Shock Absorbers and Damping Isolators for Space Systems

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Shock absorbers are essential in vehicles. The device protects the parts of a vehicle and equipment from damage when driving over rough roads and unavoidable bumps. A conspicuous dynamic effect exists when a car is driven over a *speed bump*, such as found in parking lots. Once the speed bump is safely cleared, the car encounters lesser dynamic conditions in a typical journey. Without the shock absorbers, vehicles and cargo must be stronger, thus heavier, to avoid damage.

At liftoff, rockets experience a shock effect similar to driving over a ***speed bump***. Afterwards, a rocket encounters lesser dynamic conditions from its engines in flight. The start-up effect is distinct and it nearly *doubles* the effect of the applied load (thrust) on the parts of a rocket. The overshoot is inevitable unless the thrust is applied gradually. Before a typical rocket lifts off, its parts experience the effect of the start-up magnified loads. This is when most rockets have exploded or failed.

The start-up overshoot (first speed bump) has been neglected in many systems. The genesis, nature and magnitude of the oversight were described in other write-ups. The design error is dramatic, and it gives a rational explanation for the frequent failures of, and troubles with, space systems.

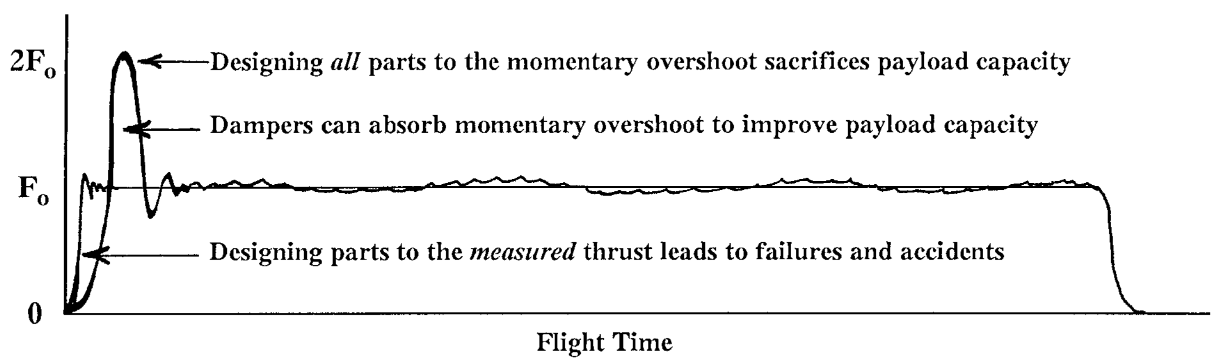
To demonstrate the significance of the start-up speed bump in rockets, consider the Space Shuttle. The three shuttle engines come up rapidly to about one million pounds of thrust, F_0 in the diagram. This produces nearly two million pounds of load, or $2F_0$, in some parts. Constructing the shuttle to only the *measured* thrust, or F_0, led to structural failures. The same applies to the more powerful solid rocket boosters. Subsequent strengthening of the parts, to withstand the nearly $2F_0$ load actually experienced, led to weight penalty and loss of payload capacity.

To offset the loss of payload capacity, major programs have been initiated, e.g., increase thrust with the Advanced Solid Rocket Motors (ASRM), or develop exotic aluminum-lithium alloy for the External Tank. But, these measures do not eliminate the detrimental start-up overshoot effect.

Designing aero-space systems to withstand the excess start-up loads is not the ideal, or desirable, solution. The excess loads are present for only a fraction of a second, see Figure below. Considerable weight penalty results from making all the parts stronger, thus heavier, to avoid damage during the short start-up period.

The analogy of the start-up overshoot in rockets to the speed bumps in parking lots suggests the rational and missing solutions. Instead of strengthening all the parts of a system, it is more effective to use shock absorbers, isolators or other dampers. A properly designed collapsible and locking device or material can isolate the parts of a vehicle and the payload from the transitory effect. Rubber or honeycomb pads, or air springs and associated hardware will do the job with minimum weight. Expendable dampers can be used for expendable vehicles, upper stages, and payloads. Reusable dampers, such as dashpots, will be worth the effort of development for reusable hardware.

The development of load absorbers, isolators and dampers for primary thrust sources in space vehicles should be given priority simply because the magnified start-up loads are momentary. It is more effective to absorb the excess loads with one device than to design all the parts to withstand the transient loads. The same is true of aircraft. The proposed devices have not been tried before, but the basic analytical, empirical, and experimental methods already exist.



Shock isolators and dampers provide rational and missing solution to transitory loads

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Correct Transient Loads in Pressure-Activated Systems

Aircraft - Spacecraft - Launch Vehicles - Nuclear Reactors - Marine Systems

jet engines - rocket engines - rocket motors - turbines - reactor vessels - heaters

The following transient situation happens millions of times every day.
The pressure in a combustion chamber rises rapidly to a maximum value P_0.
What is the maximum overshoot? - - - What overshoots?

FIND OUT

WHY the pressure does not overshoot, nor should it be expected to overshoot?
WHY the pressure is strictly a causal parameter in transient conditions?
WHY has the non-overshooting pressure been used as the transient response before?
WHY the pressure build-up is strictly the forcing function -- not the response?
WHY pressure transducers cannot detect the transient response?
WHY pressure transducers do not measure the maximum transient forces?
HOW existing methods produce dramatic errors of 70% to 100% in the design loads?

PREVENT

premature fatigue - early cracking - accelerated corrosion - unexpected accidents

AVOID

The Widespread Practice

1) Measure or calculate the pressure build-up to the maximum steady-state value, P_0.
2) Derive the maximum force, F_0, by simple conversion of pressure to force.
3) **The resulting force-time is considered the response in transient conditions.**
4) **The maximum design load, F_0, obtained by simple conversion from pressure.**

ADOPT

The Correct Procedure

1) Measure or calculate the pressure build-up to the maximum steady-state value, P_0.
2) Derive the maximum force, F_0, by simple conversion of pressure to force.
3) *The resulting force-time is strictly the forcing function in transient conditions.*
4) *The design loads are derived from the forcing function in transient analysis.*
5) **Else, make the correct measurements.**

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