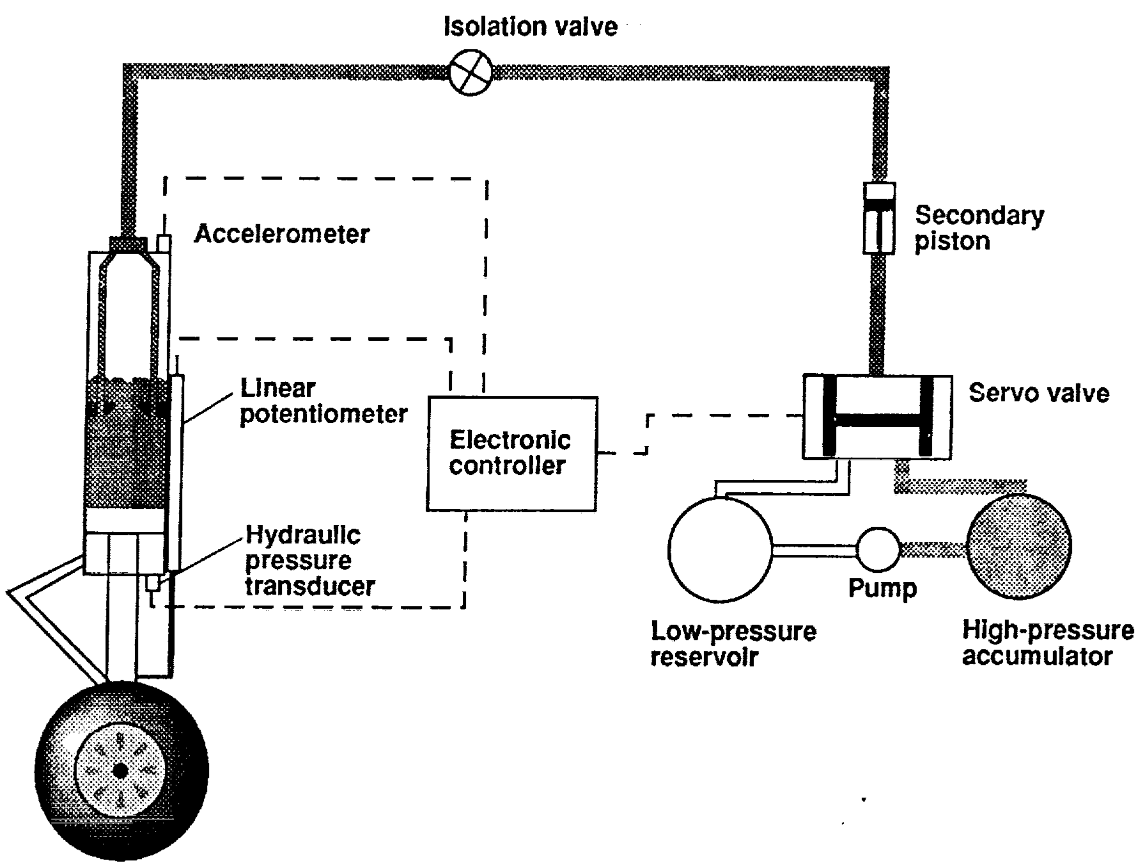

Figure 1.- Schematic of series-hydraulic active control landing gear.

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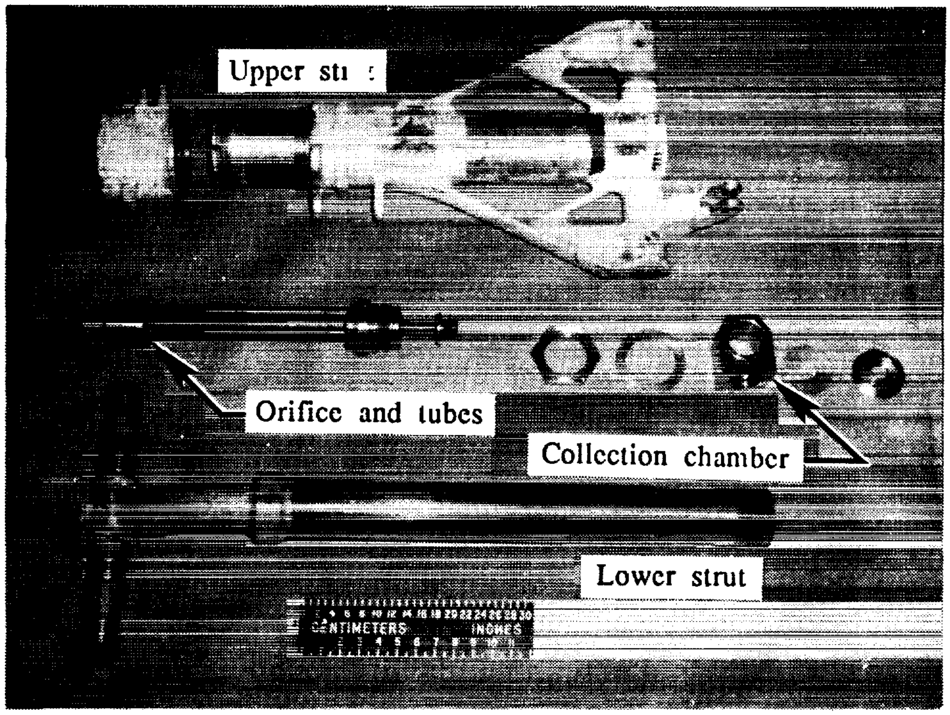

Figure 2.- Disassembled, modified F-106B nose gear.

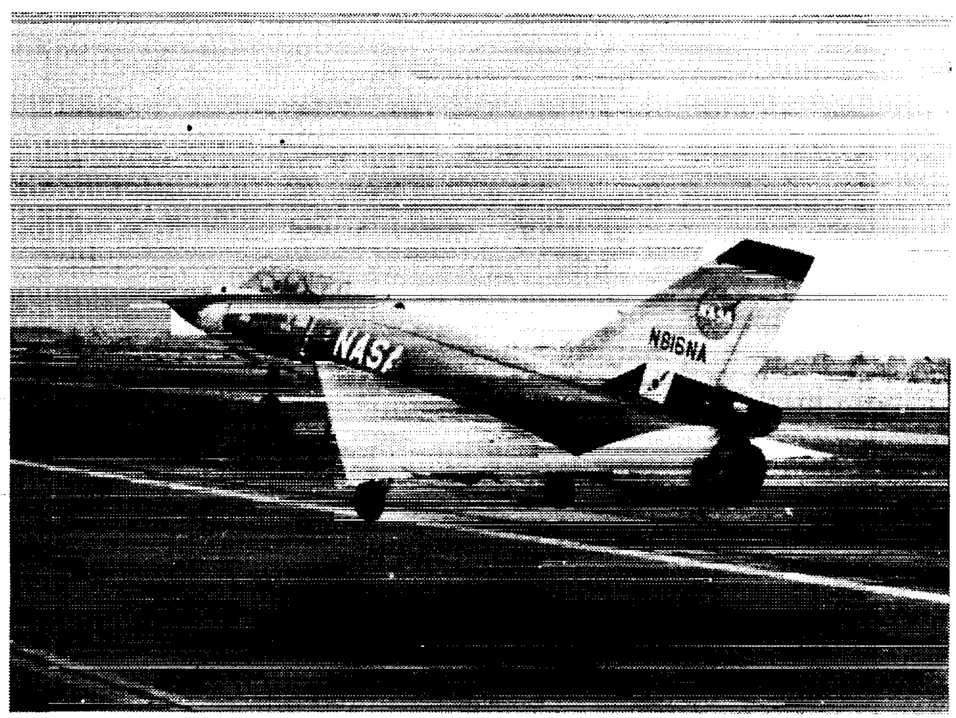

Figure 3.- F-106B fighter interceptor airplane.

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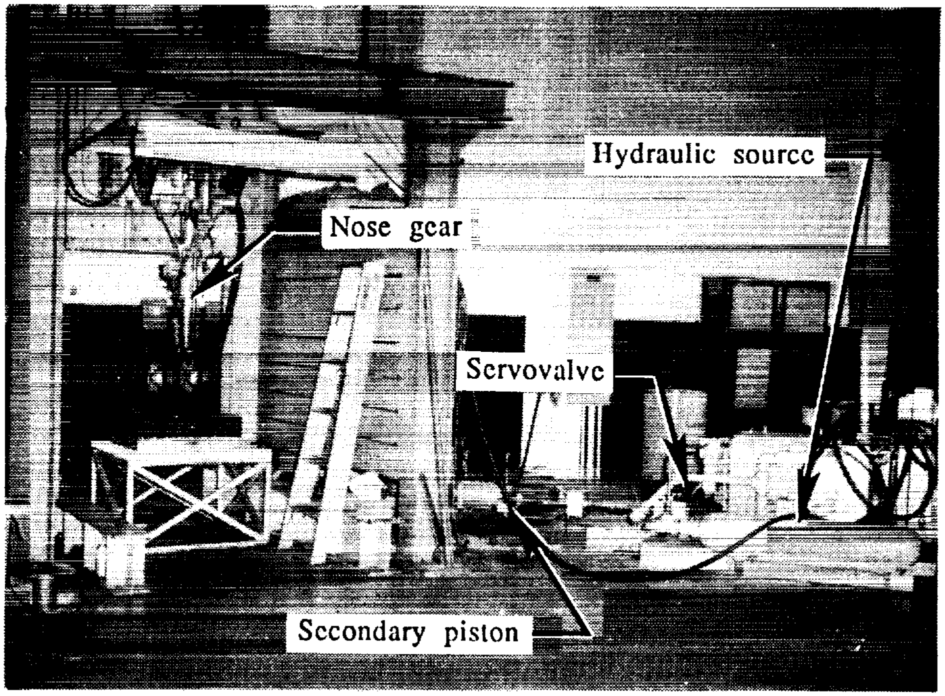

Figure 4.- Nose gear drop test apparatus.

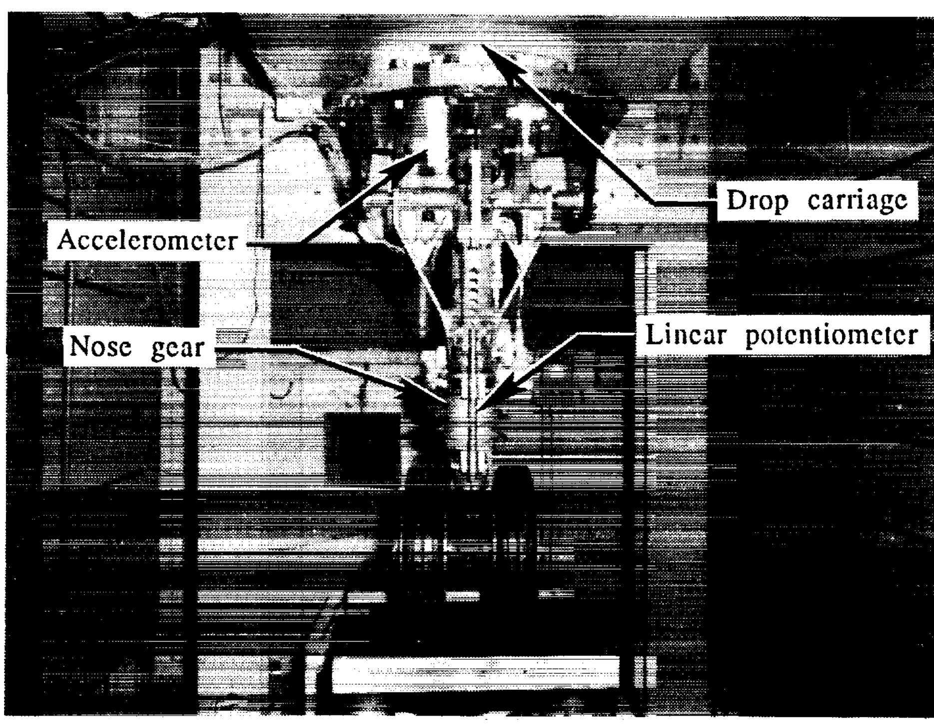

Figure 5.- Nose gear mounted on drop carriage.

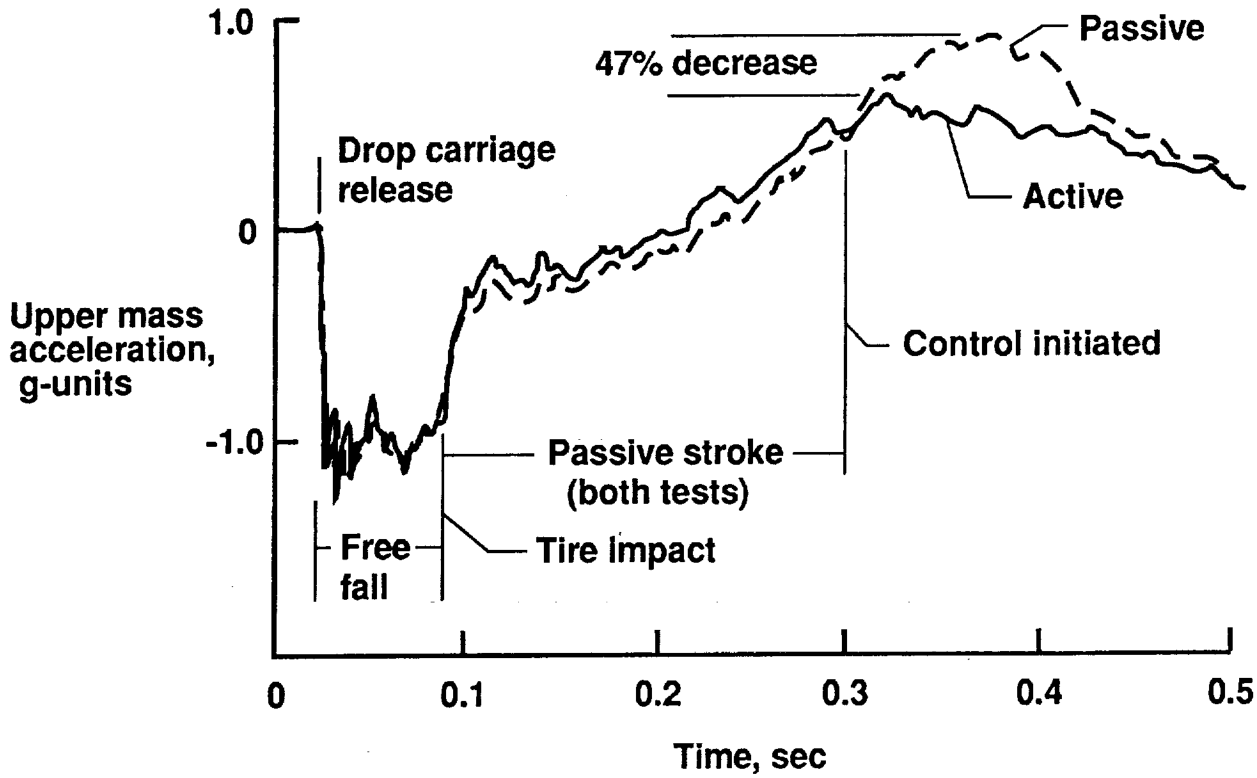

Figure 6.- Comparison of passive and active control accelerations for vertical drop of nose gear at 2.5 ft/sec (0.76 m/sec) without lift.

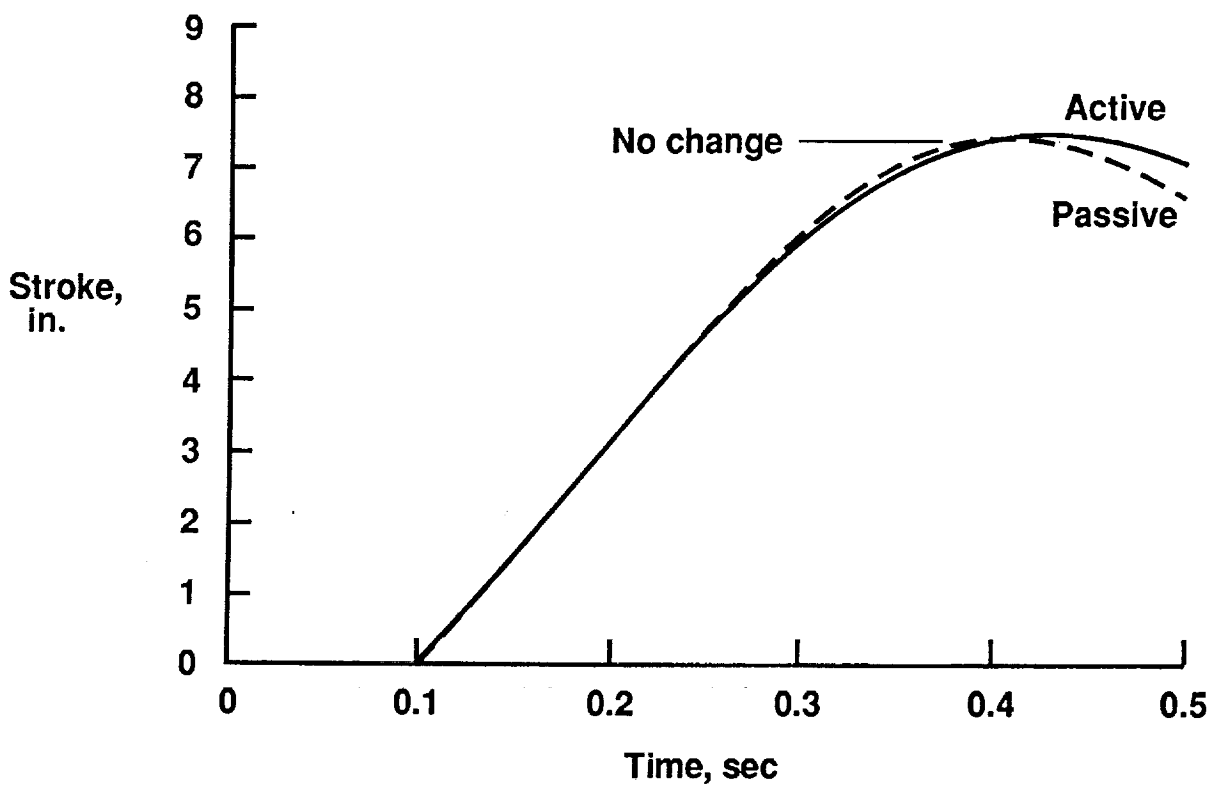

Figure 7.- Comparison of passive and active control strut stroke for vertical drop of nose gear at 2.5 ft/sec (0.76 m/sec) without lift.

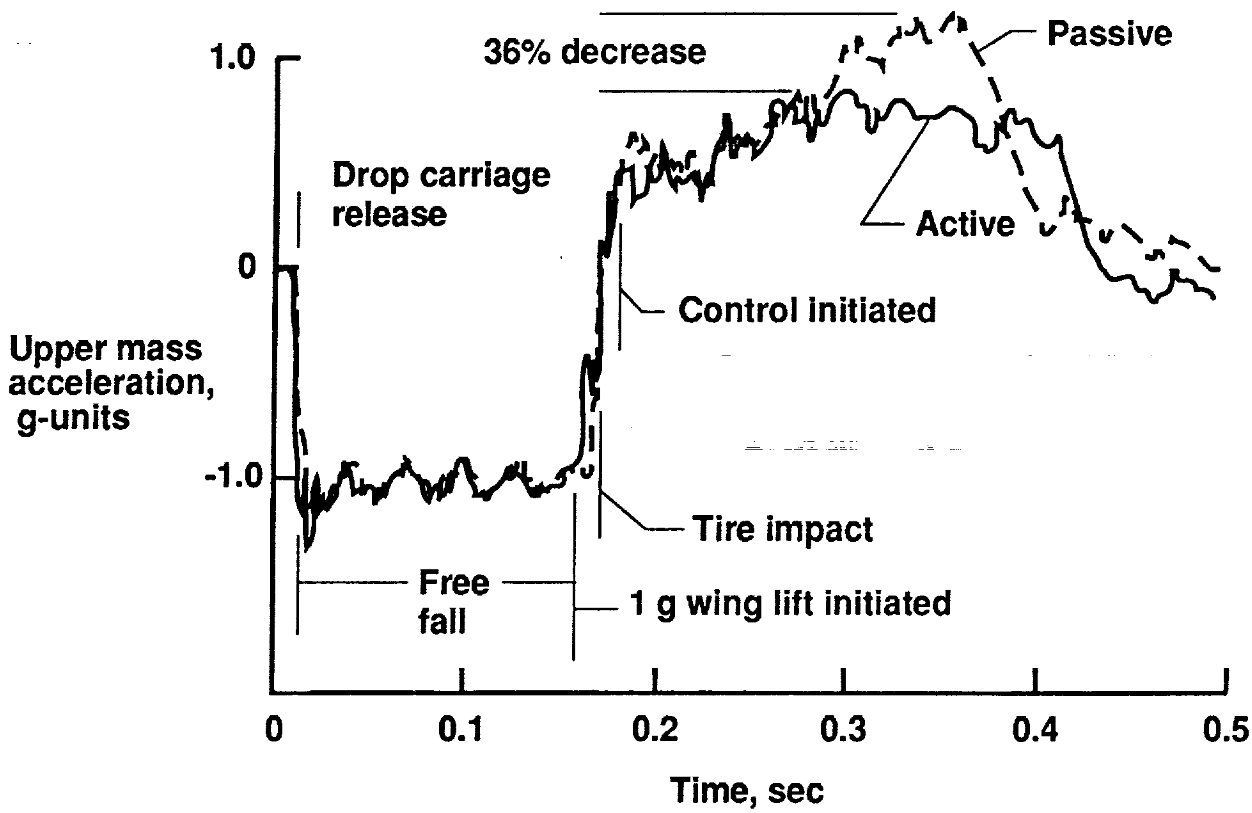

Figure 8.- Comparison of passive and active control accelerations for vertical drop of nose gear at 4.5 ft/sec (1.37 m/sec) with lift.

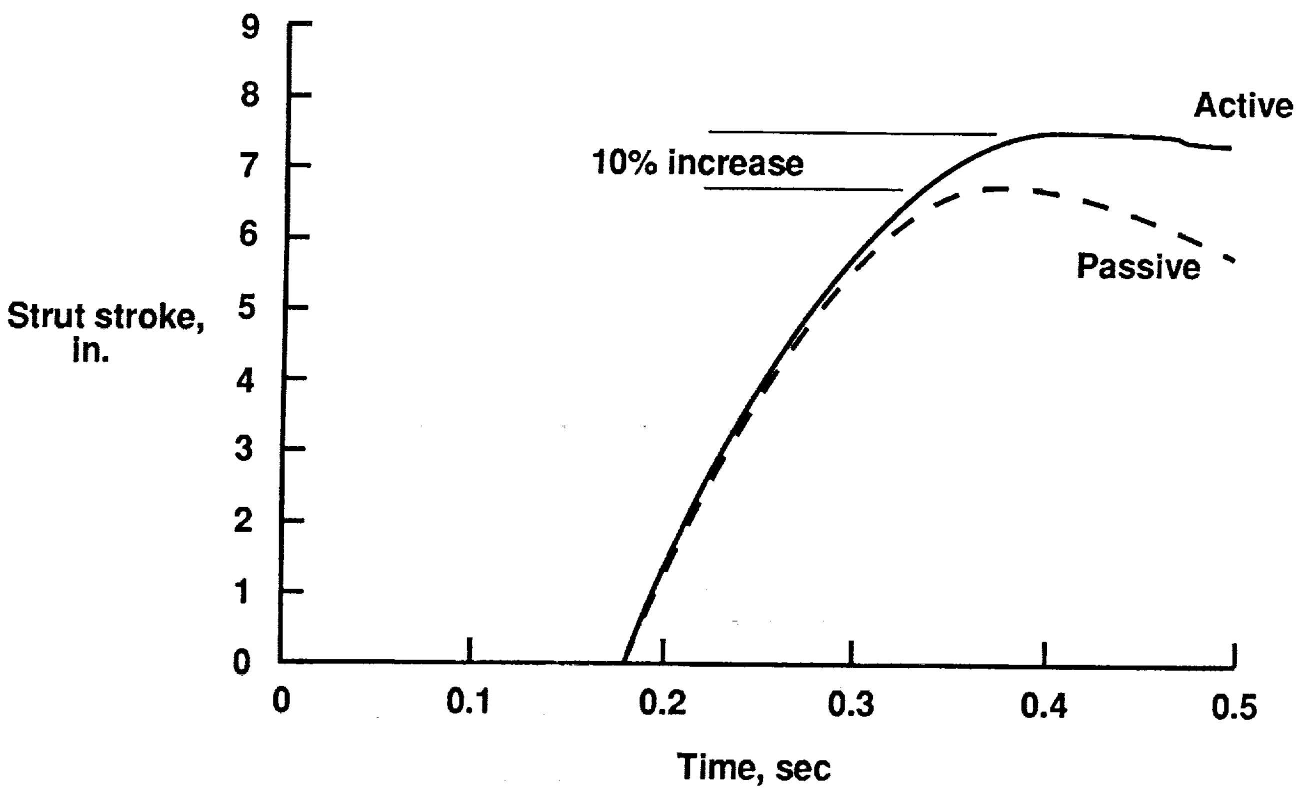

Figure 9.- Comparison of passive and active control strut stroke for vertical drop of nose gear at 4.5 ft/sec (1.37 m/sec) sith lift.

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15. Supplementary Notes

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16. Abstract

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