REVIEW ON OPTIMIZATION OF TRUCK SUSPENSION SYSTEM

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Abstract

The paper presents the optimization of truck suspension system. It is focused on improving the ride quality, reducing rollover and also to avoid fish tailing. This is achieved by varying the design and optimizing the major parameters that affect suspension. One of them is reducing lateral load transfer which is dependent on roll gradient, wheel loads, suspension stiffness,ride rate and roll rate. The pitching motion of the truck was found to improve the ride quality. The relationship between these factors and what changes would occur by varying one with respect to the other. Implementation of an improvised air suspension system and its contribution towards improvising ride is also dealt.Thus,the optimization of the conventional truck suspension system can reduce the rate of the roll over and fish tailing accidents occurring very frequently.

Keywords:Roll stability, 4-point air cab suspension, Damping force, Spring stiffness, Lateral Acceleration.

Introduction:

The rollover tendency of trucks is a potential safety issue that leads to variety of accidents. The rollover tendency of trucks increase with the increase of roundabouts on spped ways where vehicles cruise at higher speeds.(**Andrew Tarko and Thomas Hall, 2016**). Driver retention poses a significant challenge to the trucking industry. As far as vehicle lateral dynamics is concerned, Road bank angle and vehicle roll angles play a major role. Thus these values were obtained by a simple lateral vehicle model. Vehicles dynamic behaviour under moderate driving situations were obtained **(L.Menhour and D. Koenig, 2012)**. In general suspension systems can be classified into passive, semi active and active suspensiosn out of which active suspensions are found to have better characteristics (**Chen yi Kai, 2013) .**Calls for improved driver comfort and more advanced cab suspensions have led to revolutionary new ideas in the development of secondary suspension systems. This paper presents a new design concept for a "4-point -Air Cab Suspension" on a conventional truck. Simulation results are provided to quantify the advantages of this new concept relative to current systems. (**Alexander Gross, 2001**).

Research of active roll control system to reduce vehicle rollover propensity is mainly focused on two areas. One is rollover warning system and the other is anti-rollover system. The warning systems use a prediction algorithm to determine the risk of impending rollover using vehicle roll angle and lateral acceleration as inputs. They give a warning when the signals exceed the pre-selected threshold values so that the driver can take corrective action to avert a rollover. (**T. Shim , 2006**)

Roll gradient Determination:

The first step in choosing spring stiffness is to choose your desired ride frequencies, front and rear. A ride frequency is the undamped natural frequency of the body in a ride. The higher the frequency, the stiffer the ride. So, this parameter can be viewed as normalized ride stiffness.Based on the application, there are ballpark numbers to consider. Lower frequencies produce a softer suspension with more mechanical grip, however, the response will be slower in transient (what drivers report as "lack of support").

Higher frequencies create less suspension travel for a given track, allowing lower ride heights, which in turn, lowers the center of gravity.

Ride frequencies in front and rear of the vehicles are not the same, there are several theories to provide a baseline. The examples shown below exaggerates the plots of what happens with unequal ride frequencies in the front and rear of the car as it hits a bump. we can see the *undamped* vertical motion of the chassis with the front ride frequency higher than the rear as shown in Figure 1. The first period is the most dominant on the car when looking at frequency phase.

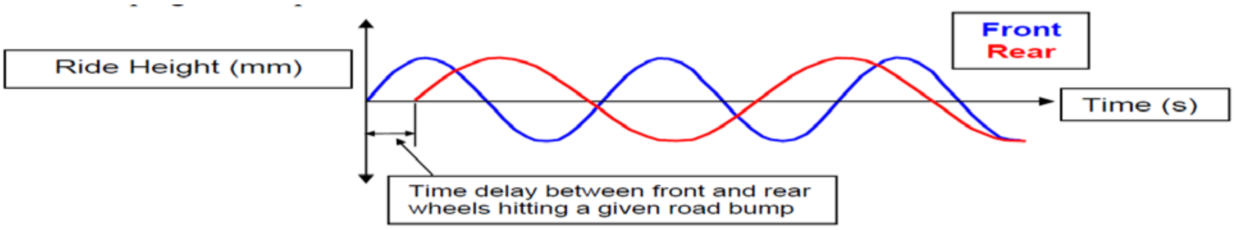

Fig 1: Roll gradient chart

This theory was initiallydeveloped for passenger cars, where comfort took priority over performance, which leads to low damping ratios, and minimum pitching over bumps. Racecars in common have higher damping ratios, and have a much smaller concern for comfort, which madesome racecars to use higher front ride frequencies. The higher damping ratios will minimize the amount of oscillation resultant from road bumps, which in return reduces the need for a flat ride. Havinga higher front ridefrequency in a racecar allows quick transient response at corner entry, minimum ride height variation on the front (the aerodynamics are usually more pitch sensitive on the front of the car) allows for better rear wheel traction (for rear wheel drive cars) on corner exit. Based on the track surface, the speed, pitch sensitivity, etc. the ride frequency split of the car must be chosen.

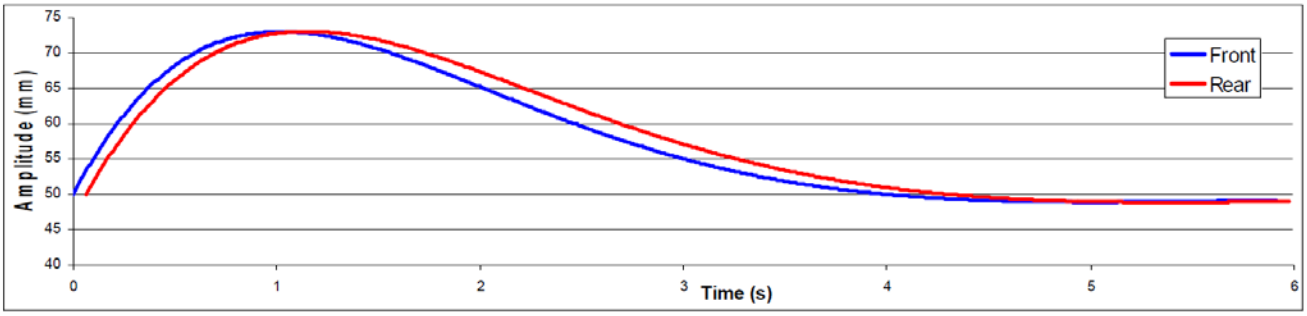

Fig 2: Motion ratio of the suspension

Once the ride frequencies are chosen, the spring rate can be determined from the motion ratio of the suspension, sprung mass supported by each wheel, and the desired ride frequency.

Using the basic equation from physics, relating natural frequency, spring rate, and mass:

$$f = 1/2\pi\sqrt{k/m}$$

f = Natural frequency (Hz)
K = Spring rate (N/m)
M = Mass (kg)

Solving for spring rate, and applying to suspension to calculate spring rate from a chosen ride frequency, measured motion ratio, and mass:

$$K_s = 4\,\pi^2 m_{sm}\,MR^2$$

Ks = Spring rate (N/m)
msm = Sprung mass (kg)
fr = Ride frequency (Hz)
MR = Motion ratio (Wheel/Spring travel)

Transmissibility of Damping ratios:

The transmissibility (TR) is the ratio between output and input amplitude. In the above case, the input amplitude is the height of the speed bump, with output amplitude being vertical movement of the body

output amplitude = TR x input amplitude

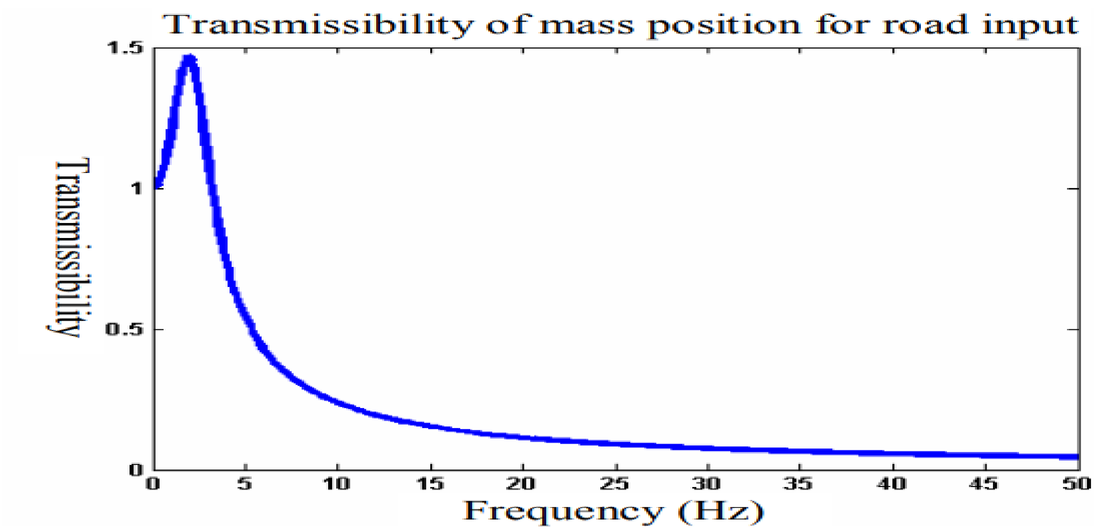

Fig 3: Transmissibility of Damping ratios

In order to get the maximum grip, you want the lowest transmissibility possible as the body is bouncing around, the forces on the springs are changing, decreasing the grip. In Figure 8, there is a crossover point, this is at 2 * Resonant Frequency. At low frequencies, if we increase thedampingwe reduce the maximum transmissibility, which is good, making a higher damping ratio at low frequencies. On the other side of the crossover point, low damping ratios give a lower transmissibility, meaning low damping ratios are desirable at high frequency. Since low frequencies generally correspond to low damper velocity, and high frequencies generally correspond to high damper velocity, you can see now that you want a higher damping ratio at low damper velocity than high damper velocity. Figure 4 shows how to take the above theoretical explanation and apply it to come up with a baseline damper curve.

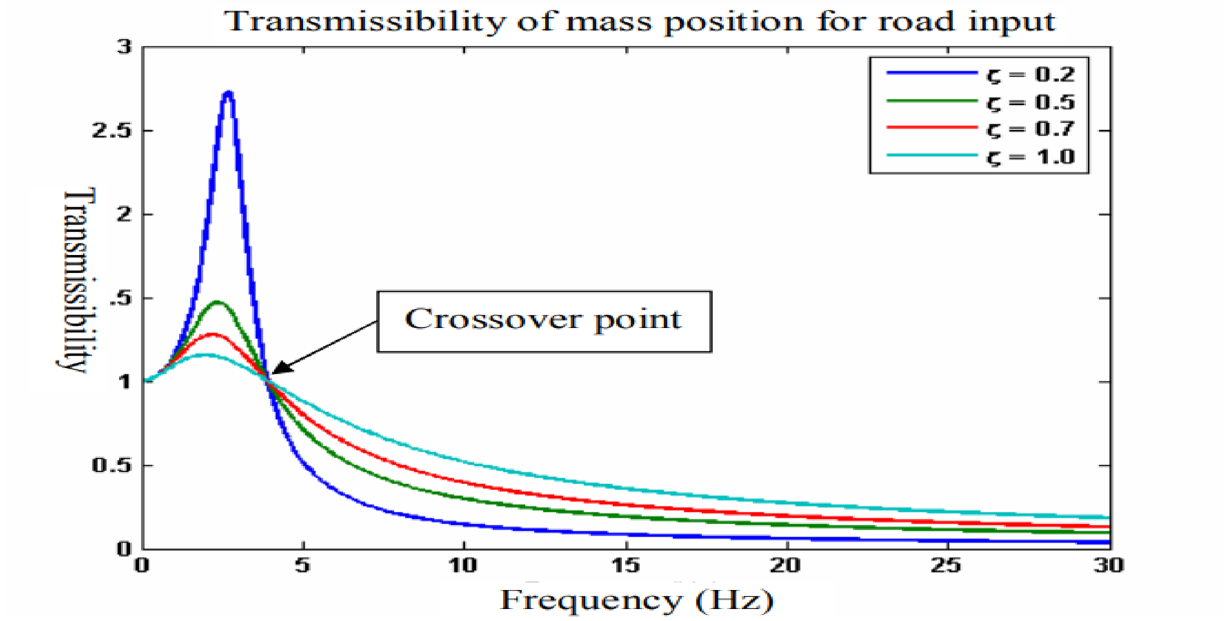

Fig 4: Transmissibility of mass position for road input

This can give a clearer picture of optimizing ride as well as reducing roll over. This is achieved by optimizing the roll gradient.

4-point air cab suspension:
The primary suspension controls the dynamic relationship between the chassis and axles in the tractor and trailer. It mainly consists of spring elements, damping elements, and guiding hardware. In addition to the primary suspension is a secondary suspension which is designed to bring the vibrations in the cab to a comfortable frequency level. The secondary suspension (hereafter, cab suspension) also consists of spring elements, damping elements, and guiding hardware. Depending on the type of spring element that is utilized, a level control system may also be present.

Conventional design:
The rear suspension on a typical linehaul conventional truck has a coil-spring or air-bellow as the spring component and a separate damper as the dampingelement. The guiding element is typically a panhard rod or two lateral dampers. The vertical frequency level is between 1.4 and 1.8 Hz for air-springs and 1.8 to 3Hz forcoil-springs. The stroke of the suspension elements is normally between 40 and 60mm. The front suspension on a typical linehaul conventionaltruck utilizes rubber block assemblies to carry outthe necessary suspension,damping, and guiding functions. These types of front suspension has a high and progressive spring rate with a typical stroke around 5 mm and maximum near 20 mm. Wherethe upper end of the vertical frequency range can easily reach 15Hz.

Proposed design concept:

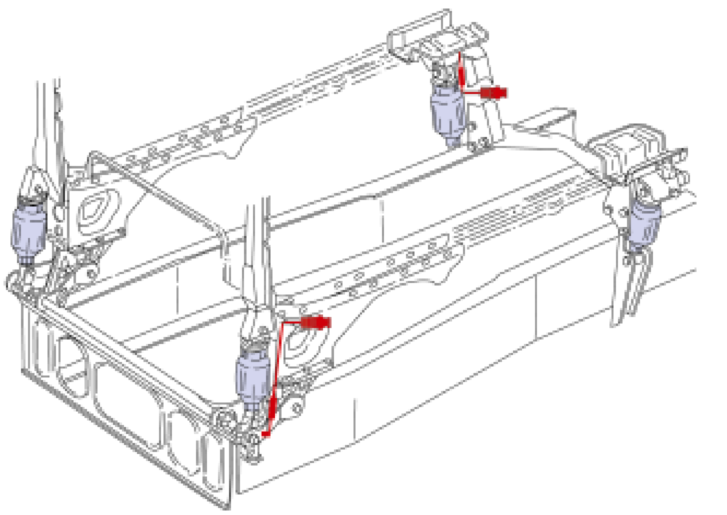

Fig5: Design model

The basic design consists of:

- 4 air-spring strut modules (co-axial)
- anti-roll bar (positioned at the rear)
- integrated leveling system (1 front, 1 rear)
- mounts, brackets, links, and bushings

Air spring strut module:
The stroke of the module is almost similar to European concepts with approximately 80mm. Theprogressive spring rates ensures a lowfrequency spectrum on smooth roads, but also enabling the high spring force on bad roads to properly limit the movement. To suit the varying road demands a stroke dependent damper is used. Based on the stoke of the damper the system allows different damping characteristics. Thisrequires a bypass in the hydraulic system which is achieved by means of control.

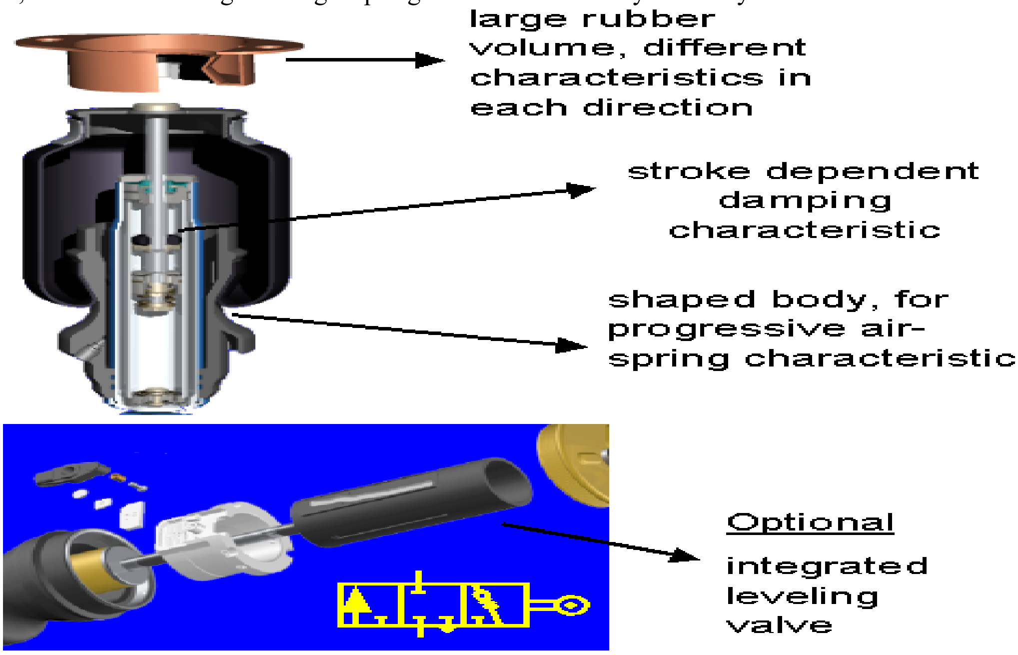

Fig 6: Air spring strut module

Ride comfort benefit:
To check the cab dynamics with the new cab suspension concept it is necessary to look at the interaction between the primary and secondary suspension.Simulation results are provided to quantify the advantages of the new concept relative to current systems. The 3- dimensional simulation model of the conventional truck and semi-trailer has 32 DOF. Refer back to Figure 1. The output of the model was animated to better visualize the movement of the cabin relative to the vehicle over the varying driving and road conditions that were analyzed.

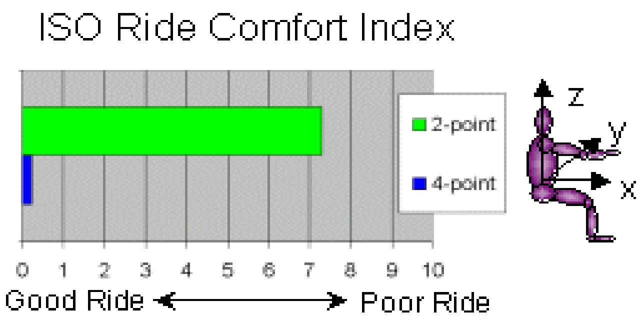

Fig 7: ISO Ride Comfort Index

Results and discussion:
1) The initial roll gradient calculation along with frequency helps in understanding and reducing rollover of the trucks. This inturn reduces the rate of a fatal accident associated with trucks.
2) The transmissibility ratio interpretation would help us in designing the appropriate damper that would soften the ride,
3) Applying the above concepts, a 4-point air cab suspension is designed to improve ride comfort. A notable change is found in the ride comfort index when compared to 2-point suspension.

Conclusion:
The proposed 4-point-air cab suspension system offers significant potential for ride improvement of conventional heavy trucks. Secondary benefits include potentially improved crash safety performance and reduced dynamic forces at the cab mounting points. The mathematical equations and graphs support to improve the efficiency of the design.

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