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INFLUENCE OF CAR'S SUSPENSION IN THE VEHICLE COMFORT AND ACTIVE SAFETY

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Abstract: Car's suspension is a dynamic state of balance, continuously compensating and adjusting for changing driving conditions and the basic objective remains the same: provide steering stability with good handling characteristics and maximize passenger comfort.

In the papers are presented an active car's suspension from two perspectives: ride and handling.

1. INTRODUCTION

Car's suspension system is meant to provide safety and comfort for the occupants. Both, vehicle comfort and driving safety are mostly influenced by vertical accelerations and vehicle movements caused by pitch and roll motions.

The components of the suspension system perform six basic functions: maintain correct vehicle ride height, reduce the effect of shock forces, maintain correct wheel alignment, support vehicle weight, keep the tires in contact with the road, control the vehicle's direction of travel.

Without a suspension system, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In this situation, the wheels can lose contact with the road completely. Then, under the downward force of gravity, the wheels can slam back into the road surface. What you need is a system that will absorb the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road.

2. DYNAMICS OF A MOVING CAR

The car suspension must to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers. The irregularities of the road interact by the forces with the wheels of a car. All forces have both magnitude and direction and cause the wheel to move up and down perpendicular to the road surface.

In general, the dynamics of a moving car is considered from two perspectives:

- Ride - a car's ability to smooth out a bumpy road
- Handling - a car's ability to safely accelerate, brake and corner

These characteristics can be described in three important principles: road isolation, road holding and cornering.

The vehicle's ability to absorb or isolate road shock from the passenger compartment is called road isolation. Goal is allows the vehicle body to ride undisturbed while traveling over rough roads. The solution of this problem is to absorbed energy from road bumps and dissipates it without causing undue oscillation in the vehicle.

Road isolation is the vehicle's ability to absorb or isolate road shock from the passenger compartment. The degree to which this is accomplished is controlled by the condition of the suspension system and its components.

A properly functioning suspension system allows the vehicle body to ride relatively undisturbed while traveling over rough roads. This is accomplished through the combined use of bushings, springs, and hydraulic dampers.

The springs support weight as the vehicle travels down the road. When a vehicle encounters a bump in the road, the bushings receive and absorb the inputs from the road, while the springs compress and store kinetic energy. This energy is then released, causing a rebound in the vehicle's weight. The rate at which the springs compress and rebound is controlled using a hydraulic damper, such as a shock absorber or strut. The result of this action is to limit the amount of road input felt in the passenger compartment.

Road holding is the degree to which a car maintains contact with the road surface in various types of directional changes and in a straight line. Worn shocks and struts can allow excessive vehicle weight transfer from side to side and front to back, which reduces the tire's ability to grip the road. Because of this variation in tire to road contact, the vehicle's handling and braking performance can be reduced. Tire loading changes as a vehicle's center of gravity shifts during acceleration, deceleration, and turning corners. The center of gravity is a point near the center of the car (it is the balance point of the car). The size of the four contact patches of traction at the tires also varies with the changes in tire load. As the vehicle brakes, inertia will cause a shift in the vehicle's center of gravity and weight will transfer from the rear tires to the front tires (fig.1). This is known as dive.

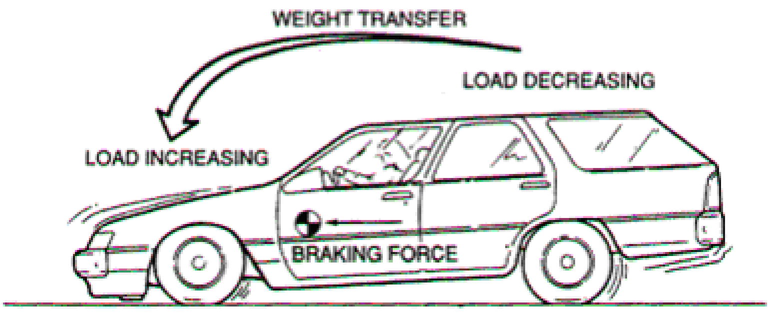

Fig.1 Dive phenomena

Similarly, weight will transfer from the front to the back during acceleration. This is known as squat.

Consistently controlling vehicle weight transfer and suspension movement enhances the road holding capability of the vehicle and ultimately its safe operation.

The ability of a vehicle to travel a curved path is called cornering (fig.2).

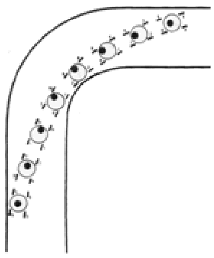

Fig. 2 Cornering phenomena

It is also referred to as cornering power or lateral acceleration. The goal is minimize body roll, which occurs as centrifugal force pushes outward on a car's center of gravity while cornering, raising one side of the vehicle and lowering the opposite side. The solution is transfer the weight of the car during cornering from the high side of the vehicle to the low side. A car's suspension (tyre stiffness, shock absorber characteristics, spring stiffness and unsprung mass) have an influence on vehicle comfort and active safety.

Many things can affect the cornering ability of a vehicle, such as: tire construction, tire tread, road surface, alignment, tire loading, etc.

3. ACTIVE SUSPENSION SYSTEMS

In case of conventional systems, springs and dampers have a constant characteristic curves. Adaptive systems can set elements to realize an adaptation of the chassis performance to different circumstances. In contrast to this system, a semi-active suspension system involves the use of a dampers or spring with variable gain. Such systems can only operate on three fixed positions: soft, medium and hard damping or stiffness. Additionally, a semi-active system can only absorb the energy from the motion of the car body.

Alternatively, an active suspension system possesses the ability to reduce acceleration of sprung mass continuously as well as to minimize suspension deflection, which results in improvement of tyre grip with the road surface, thus, brake, traction control and vehicle maneuverability can be considerably improved. An example of an active suspension for vehicle attitude control is given in Figure 3.

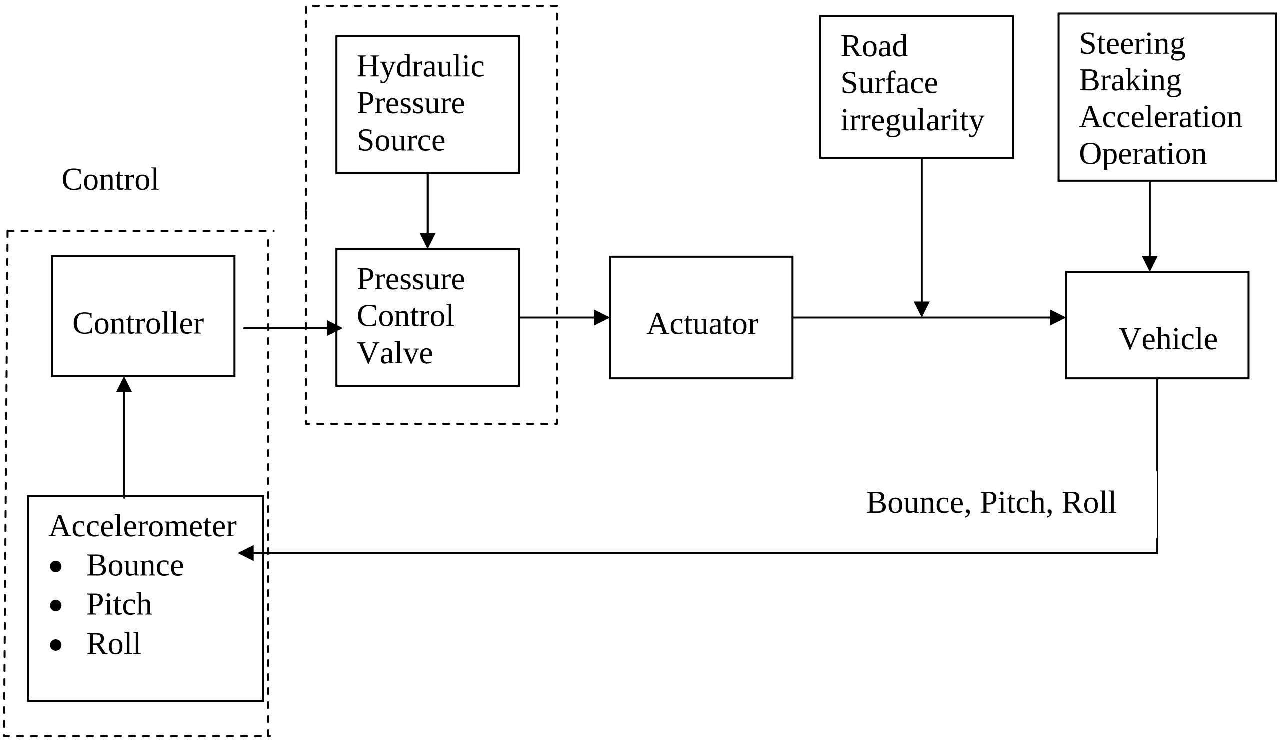

Figure 3. Hydraulic and control systems for an active suspension.

The actuator is based on the principle that accelerating a suspended mass results in a reaction force on the supporting structure (Fig.4). Considering a mass m_p connected to a rigid supporting structure by means of a spring K_p and a damper C_p; it is subjected to a force F_a provided by an electromagnetic actuator, the transfer function between the applied force and the mass displacement is:

$$\frac{X}{F_a} = \frac{1}{m_p s^2 + c_p s + k_p} = \frac{1}{m_s (s^2 + 2\xi_p \omega_p s + \omega_p^2)} \qquad (1)$$

On the other hand, accelerating the mass produces a reaction force on the supporting structure equal to:

$$F = -m_p \ddot{x} \tag{2}$$

Therefore, the transfer function between the applied force F_a and the resulting force F is:

$$\frac{F}{F_a} = \frac{-s^2}{s^2 + 2\xi_p \omega_p s + \omega_p^2} \tag{3}$$

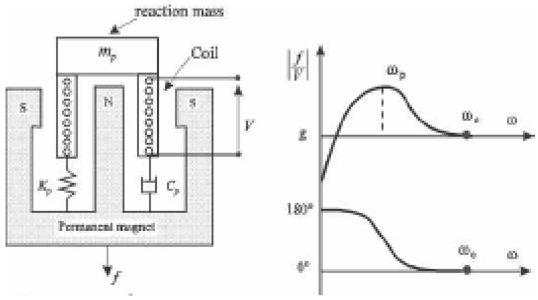

Figure 4 - Proof mass actuator dynamics

$$\frac{f}{V} = g \frac{s^2}{s^2 + 2\xi_p \omega_p s + \omega_p^2} \tag{4}$$

Figure 4 shows the theoretical transfer function between the force applied to the moving mass and the reaction force at the actuator interface. One can see that the actuator behaves as a perfect force generator for frequencies above its suspension frequency, the only design parameters being the desired bandwidth and required control force.

The active damping device is based on an inertial actuator (as described above), a collocated vibration sensor (for robustness) and a simple controller implementing a direct velocity feedback as shown in Figure 5.

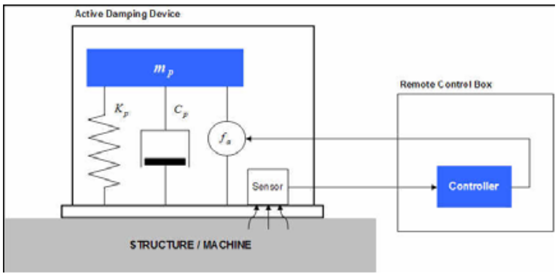

Figure 5 Active damping devices

4. CONCLUSIONS

An active suspension system possesses the ability to reduce acceleration of sprung mass continuously as well as to minimize suspension deflection, which results in improvement of tyre grip with the road surface, thus, brake, traction control and vehicle maneuverability can be considerably improved.

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