INFLUENCE OF SPRING STIFFNESS IN AUTOMOTIVE SUSPENSION SYSTEM PERFORMANCE – AN OVERVIEW

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Abstract - *Automotive suspension has undergone lot of research since its invention. The modern-day suspension systems are mainly classified into, passive, semi-active and active suspensions. Passive suspension being simple and cost effective are the most widely used systems. Active suspension being costly are not used in many practical applications. The passive and semi-active suspension both have spring as common element the only difference is the controllable damping in semi-active suspension. Once manufactured, the stiffness of spring cannot be changed hence it becomes very important to select the correct value of spring stiffness while designing suspension for any vehicle. The objective of this paper is to find the effect of spring stiffness on vehicle ride comfort and handling. There are also some newly proposed systems discussed in this paper. These systems can vary stiffness and damping and hence can provide better performance than passive and variable damping systems.*

***Key Words*: Suspension, Stiffness, Damping, Ride Comfort, Vehicle Handling.**

1.INTRODUCTION

A suspension system is a major part of automobile which affects the performance of automobile on road. A suspension system primarily consists of a spring and damper in parallel. The main role of suspension system in automobile is to soak up the undulations on road and to keep an assured contact between tyre and road surface and provide comfortable ride quality. The suspension system in old days used to consist of passive spring and damper which could not be modified once installed. The advancements in automobile technology have led to faster and more sophisticated vehicles which also need better suspension systems. The demand of advanced suspension systems has led to origin of semi-active and active suspension systems. These suspension systems offer better performance than passive system. The semi-active systems can vary damping coefficient in real time and hence can provide better comfort and handling. The active systems in addition to variable damping also provide active force to further improve the performance of suspension. The semi-active and active suspensions apart from providing better performance have their own sets of limitations as well. The semi-active suspensions which use variable damper along with passive spring needs the control strategy for changing the damping characteristics. The active systems on the other hand have complex structure and need large amount of power to operate. Hence most of the automobiles still use passive type suspension system due to its simple design and lower cost.

It is evident that suspension performance greatly depends upon the spring and damper i.e., spring stiffness and damping coefficient. Variable damping can be achieved by using semi-active and active suspensions, and it is proved to increase performance of system as compared to passive system. But achieving variable stiffness requires complex mechanisms, hence vehicles still use fixed stiffness spring. Therefore, designing a spring for vehicle suspension becomes critical task since it controls the behavior of the automobile on the road surface. The objective of this paper is to find out how the spring stiffness affects the ride quality and handling of vehicle by studying various research works.

2. LITERATURE REVIEW

Trupti P Phalke *et al*. used MATLAB Simulink determine the performance of vehicle in terms ride comfort and road holding by using 2DoF quarter car model. The outcome of the work is when spring stiffness is low the ride quality is best but the road holding is poor and as the stiffness increases the ride quality suffers but the road holding is improved. Fig-1 shows Simulink block diagram of 2DoF quarter car model [1].

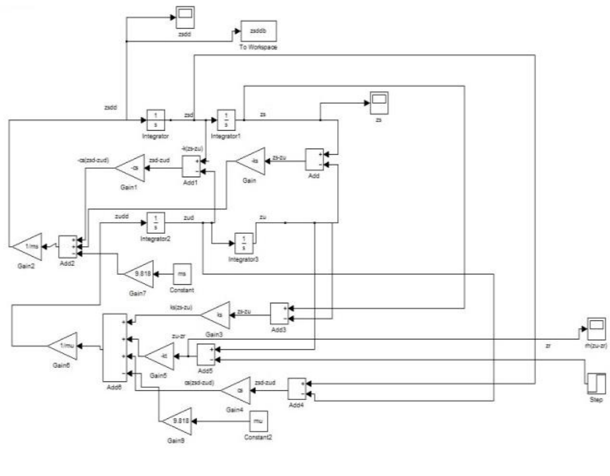
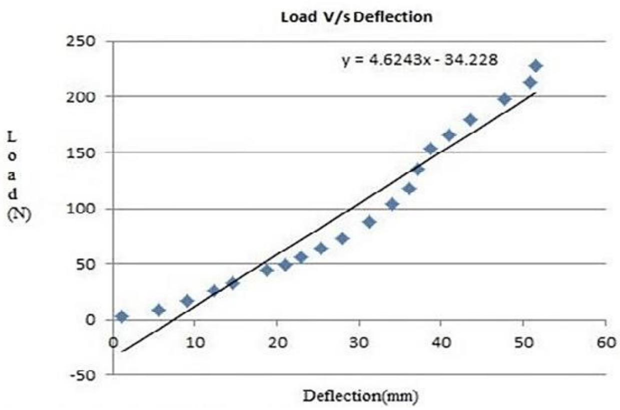
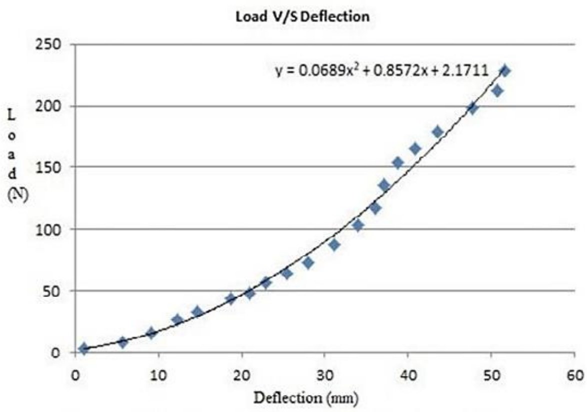


Fig-1: Quarter car Simulink Model [1].

It is known that deflection of spring is non-linear in actual practice but it is assumed to be linear for the simplification process (Fig-2). Hence there is a difference between the analytical and actual behavior of suspension system. **Ganesh D. Shelke *et al*.** carried out research to study the non-linear behavior of passive suspension system. For this work non-linear model of 2DoF was developed in MATLAB Simulink and was validated by using State Space Approach. The results of the work show the RMS value of acceleration for linear system is 0.2746 m/s^2 and for nonlinear system is 0.2474 m/s^2 which is 10.99 % in variation. Whereas the settling time for linear system is 1.4 sec and for non-linear system is 0.8 sec. Hence it was concluded that by introducing non-linearity in spring, ride comfort can be improved [2].



(a)



(b)

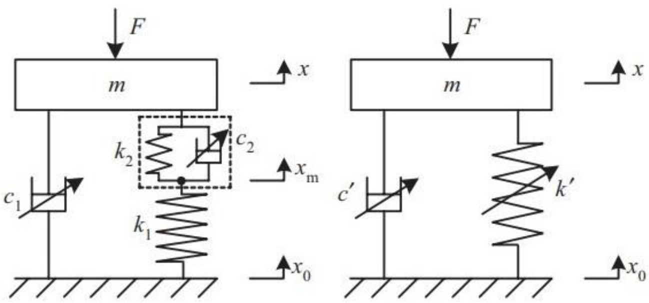
Fig-2: Load v/s deflection for (a) linear system and (b) non-linear system [2].

A similar work was carried out by **Vinay R Varude *et al.*** to study effect of non-linearity of spring. The conclusion of work was that the effect of changing spring parameters can drastically change the performance of suspension system since the change in geometry can induce non linearity [3].

The investigation of effect of spring stiffness on real vehicle performance was done by **Muhammad Zahir Hassan *et al*.** The work comprised of numerical model testing followed by field testing using Go Kart on a race track. The three different spring stiffness values viz. soft, medium and hard are taken as parameters for testing. The outcome was that medium stiffness spring provide good handling and comfort in numerical analysis as well as real vehicle testing. Authors also commented the importance of spring stiffness investigation during designing stage of any vehicle [4].

Research work carried out by **Ajit G. Mohite *et al.*** shows that when non linearity theory is implemented suspension system then the analytical results are closer to actual results which gives more accurate analysis in design stage of automobile suspension [5].

From the research on suspension spring, it can be acknowledged that choosing a proper stiffness value for suspension system in designing stage is crucial since it cannot be changed after installation in automobile. Hence it can be considered as limitation of passive suspension whereas the semi-active suspension has possibility to change damping values. The recent advancements in semi-active suspension also provide opportunity to vary stiffness during the operation. **Yanqing Liu *et al.*** proposed the suspension system with variable stiffness and variable damping by using a Voigt element in series with spring.



(a) (b)

Fig-3: Mechanical configuration of variable stiffness and damping (a)original model (b) Equivalent Model [6].

The Voigt element comprises of controllable damper and a constant spring as shown in Fig-3. The experimental research done on this newly proposed system shows that it provides better performance than passive and variable damping system [6].

Huaxia Deng *et al.* also proposed new mechanism for variable stiffness by using MR damper with two chambers and two springs in series as shown in Fig-4. In this mechanism the equivalent stiffness can be changed by varying the current in two chambers. The equivalent stiffness is proportional to ratio of stiffness of two springs and to the current supplied to the chamber of MR damper [7].

Fig-4: Variable stiffness MR damper proposed by author Huaxia Deng *et al.* [7].

A new variable stiffness system was proposed by **Chaoqing Ming *et al.*** called as serial stiffness switch system. This system uses two elements in series, each of them consists of a spring and a switch in parallel. The proposed system is shown in Fig-5.

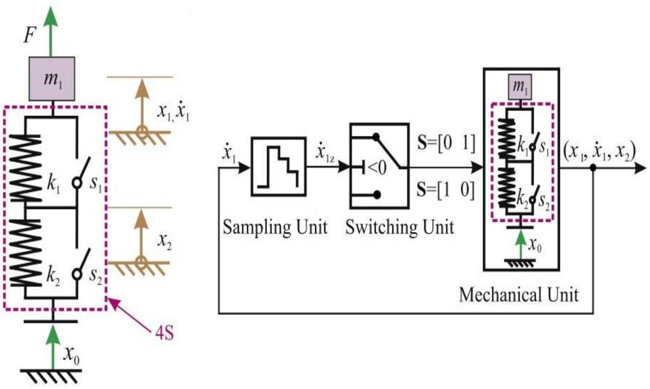


Fig-5: Serial Stiffness Switch System proposed by Chaoqing Ming *et al.* [8].

One of the spring acts as compression spring and the other acts as extension spring. Both springs are slightly pre-stressed before shock and a position PID feedback-controlled switching law is introduced. The experimental work done by authors in further research shows that the variable stiffness and variable damping can be obtained by the proposed system [8].

3. SUMMARY

It is very crucial for automobile manufacturers to design a suspension system which can provide good ride comfort and vehicle handling and for this task, selecting a proper value of spring stiffness and damping coefficient is important since for passive suspension systems the values of these parameters cannot be changed after installation. By software analysis and experimental work done by researchers it is found that the low spring stiffness provides best ride comfort but have poor handling and vice versa for high spring stiffness. Due to this drawback of passive systems semi-active and active systems are used to increase performance.

Active suspension being very expensive and requiring high power are still not suitable for commercial implementation. Semi-active systems provide only variable damping but the recent research work have also provided the variation in stiffness. Variable stiffness and variable damping semi-active suspension shows promising results by performing better than passive and variable damping systems.

4. CONCLUSIONS

Following conclusions are made by studying different research works on suspension systems.

Lower stiffness value of suspension can provide better ride comfort but vehicle handling is poor and as stiffness increases the vehicle handling improves but ride comfort decreases which is the main disadvantage of passive suspension when compared with semi-active and active systems.

The variable stiffness and variable damping suspension system proposed by Yanqing Liu *et al.* offers better performance than passive and variable damping systems the only drawback is the additional MR damper. The mechanisms proposed by Huaxia Deng *et al* and Chaoqing Ming *et al.* can vary the stiffness and damping without an additional damper. Hence there is scope for further research in this area.

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