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Optimization of Suspension Systems Parameters Utilizing MSC Adams View and Insight

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Abstract – The suspension system is undeniably one of the most important mechanisms of road vehicles in terms of ride comfort and road holding capacity. Therefore, suspension design is at the center of designers' attention. Some designer tries to improve the performance of suspension systems by introducing active or semi-active controller to the suspension system while others use optimization methods to do so. Hence in this study, we focus on the optimization of the suspension system. A new method is proposed in this study. Unlike the papers in the literature, we did not obtain the mathematical model of the suspension system. Here all design objectives and variables are set without obtaining the mathematical model. All the parts are modeled in MSC Adams view. After that MSC Adams insight is employed to optimize suspension systems parameters. The Monte Carlo Simulation method with uniform distribution is used and optimization is run for 2000 trials. From the study, the effectiveness of the method was evaluated. Also, the improvement of ride comfort and road holding capacity of the car was studied and evaluated comparatively.

Keywords – Monte Carlo simulation, MSC Adams view, Passive suspension, Optimization

I. INTRODUCTION

Passengers of all vehicles are subjected to vibration due to road irregularities. This vibration reduces the ride comfort and badly affects the road-holding capacity of the vehicles. Therefore, the suspension systems of vehicles are designed to provide sufficient ride comfort as well as road-holding capacity. However, achieving these two objectives simultaneously is not always easy since the parameters which give the best ride comfort and the best road-holding capacity are inversely proportional to each other. Suspension systems can be designed by trial and error method or by using optimization methods. In the trial and error method, the values of design variables are iteratively changed by designers and perform the analyze the system until the variables meet the requirements. This is both time-consuming and cumbersome, what is more, it is inefficient most of the time. Optimization methods deal with finding the best solution among alternatives. It is the action of making the best or most effective values that maximize or minimize the objective function. With the advent of the computer, optimization methods have become popular in designing suspension systems since it provides the best solution in a short time especially in solving complicated problems. There are lots of optimization methods such as the Monte Carlo Simulation Method, Genetic Algorithm, Particle Swarm Optimization, Ant Colony Optimization, etc.

M. Aydin and Y. Samim ünlüsoy developed and implemented a parameter optimization method for suspension systems to get better impact behavior of road vehicles using MSC Adams. The method includes the design of the experiment along with the response surface method. First, the most critical parameters affecting suspension performance were obtained by screening experiments. Once they are determined optimization is performed to achieve improvement in the impact harshness of road vehicles. From the results, it was obtained that the selected parameters are able to improve suspension system performance [1]. Gündogdu optimized the relevant parameters by using a genetic algorithm in order to obtain the best performance of the driver by using the seat and suspension model of a quarter vehicle with four degrees of freedom. In this study, a better design was obtained both in terms of health and stabilization of the vehicle, by taking into account the acceleration parameter to the driver's head as well as the suspension and wheel parameters [2]. In their study, Bhargav Gadhvi and Vimal Savsani optimized the mathematical model of a quarter car model while the vehicle was passing over a bump at different speeds in order to improve the driving comfort and handling of the vehicle. A teaching-learning-based optimization method was employed to evaluate the problem and the results were compared with those obtained by the Genetic algorithm technique. From the results, it was obtained that the spring-mass acceleration and tire displacement were reduced by 26.03% and 23.7% using the teach-learning-based optimization algorithm, and 22.3% and 18.52% using the Genetic algorithm, respectively [3]. In their studies, Anirban C. Mitraa, Sagar Agarwal, Hrushikesh Kaduskar, and Sanket Atre made an effort to optimize the ride comfort for the passive suspension system without affecting the road holding, with a multi-objective optimization technique using the Genetic Algorithm. The objective function of the ride comfort standard and handling was derived in terms of spring stiffness and damping coefficient and also verified with a SIMULINK model. From the results, it was seen that both ride comfort and handling increased by 15.04% and 9.15%, respectively [4]. In their studies, M. Mirzaei and R. Hassannejad numerically optimized the optimum values for all elasto-damping elements and the passive suspension system of the seat with a genetic algorithm in order to provide the passenger comfort feeling at a certain level. First, a tool with two degrees of freedom was optimized, and the results were compared with those obtained by nonlinear programming and its accuracy was proven. After the results were proven, the model was expanded to a five-degree-of-freedom model. The simulation results showed an improvement in vehicle driving comfort [5]. S. D. Jabeen obtained a mathematical model of the half-car model in his study to optimize the bouncing transmittance of the spring mass. The optimization vehicle was made by using a genetic algorithm numerical simulation method considering different road conditions. From the simulation results, it has been obtained that comfortable comfort has improved [6]. R. Alkhatib et al. have presented a new criterion for selecting optimal suspension parameters. The optimum solution is numerically obtained using a genetic algorithm and a cost function that aims to minimize the absolute root-mean-square sensitivity of acceleration to changes in relative displacement root-mean-square. The application of the method to a linear quarter-car model demonstrated the applicability of the method to multi-degree-of-freedom systems [7]. Vladimír Goga and Marian Klúcik optimized the parameters of passive suspension utilizing genetic algorithms in their studies. Optimization was carried out with Matlab / Simulink using the mathematical model of the half-car model. The results of the model with the optimized parameters show a significant decrease in amplitudes and faster stabilization of the measured quantities compared to the results of the model with the original parameters [8]. M.K. Hada, A. Menon, and S.Y. Bhave found the optimum values of the parameters of the suspension system using genetic algorithms in their studies. They simultaneously achieved an optimum balance between ride comfort, handling quality and suspension stroke for random road input. From the results, it has been obtained that the genetic algorithm is more advantageous than the traditional methods [9]. Sikandar Khan et al. They modelled a passive vehicle suspension system and optimized this model using a genetic algorithm optimization technique. The results show that the optimized values provide less overhang and sitting times, resulting in high passenger comfort [10].

In order to upgrade the ride comfort and road handling of a regular passenger car, in this current study, the stiffness of the suspension spring, damping coefficient of suspension, and stiffness of the tire are selected as the design variables. It is clear from the literature that all papers dealing with optimization were about obtaining mathematical models, defining the objective function, and later on optimizing the selected parameters. However, this method is time-consuming. So, the purpose of this study is to optimize the parameters of suspension systems without obtaining the mathematical model.

II. MATERIALS AND METHOD

The physical model of the quarter model is given in Figure. The equation of motion is given in (1.1). In the analytical model first, the equation of motion is obtained. Later on, the objective function is determined as in equation (1.2). After obtaining a mathematical model and determining the objective function one can perform optimization by employing a suitable algorithm. However, optimization in this method gets harder and harder as degrees of freedom increase especially when 8-wheeled vehicles or tracked vehicles are being investigated.

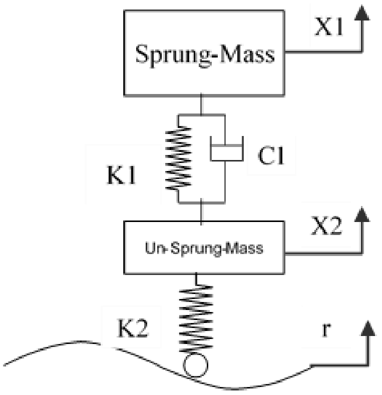


Fig. 1 Suspension system.

$$\begin{aligned} \ddot{x}_1 m_1 &= k_1(x_2 - x_1) + c_1(\dot{x}_2 - \dot{x}_1) \\ \ddot{x}_2 m_2 &= -k_1(x_2 - x_1) - c_1(\dot{x}_2 - \dot{x}_1) + k_2(r - x_2) \end{aligned} \tag{0.1}$$

$$\begin{aligned} f &= w_{ride} * f_{ride} + w_{holding} * f_{holding} \\ f_{ride} &= rms(\ddot{x}_1) = \sqrt{\frac{1}{t_f}\int_{t_0}^{t_f} (\ddot{x}_1)^2 dt} \\ f_{holding} &= rms(x_2 - r) = \sqrt{\frac{1}{t_f}\int_{t_0}^{t_f} (x_2 - r)^2 dt} \end{aligned} \tag{0.2}$$

In this research work parameters of suspension systems are optimized. In order to design mechanical parts MSC Adams view was used. MSC Adams insight was used to apply optimization. Suspension systems parameters used in this study are given in Table 1.

Table 1. Parameters of the suspension system and their initial values

Parameters	**Values**	**Units**
Ms	300	kg
Mu	50	kg
Ks	80000	N/m
Cs	1250	N.s/m
Kt	280000	N/m

The suspension system is simplified as a spring mass damper and modeled using MSC Adams view as shown in Figure 1. Stiffness of suspension, damping of suspension, and stiffness of tire are set as optimization parameters whereas sprung mass acceleration and tire deflection are defined as design objectives. The range of parameters is as follows;

$$260000 \le kt \le 280000$$
$$71000 \le ks \le 80000$$
$$950 \le cs \le 1250$$

The objective function is defined as follows;

$$f_{objective} = w_1 * f_{tire} + w_2 * f_{acceleration}$$

Here, w_1 and w_2 are weight constants and they are used to emphasize how objective functions are important relative to one another. In this study and are set equally at 0.5. is tire deflection and is the root mean square of sprung mass acceleration. Here, and are determined in MSC Adams using measure tool as shown in figure 2.

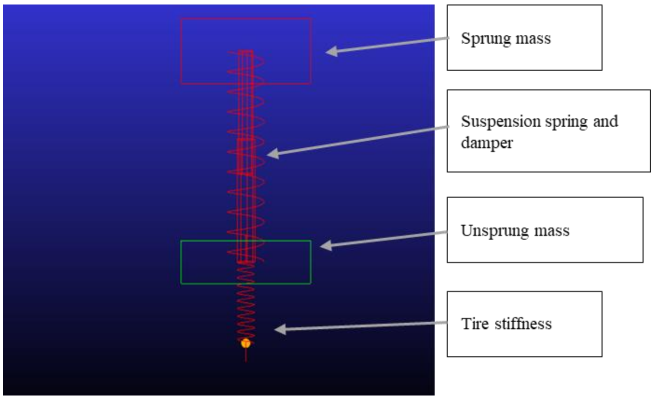
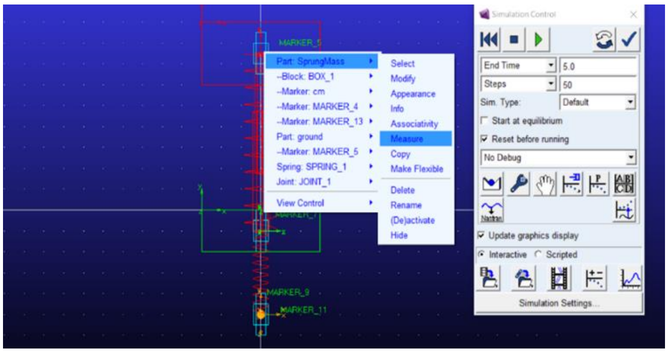


Fig. 2 Suspension system.



End Time 5.0
Steps 50
Sim. Type: Default
No Debug

Fig. 3 Measure command in MSC Adams.

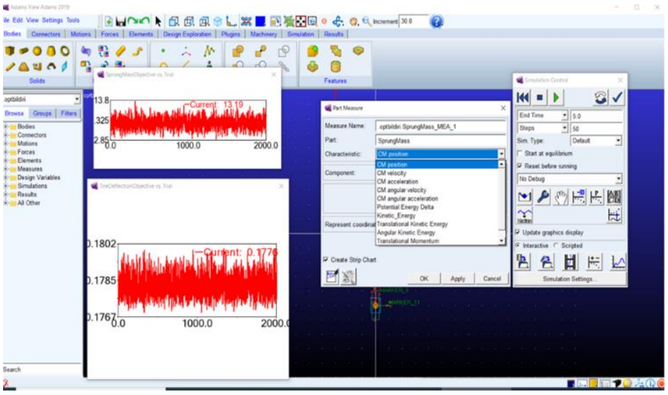


Fig. 4 Measure command parameters selection in MSC Adams

After setting the mechanical part in MSC Adams view, the MSC Adams insight is turned on in order to continue optimization. In the MSC Adams environment, all design parameters are set again based on Normal variation. Monte Carlo simulation is set in the design specification section for 2000 runs under 0.05*sin(10*time) road excitation.

III. DISCUSSION

As discussed in the previous section the aim of the study is to optimize the suspension system parameters by using the proposed method. Instate of obtaining a mathematical model and establishing objective functions, which are time-consuming, MSC Adams is used to optimize the suspension system practically. From the simulation, the best value of all parameters is found and given in table 2. Figure 5 shows the sprung mass acceleration versus trials. Similarly, figure 6 shows the tire deflection versus trials. After finding the optimum values of design parameters, analysis is run one more time with original values and optimum values. Sprung mass acceleration and tire deflection are comparatively plotted using original values and optimum values and presented in Figures 7 and 8 respectively.

From the simulation, the optimum parameters of the suspension system are obtained. From the simulation, the advantage of the proposed method can be seen clearly because this method does not only optimize parameters but also enables the designer to change his design simultaneously. Since simulation and optimization can be performed in the same software there is no need to use two different software namely, one for optimization and one for simulation. Furthermore, this method provides more information about the dynamics system being analyzed. Consequently, the design process can be reduced by a considerable amount when this method is used.

Table 2. Optimized parameters of the suspension system

Parameters	**Optimum values**
Suspension stiffness	71002.7
Suspension damping	950.095
Tire stiffness	260004

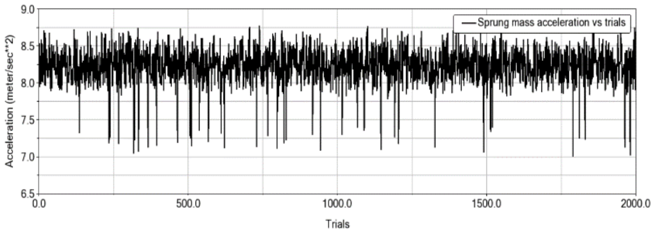


Fig. 5 Objective 1 (Sprung mass acceleration vs trials)

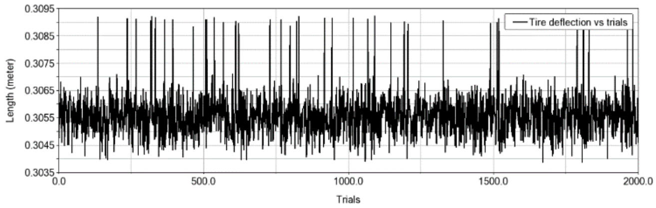


Fig. 6 Objective 2 (Tire deflection vs trials)

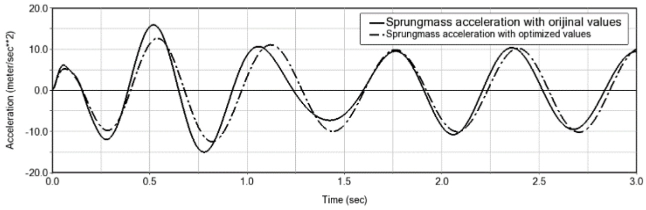


Fig. 7 Comparison of sprung mass acceleration.

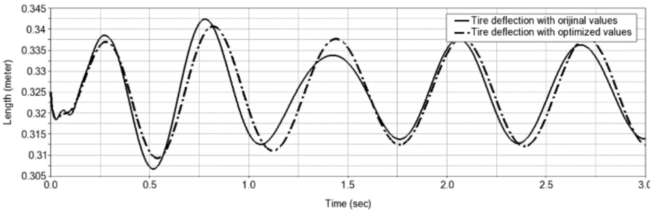


Fig. 8 Comparison of tire deflection.

Besides investigating the effectiveness of the proposed method, the results of optimization are evaluated comparatively. Figure 7 and figure 8 show the objective functions' response with original values and with optimized values. Table 3 gives the objective function values before and after the optimization comparatively. As can be seen from table 3 sprung mass acceleration and tire deflection are reduced by a considerable amount. To put that another way, ride comfort and road holding capacity of the car are improved by 20.6577 % and 11.5385 % respectively.

Table 3. Optimized parameters of the suspension system

Objective	**Before optimization** **Ks=78000,Kt=280000 and Cs=1250**	**After optimization** **Ks=71002.7,Kt=260004 and Cs=950.095**	**% improvement**
Sprung mass acceleration	15.9282 m/s2	12.6378 m/s2	20.6577
Tire deflection	0,0135 m	0,0120 m	11.5385

IV. CONCLUSION

The suspension system of a car is simplified as spring, mass, and damper modeled in MSC Adams view. Parameters of suspension systems are taken from the literature. Later on, design objectives and constraints are set in MSC Adams environment. Optimization is run to find optimal values of suspension system parameters that give both improved ride comfort and road holding capacity. In this study, a mathematical model of the system is not obtained, in order to optimize, in fact, virtual prototyping is used for simulation. From the result, it was observed that the proposed method is significantly effective for the optimization process. Consequently, one can reduce the time of the optimization process and speed up the design process. Additionally, using this method gives more insight into the dynamics of the mechanical system since the software provides visual animation.

ACKNOWLEDGMENT

The heading of the Acknowledgment section and the References section must not be numbered.

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