International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020

Variable Spring Rate Adaptive Suspension System

Gayathri naidu,

India

Abstract: take the place of the traditional passive system in passenger cars. The suspension is a part of a vehicle that acts as a buffer between the rider and the road. In order to improve ride comfort, road holding, and stability, the suspension system is designed to protect the chassis and passengers from the excitation caused by road imperfections. Additionally, it is observed that an ideal suspension setup would consist of a soft setting for a comfortable ride, a stiff setting for a suspension that is insensitive to changes in applied loads, and a middle ground setting for optimal handling. Attempts to strike a compromise between ride comfort and road handling with current conventional passive suspension systems have failed. Findings indicate that a pleasant ride quality may be achieved with damping levels as low as 20% critical damping, while keeping suspension displacement and dynamic tire force to a minimum. Traditional passive suspension systems fail to achieve these goals due to their restricted range of adjustment for spring stiffness and damping coefficient. We suggest a variable-hydraulic suspension system by figuring out where we may make improvements to the standard suspension concept. Adapting the spring's stiffness to the driver's input is the primary focus of my article. Adjusting the suspension's travel adjusts the spring's stiffness. Within the driver's cockpit, there are three settings that the driver may choose from. There are three different settings to choose from: racing, regular, and luxury. When in racing mode, the spring's movement is limited to improve the vehicle's handling. The spring's journey is expanded in luxury mode to enhance the passenger's comfort. To strike a good balance between handling and comfort, the regular mode has modest travel. Therefore, our technology gives the driver the ability to adjust the system's properties according to their needs. As a result, this system may affordably

Keywords: Semi-active, adaptive suspension, dampers, spring rates that can be adjusted

1. Introduction

- The suspension system's principal role is to provide a comfortable and secure ride. A majority of suspensions include passive force components to optimize the trade-off between ride quality, suspension travel, and wheel load variance. A well-designed suspension is meant to shield the human body from the painful effects of road bumps. Careful selection of spring and damper qualities allows the suspension to filter out frequencies that are uncomfortable for the human body. The flip side is that these characteristics should make the trip risk-free. That being said, a little wheel-load variation will prevent the wheels from spinning off the road. All of this should be possible with the suspension travel that is available. Because there are only four areas where the tire makes contact with the road, getting the most out of them is essential. As a result, in a standard car, a number of linkages link the vehicle's sprung mass—the body—to its unsprung mass—the wheels, brakes, and steering hub. The design of these links finds a happy medium between reducing suspension travel and optimizing wheel alignment relative to the road in the case of suspension travel caused by road bumps or cornering. Another trade-off is seen while the car is negotiating a turn. Assuming the spring is sufficiently stiff, the suspension design should be able to compensate for excessive body roll. The anti-roll bar is a typical device for preventing excessive rolling. Then, you may soften it by lowering the spring's stiffness. The problem with anti-roll bars is that they can only be so stiff before transmitting road vibrations to the other wheels, which is obviously not good. The suspension is responsible for more than just controlling the vehicle's height; it also has to hold the sprung mass in place. Still another is dampening the impact of road vibrations on the human body.

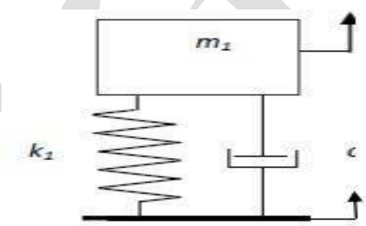
- in order to enhance handling stability throughout a range of driving situations. In terms of suspension systems, there are two main categories:

- Passive suspension system
- Active suspension system

Passive suspension system:

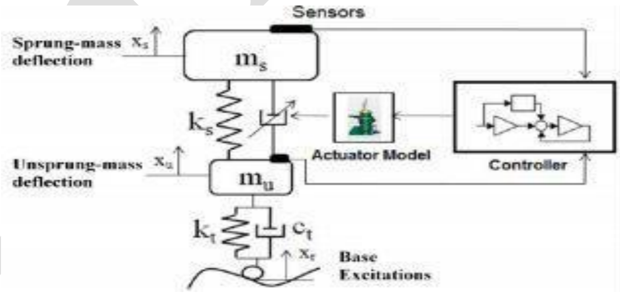
The commercial vehicles today use passive suspension systemto control the dynamics of a vehicle,,s vertical motion as well as pitch and roll. Passive indicates that the suspension elements cannot supply energy to the suspension system. The passive suspension system controls the motion of the body and wheel by limiting their relative velocities to a rate that gives the desired ride characteristics. This is achieved byusing some type of damping element placed between the bodyand the wheels of the vehicle, such as hydraulic shock absorber. Properties of the conventional shock absorber establish the tradeoff between minimizing the body vertical acceleration and maintaining good tire-road contact force.These parameters are coupled. That is, for a comfortable ride,it is desirable to limit the body acceleration by using a soft absorber, but this allows more variation in the tire-road contact force that in turn reduces the handling performance. Also, the suspension travel, commonly called the suspension displacement, limits allowable deflection, which in turn limitsthe amount of relative velocity of the absorber that can be permitted. By comparison, it is desirable to reduce the relative velocity to 6 improve handling by designing a stiffer or higher rate shock absorber. This stiffness decreases the ride quality performance at the same time increases the body acceleration, detract what is considered being good ride characteristics. An early design for automobile suspension systems focused on unconstrained optimizations for passive suspension system which indicate the desirability of low

suspension stiffness, reduced unsprung mass, and an optimumdamping ratio for the best controllability [57]. Thus the passive suspension systems, which approach optimal characteristics, had offered an attractive choice for a vehicle suspension system and had been widely used for car. However, the suspension spring and damper do not provide energy to the suspension system and control only the motion of the car body and wheel by limiting the suspension velocityaccording to the rate determined by the designer. Hence, the performance of a passive suspension system is variable subject to the road profiles.



Active suspension system:

In early active suspension system, the regulating of the damping force can be achieved by utilizing the controlled dampers under closed loop control, and such is only capable of dissipating energy (Williams, 1994). Two types of dampersare used in the active suspension namely the two state dampers and the continuous variable dampers. A 2 DOF Active Suspension System Model The two state dampers switched rapidly between states under closed-loop control. In order to damp the body motion, it is necessary to apply a force that is proportional to the body velocity. Therefore, when the body velocity is in the same direction as the dampervelocity, the damper is switched to the high state. When the body velocity is in the opposite direction to the damper velocity, it is switched to the low state as the damper is transmitting the input force rather than dissipating energy. The disadvantage of this system is that while it controls the body frequencies effectively, 8 the rapid switching, particularly when there are high velocities across the dampers, generates high-frequency harmonics which makes the suspension feel harsh, and leads to the generation of unacceptable noise. The continuous variable dampers have a characteristic that can be rapidly varied over a wide range. When the body velocity and damper velocity are in the same direction, the damper force is controlled to emulate the skyhook damper. When they are in the opposite directions,the damper is switched to its lower rate, this being the closest it can get to the ideal skyhook force. The disadvantage of the continuous variable damper is that it is difficult to find devices that are capable in generating a high force at low velocities and a low force at high velocities, and be able to move rapidly between the two. The control strategy utilized afictitious damper that is inserted between the sprung mass andthe stationary sky as a way to suppress the vibration motion of the spring mass and as a tool to compute the desiredskyhook force. The skyhook damper can reduce the resonant peak of the sprung mass quite significantly and thus achieves a good ride quality. But, in order to improve both the ride quality and handling performance of a vehicle, both resonant peaks of the sprung mass and the unsprung mass need to beeduced. More recently, the possible applications of electrorheological (ER) and magnetorheological (MR) fluids in the controllable dampers were investigated by Yao et al. However, since MR damper cannot be treated as a viscous damper under high electric current, a suitable mathematical model is needed to describe the MR damper.



2. Principle

As the tire strikes a bump in the road, so a vertical force is applied to the spring‟ which is compressed or deflected. Therefore the wheel moves vertically relative to the body, andthe tire maintains contact with the road surface. However, some of this force is transmitted through the spring to the body, which also tends to rise. If the springs are very „soft‟ (i.e. have relatively low spring rates) the body rises little, but if the springs are very stiff the body rises quite a bit, depending on the severity of the bump. For a good ride, therefore, the springs should be soft. Although soft springs give a good ride in most circumstances, they allow the bodyto roll a lot during cornering. In practice, spring rates are a compromise between the requirements of ride and handling.

This system is based on the principle that “liquid are incompressible”. There is a small modification done to the inner tube of the dampers. The inner tube is divided into two chambers. The lower chamber is filled with a fluid. Since the diameter of the inner tube is constant, The height of thechamber can be varied by changing the volume of the lower chamber, As more liquid accumulate the length of the liquid chamber increases and hence the effective stroke length can be increased. If there is more liquid, excess liquid will flow back to the reservoir and hence the height of the chamber is decreased. Thus by altering the effective stroke length, the stiffness of the spring can be altered.

International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020

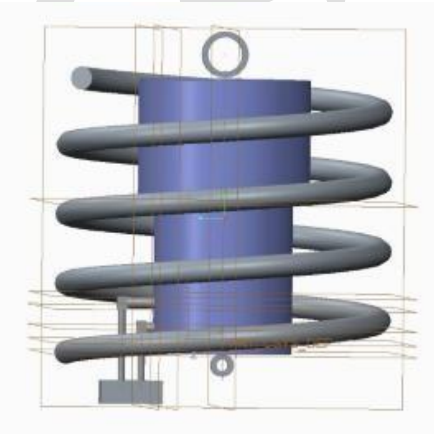
3. Components Required

- Liquid reservoir- A reservoir is a storage space for liquids.
- Pump- It is a device that moves fluids by mechanicalaction.
- Uni-directional valve- A uni-directional flow control valveallows the control of liquid flow in one direction only.
- Level sensor- level sensor is used to monitor the level of aparticular free flowing substance within a contained space.

4. System Setup

The space under the piston of the damper is divided into two chambers. The upper chamber contains the usual working fluid as in normal dampers. The piston slides in the upperchamber. The upper chamber is connected to the bottom ofthe inner tube through a rubber tube. The lower chamber is a separate chamber that contains a separate liquid. There is a liquid reservoir which is connected to lower chamber. The liquid is almost present to 3/4th of the reservoir. The centrifugal pump is different in working than a positive displacement pump. All centrifugal pumps include a shaft- driven impeller that rotates inside a casing. Centrifugal pumpsare unique because they can provide high or very high flowrates and because their flowrate varies considerably with changes in the Total Dynamic Head of the particular piping system. This allows the flowrate from centrifugal pumps to be"throttled" considerably with a simple valve placed into the discharge piping, without causing excessive pressure buildup in the piping or requiring a pressure relief valve. It is used supply the liquid to the chamber through a Uni-directional valve. The excess liquid in the chamber flows back to the reservoir through another Uni-directional in the return pipe. . The valve restricts liquid flow by the use of screw adjuster which when driven into the valve begins to block the way reducing the liquid flow rate. This restriction is active in only one direction. The level sensor is placed inside the inner tube.It is used to identify the level of the lower chamber.

Figure 1: System setup of spring and damper



ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020

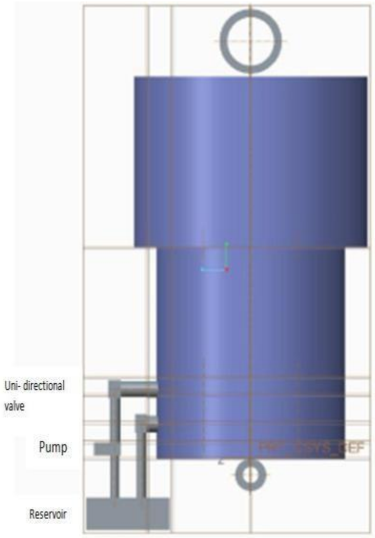


Figure 2: Front view of damper with pump and reservoir

5. Working

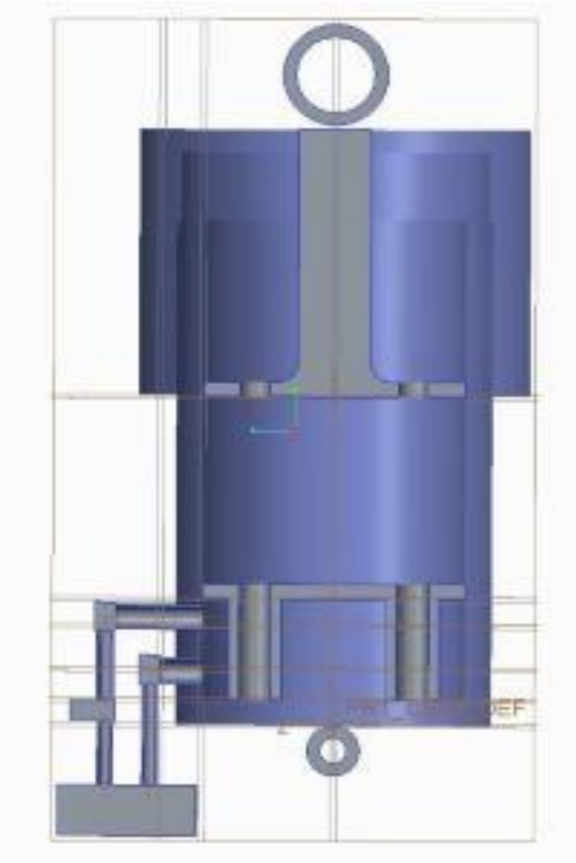
The working of this system is based on the fact that "liquids are incompressible". This system works effectively byvarying the length of the liquid chamber. The driver can able to select three modes.

- Race mode
- Normal mode
- Luxury mode

In race mode, the stiffness of the spring should be more so thetravel of the spring should be less. Hence the volume of the liquid chamber should be more. Since the radius of the damper is constant, we can vary the length of the liquidchamber. A volume sensor is used to determine the required volume. In case of less volume, this sensor sends signal to ECU and it drives a pump which suck the liquid from the reservoir and deliver it to the chamber through the uni- directional valve. Once the optimum volume is reached the valve closes and the pump stops working. Thus the length andvolume of the chamber is increased and the spring travel can be effectively reduced. In luxury mode, the stiffness of the spring should be less so the travel of the spring should be more. Hence the volume of the liquid chamber should be less. Since the radius of the damper is constant, we can vary the length of the liquid chamber. A volume sensor is used to determine the required volume. In case of more volume, this sensor sends signal to ECU and the valve in the return pipe is opened so that the excess liquid flows back to the reservoir. Once the optimum volume is reached the valve closes. Thus the length and volume of the chamber is increased and the spring travel can be effectively reduced. . In normal mode, the stiffness of the spring should be medium so the travel of the spring will be moderate. Hence the volume of the liquid chamber will be medium. Since the radius of the damper is constant, we can vary the length of the liquid chamber. A volume sensor is used to determine the required volume. In case of more volume, this sensor sends signal to ECU and thevalve in the return pipe is opened so that the excess liquid flows back to the reservoir. . In case of less volume, this sensor sends signal to ECU and it drives a pump which suck the liquid from the reservoir and deliver it to the chamber through the uni-directional valve. Once the optimum volume is reached the valve closes. Thus the length and volume of thechamber is increased or decreased and the spring travel can altered accordingly.

ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020



= (400*9.81)/200
= 19.62
N/mmω_n =
√ (s/m)
= √ (19.62/400)
= .22 cyc/sec

Rear:

ω_n (rear) = 1.3* ω_n (front)
= 1.3* .22
= .287 cyc/sec
Stiffness of spring = ω_n^2 * m
= $.287^2$ * 200
= 16.57 N/mm

NORMAL MODE:

Length of fluid chamber = .15 m

Front:

Volume of fluid in the chamber = $\pi*r^2*h-2(\pi*r_1^2*h)$
= $3.14*30^2*150 - 2(3.14*2^2*150)$
= $420132mm^3$

Figure 3: sectional view of damper with pump and reservoir

6. Calculation

Stiffness of spring = load on one wheel/compression of spring
= (400*9.81)/150
= 26.16 N/mmω_n = √ (s/m)
= √ (26.16/400)
= .255 cyc/sec

Rear:

ω_n (rear) = 1.3* ω_n (front)
= 1.3* .255
= .287 cyc/sec
Stiffness of spring = ω_n^2 * m

RACE MODE:

Length of fluid chamber = .2 m

Front:

Volume of fluid in the chamber = $\pi*r^2*h -2(\pi*r^2*h)$

ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020

$=3.14*30^2*200 - 2(3.14*2^2*200)$
$= 560176\ mm^3 = .332^2 * 200$
$= 22.10$ N/mm

Table 1: Stiffness of the spring, N/mm

Stiffness of spring = load on one wheel/compression ofspring
= (400*9.81)/100
= 39.24 N/mm $\omega_n = \sqrt{(s/m)}$
$= \sqrt{(39.24/400)}$
=.313 cyc/sec

Rear:

	Race mode	Normal mode	Luxury mode
Front	39.24	26.16	19.62
Rear	33.15	22.10	16.57

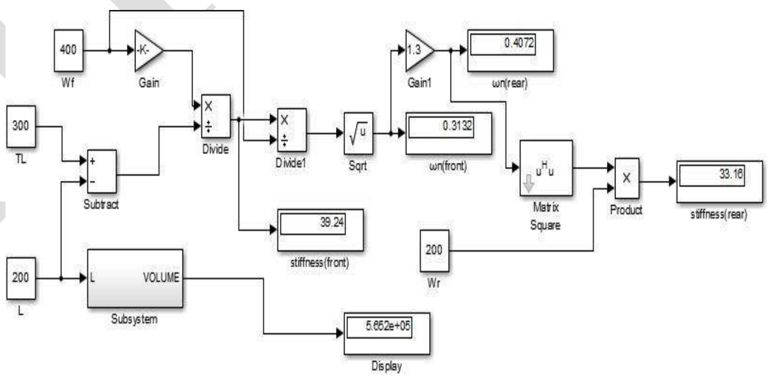
Table 2: Volume of liquid chamber, mm^3

ω_n (rear) = 1.3* ω_n (front)
= 1.3*313
= .407 cyc/se

Stiffness of spring = $\omega_n^{\ 2} * m$ The mat lab design for all the three modes are givenbelow:

	Race mode	Normal mode	Luxury mode
Volume of liquid chamber	560176	420132	280088

$= .407^2 * 200$
$= 33.15$ N/mm



International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-15 Issue-01 Sept 2020

LUXURY MODE:

Length of fluid chamber = .1 m

Front:

Volume of fluid in the chamber = $\pi * r^2 * h - 2(\pi * r^2 * h)$

$= 3.14*30^2*100 - 2(3.14*2^2*100)$

$= 280088\ mm^3$

Stiffness of spring = load on one wheel/compression of spring

Figure 4: Matlab for race mode

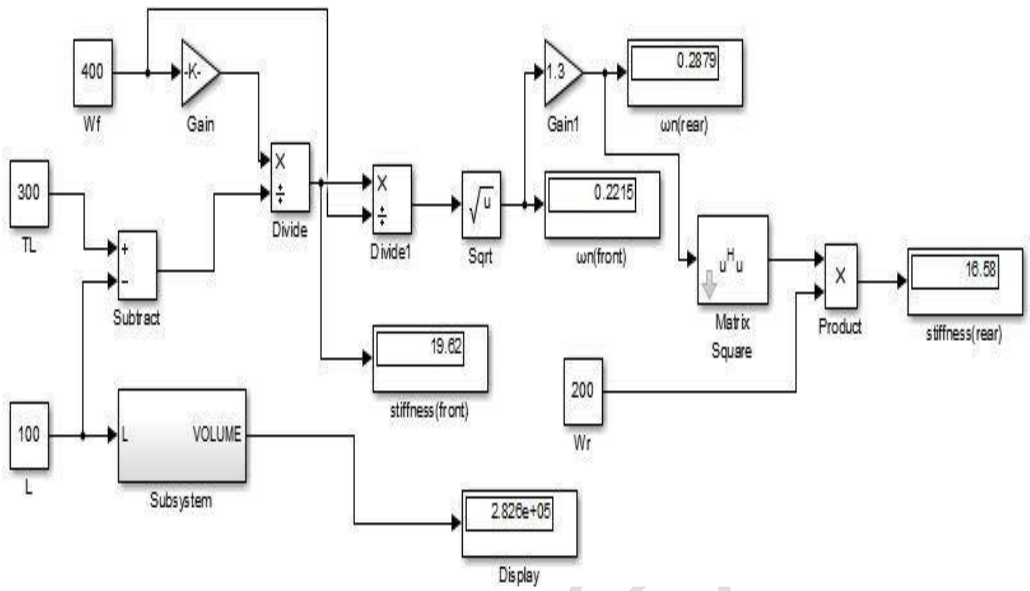


Figure 5: Matlab for luxury mode

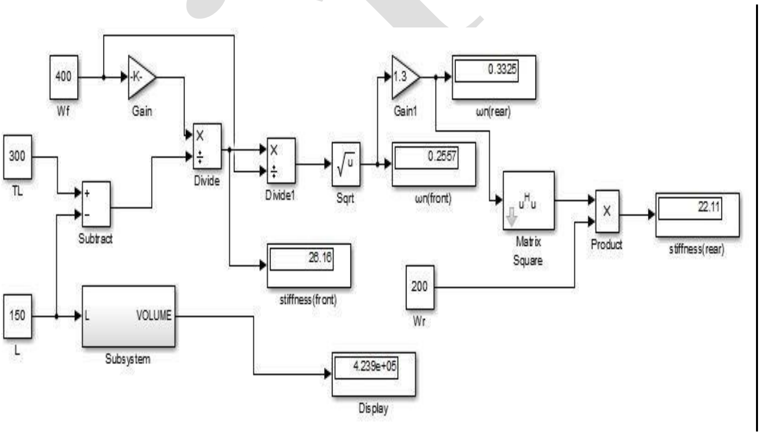
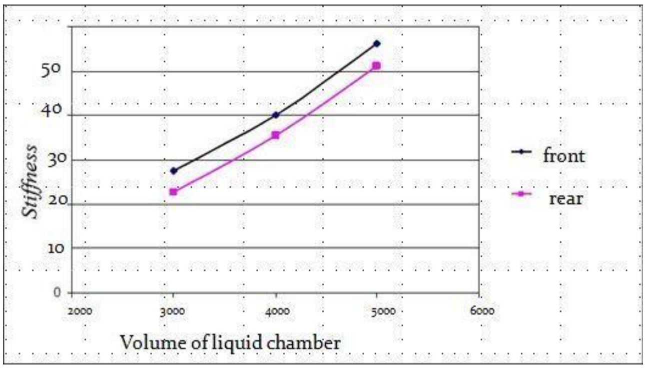


Figure 6: Matlab for normal mode



ERROR! REFERENCE SOURCE NOT FOUND.

7. Conclusion

Since the spring's stiffness may be adjusted, this setup can be considered a semi-active suspension system. This setup allows the driver to choose between three different suspension modes by making minor adjustments to the current system. Because it is inexpensive and easy to implement, this technology may be used in regular passenger cars. By manipulating the piston's movement inside the inner tube of the dampers, the spring's stiffness may be adjusted using this technique. This allows for an improvement in the vehicle's handling.

References

[1] "Recent Researches in Active Suspensions for Ground vehicles" by M. Nagai, published in Series C, volume 36, issue 2, 1996, pages 161–170.
[2]"Electronically Controlled Automotive Suspensions" by R.A. Williams was published in the Computing & Control Engineering Journal in June 1994 and spans pages 143 to 148.A review of road vehicle suspension design was published in 1987 in Vehicle System Dynamics by R. S. Sharp and D. A. Crolla, with pages 167–192.
the thirdIn the December 2002 issue of the Journal of Mechanical Design, vol.124, pages 697–705, C. Kim and P. I. Ro published an accurate whole car ride model utilizing model reducing techniques.
[4]The article "Numerical Modeling for the Hydraulic Performance Prediction of Automotive Monopipe Dampers" by K. Lee was published in Vehicle System Dynamics in 1997 and can be found on pages 25–39.
[5]"The National Conference on Advances in Mechanical Sciences AIMS07, 22th - 24th March 2007, Sponsored by AICTE, New Delhi, pp 85-90" was published in 2007 by P. V. Kumar and P. S. Rao and is titled "Vibration Isolation Performance of a Full Car Suspension System Model using Delayed Resonator Vibration Absorber."
[6]In the July 2004 issue of the IE (I) Journal MC, T. R. Gawade, Dr. S. Mukharjee, and Prof. D. Mohan published an article titled "Wheel Lift-Off and Ride Comfort of Three-Wheeled Vehicle Over Bump," which can be found on pages 78 to 87.
[7]In the proceedings of the 1997 IEEE International Conference on Control Applications, held in Hartford, CT from October 5-7, 1997, R. Majjad's paper titled "Estimation of Suspension Parameters" is available on pages 522-527 and 140.
[8]"Vibration Analysis in a Light Passenger Vehicle by Rigid Body / Finite Element Modeling" (pp. 107-120), published in 2003 by Universities Press (India) Pvt. Ltd., was written by N. Karuppaiah, P. S. Deshapande, C. Sujata, and V. Ramamurti.
[9]―Polygon Wear of Automobile Tyre‖, published in the JSME International Journal, Series C, Vol. No. 2, 1997, pages 209–217, was written by A. Sueoka, T. Ryu, T. Kondu, M. Togashi, and T. Fujimoto.