Principles of Passive Vibration Control: Shock Absorber

INTRODUCTION

A shock absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy, which is a type of dashpot. Spring-based shock absorbers commonly use coil springs or leaf springs, though torsion bars are used in torsional shocks as well. Ideal springs alone, however, are not shock absorbers, as springs only store and do not dissipate or absorb energy. Vehicles typically employ both hydraulic shock absorbers and springs or torsion bars. In this combination, "shock absorber" refers specifically to the hydraulic piston that absorbs and dissipates vibration. Pneumatic and hydraulic shock absorbers include cushions and springs. An automobile shock absorber contains spring-loaded check valves and orifices to control the flow of oil through an internal piston. The shock absorber absorbs and dissipates energy. The basic function of the shock absorber is to absorb and dissipate the impact kinetic energy to the extent that accelerations imposed upon the airframe are reduced to a tolerable level [2 and 20]. Existing shock absorbers can be divided into two classes based on the type of the spring being used: those using a solid spring made of steel or rubber and those using a fluid spring with gas or oil, or a mixture of the two that is generally referred to as oleo-pneumatic.

One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most dashpots, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid heats up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of dashpots, such as electromagnetic types, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion vehicles on uneven roads. Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in passenger railroads, commuter rail and rapid transit systems because they prevent railcars from damaging station platforms.

In a vehicle, shock absorbers reduce the effect of traveling over rough ground, leading to improved ride quality and increase in comfort. While shock absorbers serve the purpose of limiting excessive suspension movement, their intended sole purpose is to dampen spring oscillations. Shock absorbers use valving of oil and gasses to absorb excess energy from the springs. Spring rates are chosen by the manufacturer based on the weight of the vehicle, loaded and unloaded. Some people use shocks to modify spring rates but this is not the correct use. Along with hysteresis in the tire itself, they dampen the energy stored in the motion of the unsprung weight up and down. Effective wheel bounce damping may require tuning shocks to an optimal resistance. Spring-based shock absorbers commonly use coil springs or leaf springs, though torsion bars are used in torsional shocks as well. Ideal springs alone, however, are not shock absorbers, as springs only store and do not dissipate or absorb energy. Vehicles typically employ both hydraulic shock absorbers and springs or torsion bars see Fig. 7.18. In this combination, "shock absorber" refers specifically to the hydraulic piston that absorbs and dissipates vibration.

Fig. 7.19 Rear shock absorber and spring of a motorcycle

Types of shock absorbers: There are several commonly-used approaches to shock absorption such as: Metal spring, Metal Spring, Rubber Buffer, Hydraulic Dashpot, Collapsing safety Shock Absorbers, Pneumatic Cylinders and Self compensating Hydraulic.

Metal Springs

Simply locating metal springs to absorb the impact loads are a low cost method of reducing the collision speed and reducing the shock loading. They are able to operate in very arduous conditions under a wide range of temperatures. These devices have high stopping forces at end of stroke. Metal springs store energy rather than dissipating it. If metal sprint type shock absorbers are used then measures should be provided to limit oscillations ---Metal springs are often used with viscous dampers. There are a number of different types of metal springs including helical springs, bellville washers (cone-springs), leaf springs, ring springs, mesh springs etc. Each spring type has its own operating characteristics.

Fig. 7.19 Metal Spring Shock Absorber

Elastomeric Shock absorbers

These are low cost options for reducing the collision speed and reducing the shock loading and providing system damping. They are conveniently molded to suitable shapes. These devices have high stopping forces at end of stroke with significant internal damping. Elastomeric dampers are very widely used because of the associated advantages of low cost and mouldability together with performance benefits. The inherent damping of elastomers is useful in preventing excessive vibration amplitude at resonance - much reduced compared to metal springs. However elastomer based shock absorbers are limited in being affected by high and low temperatures and are subject to chemical attack. Silcone rubber is able to provide reasonable mechanical properties between temperatures of -50^{O} to $+180^{O}$ deg. C- most other elastomers have inferior temperature tolerance.

Hysteresis of structural material, for example the compression of rubber disks, stretching of rubber bands and cords, bending of steel springs, or twisting of torsion bars. Hysteresis is the tendency for otherwise elastic materials to rebound with less force than was required to deform them. Simple vehicles with no separate shock absorbers are damped, to some extent, by the hysteresis of their springs and frames.

Fig. 7.20 Elastomeric Shock absorbers

<u>Hydraulic Dashpot</u>

This type of shock absorber is based on a simple hydraulic cylinder. As the piston rod is moved hydraulic fluid is forced through an orifice which restricts flow and consequently provides a controlled resistance to movement of the piston rod. With only one metering orifice the moving load is abruptly slowed down at the start of the stroke. The braking force rises to a very high peak at the start of the stroke and then falls away rapidly. On completion of the stroke the system is stable - the energy being dissipated in the hydraulic fluid as heat. These types of shock absorbers are provided with springs sufficient to return the actuator to its initial position after the impacting load is removed.

Dry friction as used in wheel brakes, by using disks (classically made of leather) at the pivot of a lever, with friction forced by springs. Used in early automobiles such as the Ford Model T, up through some British cars of the 1940s. Although now considered obsolete, an advantage of this system is its mechanical simplicity; the degree of damping can be easily adjusted by tightening or loosening the screw clamping the disks, and it can be easily rebuilt with simple hand tools. A disadvantage is that the damping force tends not to increase with the speed of the vertical motion.

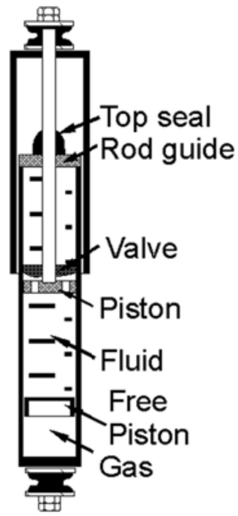

Fig. 7.21 Hydraulic Dashpot

Collapsing Safety Shock Absorbers

These are single use units which are generally specially designed for specific duties. They are designed such that at impact they collapse and the impact energy is absorbed as the materials distort in their inelastic/yield range. They therefore are more compact compared to devices based on deflections within their elastic range.

Fig. 7.22 Safety Shock Absorber

Air (Pneumatic) Springs

These devices use air as the resilient medium. Air has a high energy storage capacity compared to metal or elastomer materials. For duties with high loads and deflections the air spring is generally far more compact that the equivalent metal or elastomer device. Due to the compressibility of air these have a sharply rising force characteristic towards the end of the stroke. The majority of the energy is absorbed near the end of the stroke. The force on an air cylinder buffer is determined by the relationship PV^n = constant. Air springs require more maintenance than meal or elastomer based springs and the temperature range is restricted compared to metal springs.

Fig. 7.23 Air (Pneumatic) Springs

Self compensating Hydraulic

These devices are similar to the hydraulic dashpot type except that a number of orifices are provided allowing different degrees of restriction throughout the stroke. These devices are engineered to bring the moving load is smoothly and gently to rest by a constant resisting force throughout the entire shock absorber stroke. The load is decelerated with the lowest possible force in the shortest possible time eliminating damaging force peaks and shock damage to machines and equipment. These types of shock absorbers are provided with springs sufficient to return the actuator to its initial position after the impacting load is removed.

Fig. 7.24 Self compensating Hydraulic

Fluid friction for example the flow of fluid through a narrow orifice (hydraulics), constitute the vast majority of automotive shock absorbers. An advantage of this type is that using special internal valving the absorber may be made relatively soft to compression (allowing a soft response to a bump) and relatively stiff to extension, controlling "rebound", which is the vehicle response to energy stored in the springs; similarly, a series of valves controlled by springs can change the degree of stiffness according to the velocity of the impact or rebound. Specialized shock absorbers for racing purposes may allow the front end of a dragster to rise with minimal resistance under acceleration, then strongly resist letting it settle, thereby maintaining a desirable rearward weight distribution for enhanced traction. Some shock absorbers allow tuning of the ride via control of the valve by a manual adjustment provided at the shock absorber. In more expensive vehicles the valves may be remotely adjustable, offering the driver control of the ride at will while the vehicle is operated. The ultimate control is provided by dynamic valve control via computer in response to sensors, giving both a smooth ride and a firm suspension when needed. Many shock absorbers are pressurised with compressed nitrogen, to reduce the tendency for the oil to cavitate under heavy use. This causes foaming which temporarily reduces the damping ability of the unit. In very heavy duty units used for racing or off-road use, there may even be a secondary cylinder connected to the shock absorber to act as a reservoir for the oil and pressurized gas.

SHOCK ABSORBERS HOW THEY WORK

A shock absorber is designed to smooth out a sudden shock impulse and dissipate kinetic energy. Shock absorbers are an important part of a vehicle's suspension. In a vehicle, it will reduce the effect of traveling over any rough ground. If there were no shock absorbers, the vehicle would just have a very bouncy ride, as energy is stored in the springs and then released to the vehicle. This could possibly exceed the allowed range of suspension movement.

• To control excessive suspension movement without shock absorption, it will require stiffer springs. This then would give a harsh ride.

• Shock absorbers allow the use of soft springs, and at the same time it controls the rate of
Suspension movement in response to any bumps.

They also, with hysteresis in the tire itself, damp the motion of the unsprung weight up and down on the springiness of the tire. Since the tire is not as soft as the springs, to get effective wheel bounce, damping may require stuffer shocks than what would be ideal for the vehicle motion alone

Pneumatic and hydraulic shock absorbers often take the form of a cylinder with a sliding piston inside. Here the cylinder must be filled with a viscous fluid, which is either hydraulic fluid or air. This fluid filled piston or cylinder combustion is then a dashpot (mechanical device or damper that resists motion via viscous friction). Spring based shock absorbers often use coil springs or leaf springs, torsion bars can be used in torsional shocks as well. Ideal springs alone, are not shock absorbers as springs only store, they do not dissipate or absorb energy. Vehicles mostly use springs or torsion bars as well as hydraulic shock absorbers. In this combination the shock absorbers or the shocks (as we know them) is reversed specifically for the hydraulic piston that absorbs and dissipates vibration.

There are many different types of shock absorbers and some commonly used approaches to shock absorption.

• Hysteresis – the compression of rubber disks, bending of steel springs or the twisting of torsion bars.

• Dry friction – used in wheel brakes, but using disks that are made of leather, at the pivot of a lever, with friction that is forced by springs. It was used in earlier vehicles and is now considered obsolete. There was an advantage to this system, as the degree of damping could easily be adjusted by tightening or loosening the screw clamping the disks, and it could easily be rebuilt with hand tools. The disadvantage is that the damping force tends to not increase
with the speed of the vertical motion.

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• Fluid friction – this is the flow of fluid through a narrow opening, the hydraulics. This constitutes the vast majority of automotive shock absorbers. An advantage of this type is that by using special internal valuing the absorber can be made very soft to compression. This then allows a soft response to a bump. Then quite it is quite stiff extension, which is the vehicle response to energy stored in the springs.

Specialized shock absorbers for racing purposes can allow the front end of a dragster to rise with a little resistance under acceleration, then it strongly resists letting it settle, thereby maintaining a desirable rearward weight distribution for enhanced traction. With some shock absorbers you can manually adjust them. Others can be adjusted by remote. But the ultimate control is provided by dynamic valve control via a computer in response to the sensors. This then gives a smooth ride and a firm suspension when it needed

• Compression of a gas – for example pneumatic shock absorbers. These can act like springs as the air pressure builds to resist the force on it. Once the air pressure reaches the necessary maximum, air dashpots will then act

• Magnetic effects – many hybrid automobiles now days have regenerative braking. This uses a reversed electric motor to dampen and eventually stop the motion of the vehicle. • Inertial resistance to acceleration – some vehicles have an additional pair of rear shock absorbers that damp wheel bounce with no external moving parts. The energy is absorbed by hydraulic fluid friction, but the operation all depends on the inertia of an internal weight. • Composite hydro pneumatic devices – these combine in a single device spring that allows ride height adjustment or control.

The Gyroscopic Vibration Absorber

The Gyroscopic Vibration Absorber, shown schematically in Figure 8, is a completely inertial, conservative means of reacting a sinusoidal force. A natural frequency in the decoupled GVA is achieved through an oscillating flow of energy between the processional and notational kinetic states of the gyroscopic disc which is analogous to the more common case of the elastic-inertial system in which the energy flows between the potential energy
and kinetic energy states. The anti-resonant frequency of the GVA is, for small processional and notational angles, linearly proportional to the angular velocity of the gyroscopic disc. If the disc velocity is properly synchronized to the frequency of a sinusoidal excitation, the GVA will produce anti-resonance on the structure at all values of the excitation frequency, thereby producing the effect of theoretically infinite bandwidth as re gards the excitation to which the GVA is synchronized. Helicopters, compound aircraft, rotary wing spacecraft decelerators, and certain VTOL aircraft are usually excited primarily by the nth harmonic of the rotational speed of the N-bladed rotor or propeller. Almost all vehicles, from rockets to railroad cars are subjected to some excitation which is a harmonic of the speed of rotating machinery, such as wheels, pumps, actuators, etc. Synchronization of the GVA to such discrete harmonics is uncomplicated, involving only an open-loop means of driving the gyroscopic disc at a speed which is a multiple of the speed of the disturbing machinery.
It is conceivable that the GVA anti-resonant frequency could be synchronized to the frequency of the worst disturbance in a distributed excitation spectrum using circuitry which would pass only input signals above a certain predetermined magnitude and select a synchronization frequency within the bandwidth of the greatest disturbance. Before such a scheme would be of practical value, it is necessary to attenuate the resonant response of the GVA without deterioration of the anti-resonant effectiveness;

a means for accomplishing this was found in the course of this re search, and it is reported in the section titled "Parallel GVA Mounting". However, in light of the serious, more immediately practical problem of discrete harmonic disturbance, the matter of absorption of purely distributed or so-called random, excitation is of secondary concern in this project.

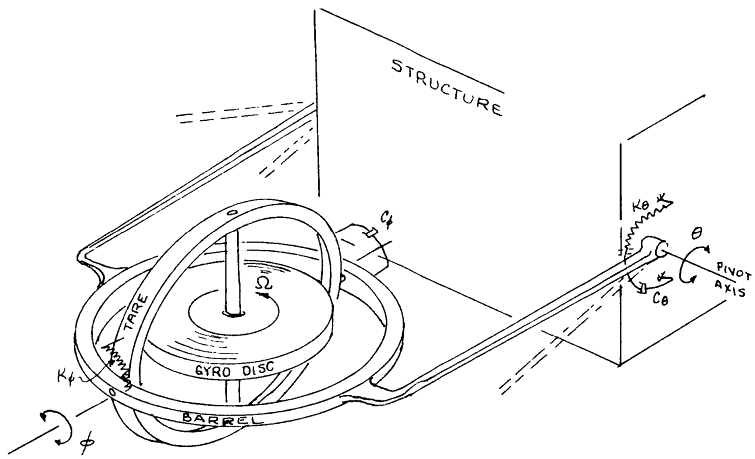

Fig. 7.25 Gyroscopic Vibration Absorber

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