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Study on Dynamic Behaviour of Wishbone Suspension System

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Study on Dynamic Behaviour of Wishbone Suspension System

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Abstract. This paper presents the characteristic model of the wishbone suspension system using the quarter car model approach. Suspension system in an automobile provides vehicle control and passenger comfort by providing isolation from road disturbances. This makes it essential that the detailed behavior of suspension should be known to optimize the performance. A kinetic study is performed using multi body system (MBS) analysis. The dirt road profile is considered as an applied loading. The spring constant, damping coefficient and sprung mass are studied on the performance of the suspension system. It can be observed that the spring constant is inversely related with time required to return to initial position and the amount of deformations. The damping ratio affects the suppression of spring oscillations, beyond a certain limit damping ration has the negligible effect. Sprung mass effected the equilibrium position of the suspension system with a small effect on its oscillation behavior. It is shown that the spring constant, damping ratio and sprung mass are significant parameters to design the suspension system. This study is essential for complete understanding of working of the suspension system and a future study with real geometries.

1. Introduction

Suspension system in its simplest form may be thought of as a linkage to allow the wheel to move relative to the body and some elastic element to support loads while allowing that motion. It is an assembly of springs, shock absorbers (dampers) and suspension arms that connects a vehicle to its wheels. In a running vehicle, the suspension system keeps the occupants comfortable and isolated from road noise, bumps, and vibrations. It also provides the vehicle, handling capabilities, allowing the driver to maintain control of the vehicle over rough terrain or in case of sudden stops. Additionally, the suspension system prevents the vehicle from damage and wearing [1-2].

Basically suspension system consists of spring, damper and structural components carrying the sprung mass (car chassis). The springs absorb impacts and provide cushioning when a wheel hits a bump in the road. The springs also resist the wheel’s movement and rebounds, pushing the wheel back down, so to keep the control of vehicle by keeping the wheels in contact with the road. Shock absorbers (dampers) perform two functions. They absorb any larger than average bumps in the road so that the upward velocity of the wheel over the bump is not transmitted to the car chassis. Secondly,

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they keep the suspension at full as much as possible during the travelling for the given road conditions, in brief, they keep the wheels planted on the road [3-4]. Due to the criticality of suspension system performance related to ride comfort and vehicle control and passenger safety, the understanding of design variables and behavior of suspension system in severe or harsh loading cases should be well known and optimized. This paper analyze a characteristic model of wishbone type suspension system, with study the effects of spring constant, damping coefficient and supported sprung mass, which is not part of suspension system but can affect the response of suspension. As passenger comfort is one of the prime criteria for performance evaluation of suspension, the same is used to monitor the system under study by plotting the deflection of sprung mass when a dirt road profile is applied as loading.

2. Description of Basic Suspension System

Different types of suspension systems are being used in modern vehicles. Generally, the suspension systems can be divided into two groups: dependent suspension system and independent suspension system. The dependent suspension system has one or more solid axles that hold opposite wheels together, therefore the wheels cannot move independently. The independent suspension system does not have such a wheel axle so that the wheels are allowed to rise and fall without affecting the opposite wheel [5-6]. A suspension hierarchy is defined in figure 1 and schematic diagram of wishbone system is shown in figure 2.

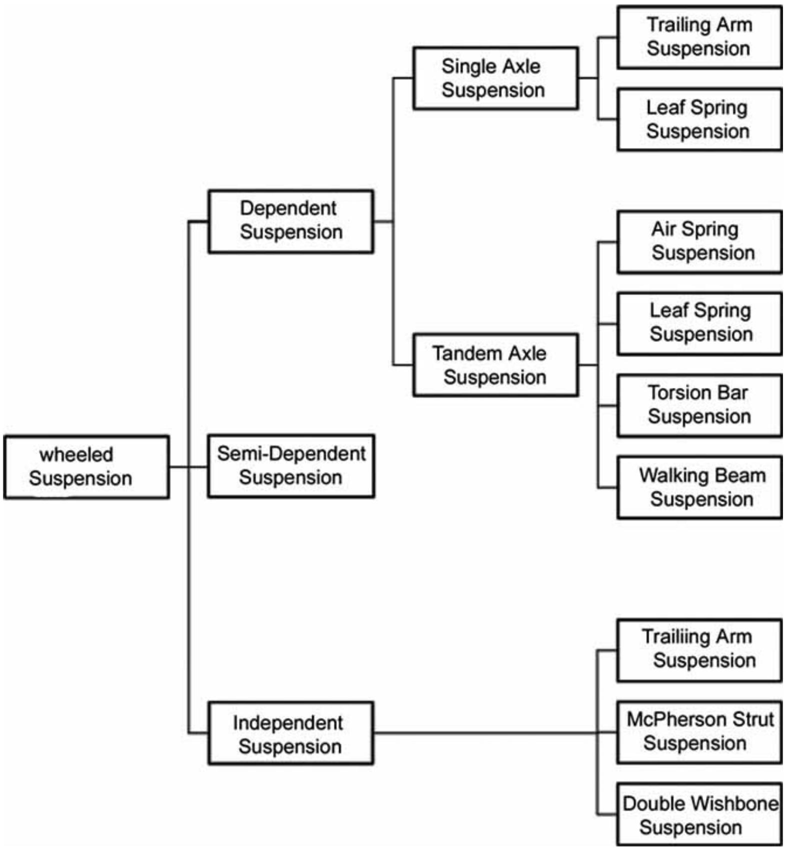


Figure 1. Hierarchy of popular suspension types.

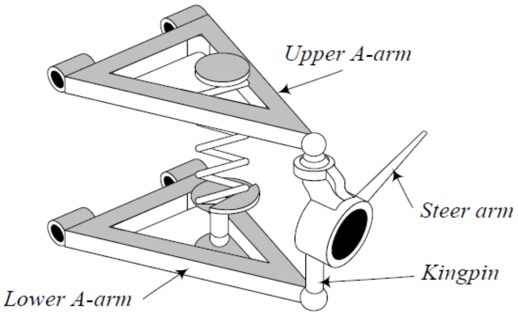


Figure 2. Wishbone suspension system.

3. Computational Model

A characteristic model of wishbone suspension system is developed in MSC ADAMS for the current study as shown in figure 3. The dimensions of components are taken from literature [7]. Material of connecting arms, and knuckle is aluminum (Density: 2700 Kg/m^3) (ASM Data sheet). Applied loading is in the form of dirt road profile, figure 4, induced in model through excitation platform [8]. The components are considered as rigid bodies. The model is constrained using revolute (one rotation D.O.F. allowed) and ball joints (three rotation D.O.F. allowed) (shown in figure 3), to properly simulate the suspension components motion. Due to simplified geometry the center of gravity of suspension arms and other components are not as in the real wishbone suspension. Tire is considered to be rigid, with weight assumed to be of a standard car tire (rubber + rim) taken as 11kg. Dirt road profile is converted to time history graph with respect to assumed speed of vehicle (30 km/hr). The values of spring constant and damping coefficient and sprung mass are assumed, table. 1. Spring is assumed to be pre-loaded, such that it is in equilibrium at initial condition.

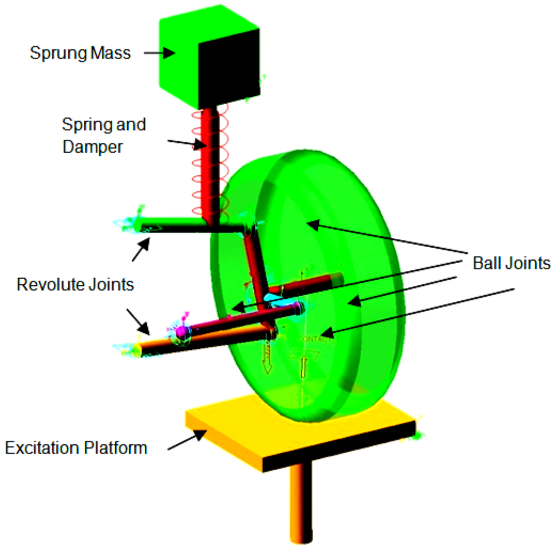


Figure 3. Characteristic model of wishbone suspension system.

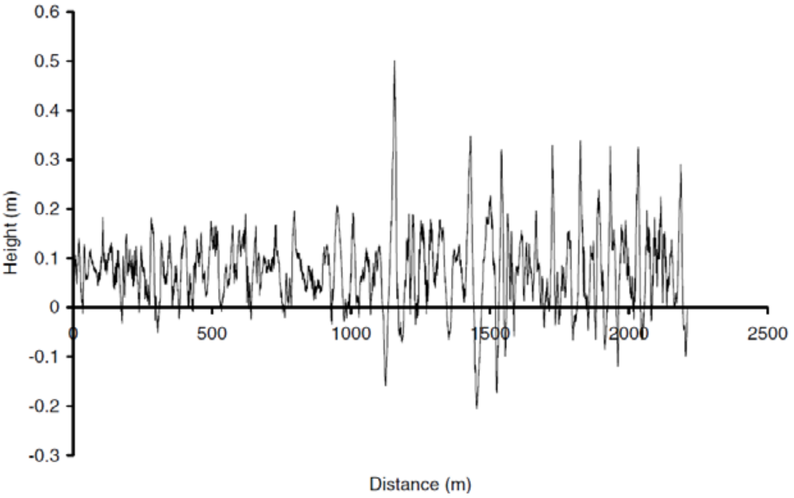


Figure 4. Dirt Road Profile [6].

Table 1. Assumed values of stiffness, damping and sprung mass.

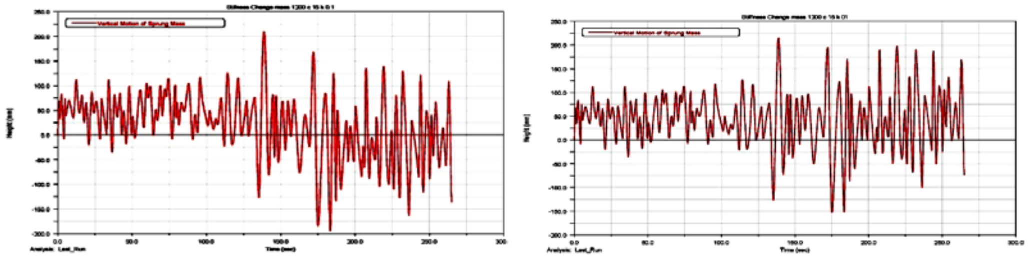
Spring stiffness, *k* (N/mm)	**Damping coefficient, *c* (N.s/mm)**	**Sprung mass (Kg)**
0.1	0	600
1	2	1200
10	6	1800
100	10	2400
150	15	3500

4. Results and Discussion

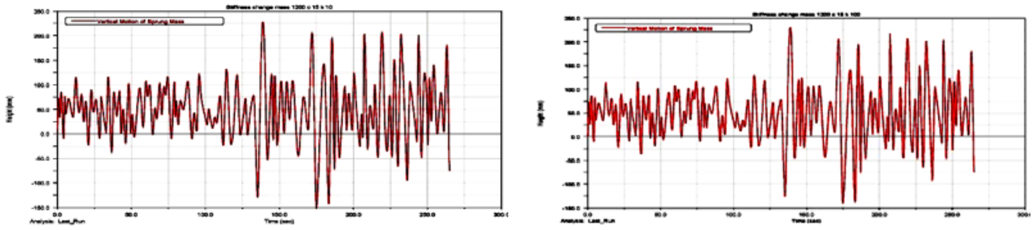
The effect of spring stiffness, damping coefficient and sprung mass is studied separately with values mentioned in table 1. Following is the time history response of sprung mass to the dirt road profile input, for each value of variables under study.

4.1. Spring Stiffness Effects

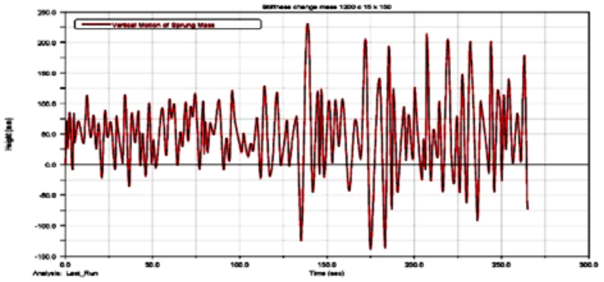
Effects of stiffness change on the time history of motion of sprung mass is shown in figure 5. Figure 6 shows the spring deformation time history with changed stiffness. From the sprung mass response time history it can be concluded that, with respect to the input profile the motion induced in the sprung mass has no noticeable change with changing stiffness of spring. This means that for every stiffness value the sprung mass response is similar without any noticeable difference. But the spring deformation in figure 6 with two different stiffness show that the difference is in the force present in spring. That is what makes the stiffness calibration important for the optimum behavior of suspension system. As this is the force responsible to keep the tires to remain in contact with the road and minimize the return time of suspension system to its normal position.



(a) k = 0.1 N/mm (b) k = 1.0 N/mm

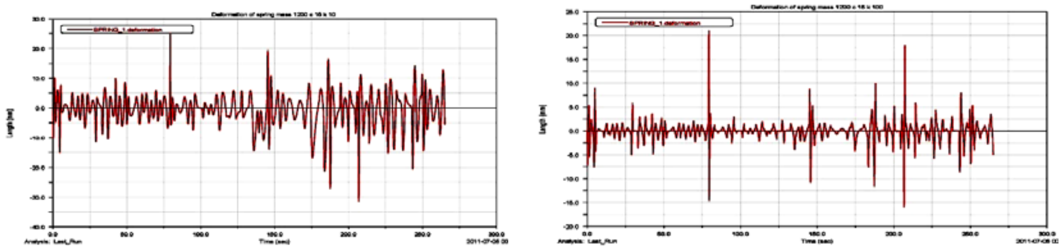


(c) k = 10 N/mm (d) k = 100 N/mm



(e) k = 150 N/mm

Figure 5. Time history response of sprung mass with various spring constants.

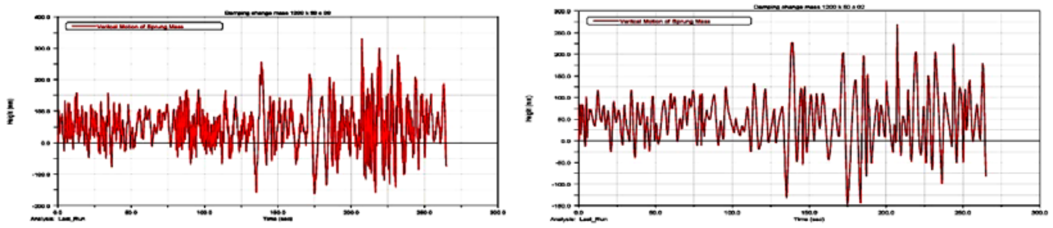


(a) k = 10 N/mm (b) k = 100 N/mm

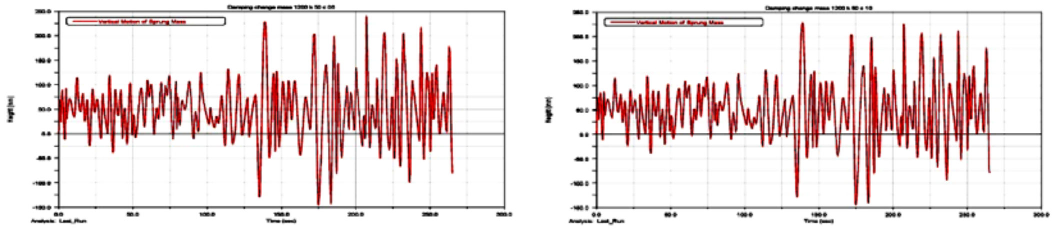
Figure 6. Deformation change with change in spring stiffness.

4.2. Damping Coefficient Effects

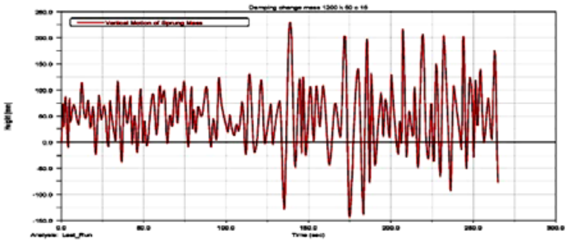
The effect of damping coefficient is illustrated in figure 7. After comparing these sprung mass response time histories, it can be concluded that damping control the oscillations in spring. The response figure 7(a) is without damping and spring oscillations are clearly visible. For vehicle control these oscillations should be damped as soon as possible so suspension is ready to counter next road bump in minimum possible time and improve the handling of vehicle. Figure 7(b-e) shows the effect of damping as it is introduced in the system, the spring oscillations are damped and the resulting response shape is very close to the induced profile.



(a) c = 00 N.sec/mm (b) c = 02 N.sec/mm



(c) c = 06 N.sec/mm (d) c = 10 N.sec/mm

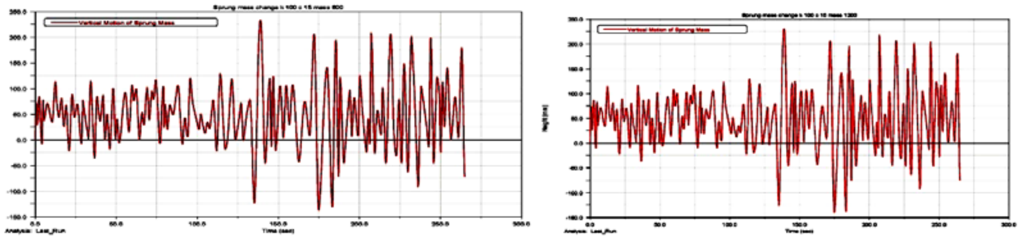


(e) c = 15 N.sec/mm

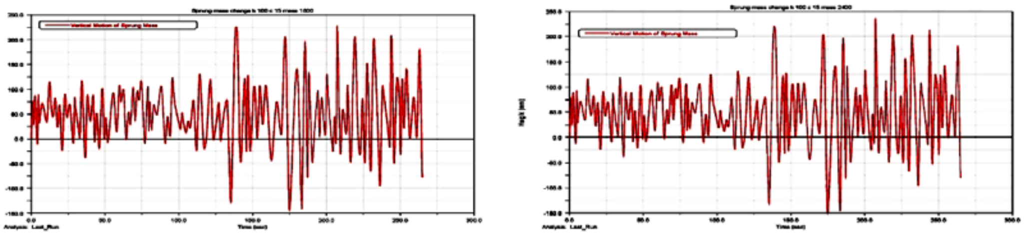
Figure 7. Time history response of sprung mass with various damping ratios.

4.3. Sprung Mass Effects

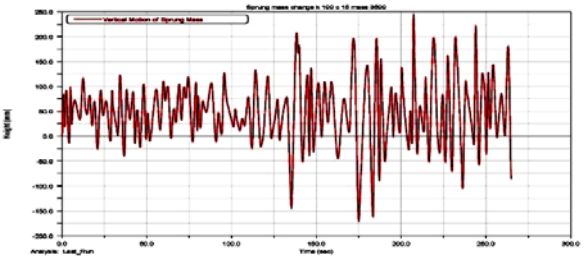
The effect of sprung mass change is reflected in figure 8. It can be clearly deduced that increase in mass only change the equilibrium position of the sprung mass. This makes the quantity of sprung mass important, such that when it is at equilibrium position it should leave enough deformation space for spring to counter the road disturbances and not reach its solid length.



(a) mass = 600 kg (b) mass = 1200 kg



(c) mass = 1800 kg (d) mass = 2400 kg



(e) mass = 3500 kg

Figure 8. Time history response of sprung mass with various mass values.

5. Conclusions

The present study provides the initial understanding of the effects of some important parameters of suspension system performance. The spring and damper characteristics are the most vital for the optimum behavior of suspension and should be thoroughly studied. The sprung mass effects must be known so the correct combination of spring damper combination can be selected and calibrated according to the design requirements. A study with real geometry of suspension system components is suggested to fully capture the response behavior. Tire should be modeled as flexible to capture the real forces transmitted to the suspension system.

Acknowledgments

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