Development of Computational Model of Half Car through Bond Graph for Comfort Evaluation

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Abstract - The ride comfort that passengers experiences is a highly complex and individual phenomenon. The improvement of passenger comfort while travelling has been subjected of intense interest for many automobile manufacturers, researcher and companies around the world. Although a new technique in manufacturer and design ensure better ride quality. The dynamic behavior of a car fully depended on the suspension system such as spring, damper etc. This study deals with the ride comfort and evaluation effect of the vehicle at various speeds on the bump road. Symbol software is used for simulating the bond graph model of vehicle at variable operating speeds.

Keywords:-Bond graph, half car model, physical model, Simulation model

I. INTRODUCTION

The ride quality concept sweeps over many disciplines in automotive engineering. so it must offer high comfort level for the passengers and the staff. However, the comfort that passengers experience is a highly complex and individual phenomenon. In several researches, noise and vibration have been identified as the most important factors for high comfort. The main sources of vibration in a road irregularity bump etc. The improvement of passenger comfort while travelling has been the subject of intense interest for many vehicle manufacturers, researchers and companies all over the world. Although new technique in manufacturing and design ensure provide better ride quality. In India cars are one among the major automobiles used by people for transportation. Apart from population and performance, economy, safety and comfort are major factors to consider. Comfort of the driver plays a vital role in the passenger safety, fatigue during long drive, and drivability in heavy traffic. Comfort means absence of any discomfort. A car driver often drives the vehicle through all types of road conditions. While considering the comfort, this research suspension system is focused around improving the ride comfort and safety or evaluating ride quality and control of the vehicle ,generally half car models are used for better results. There has been a trend to model the vehicle dynamic using bond graph based technique as it allow easy up gradation and merger with the development of control system for the vehicle.

This present work deal with the modeling of a half car using bond graph technique. There have been several studies, which are contributed by many researchers regarding the dynamic analysis and to enhance the ride comfort while travelling. Lee and Pradko [13] discussed the absorbed power method used analytically to determine human response to vibration for periodic and random environments. They argued that vibration in real world occurs as a time function, which can be periodic or a periodic. Donati et al. [6] developed an experimental technique known as the ‘floating reference’ to compare the subjective response of seated subjects to sinusoidal vibrations in the range 1−10 Hz. Fairley and Griffin [7] investigated a procedure on predicting the discomfort produced by vibration in the fore-and-aft, lateral and vertical axis directions. Soliman et al. [15] aimed at introducing a solution of the vehicle dynamics problem by studying the effect of various types of suspension element on the vehicle suspensions. Faris et al.,[8]. They analyzed and compared their ride comfort, suspension displacement and road-holding performances with passive system.

II. METHODOLOGY

The paper is focused towards development of computational model of half car through bond graph for comfort evaluation is an important area of study. Further shows that new modeling technique like one based on the use of bond graph is becoming popular as it help in several ways like flexibility and extensibility of model and automatic generation and solution of the system equations etc. Bond graph was invented by the Paynter [14] are pictorial representation of essential dynamic of physical system through exchange of power amongst the basic elements the system is composed of and its environment. The basic element of bond graph Inertance (I), Capacitance (C), Resistance (R), Source of flow (SF), Source of effort (SE), Gyrator (GY), Transformer (TF), Constant effort junction (0), Constant flow junction (1) and Time integral of effort (P). In the context of mathematical models of dynamical system, the equations for the system can be easily formulated in a systematic way from the bond graph representation. The bond graph representation of a system may be constructed in total abstraction from the mathematical model of the system. The bond graph causality concept, presented by Karnopp and Rosenberg [11], orientates the calculus schemes in the system model. This constitutes the physical level of the description contained in the bond graph representation. Karnopp [12] proposed algorithmic generation of Lagrange's equation for complex systems. Few other contributions in this line, devoted to the mathematical formulations of dynamical systems are as presented by Brown [4] . Breedveld [5] were also credited with the multi-bond graph representation of Lagrangian mechanics. Thoma [16] have given a graphical method for simulation by bond graph. Gawthrop and smith [9] have done Meta Modeling for dynamic system through bond graph. Granda*et al.* [10] have presented a computer generation of physical system differential equation using bond graphs. Broenink [3] has presented broad scope of bond graph model for engineering system. the basic idea of Karnopp's algorithm to a broader class of systems, In this approach two similar bond graphs of the system are created. In this technique to develop a computational model of half car through bond graph for comfort evaluation. The bond graph modeling technique has been attracted considerable attention of engineer and researcher in modeling and simulation of dynamic system it has ability to model systems with the elements from different energy domain. This ability makes this technique very powerful. Sub models may also be developed using this technique.

III. DEVELOPMENT OF HALF CAR MODEL THROUGH BOND GRAPH

The half car model has been developed through the symbol sonata software.

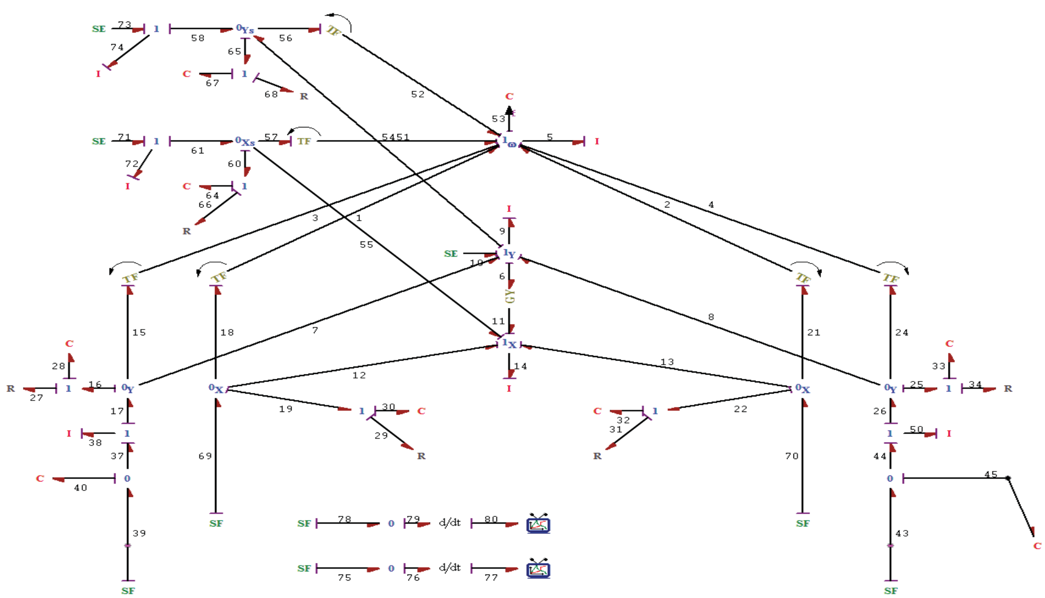
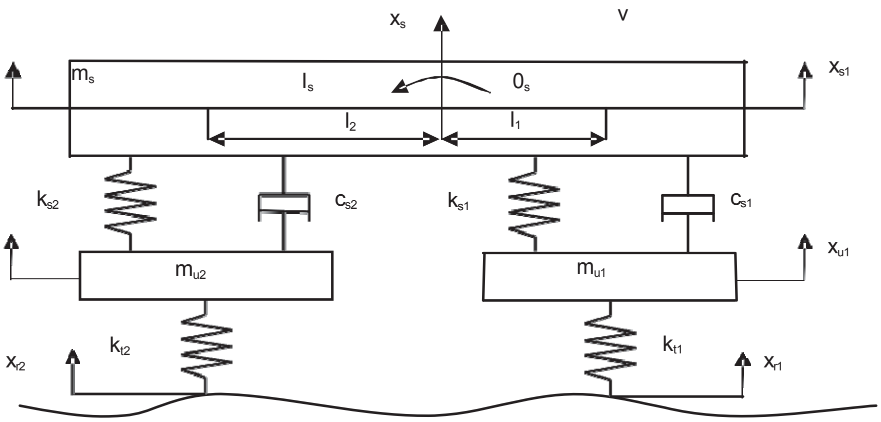


Fig (3.1) half car model through bond graph



Figure(3.2) The physical model of the half-car

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From fig (3.1). To describe the following numeric values, the half arrow to provide the directional command of flow and effort and it is also called as power bond. Zero is represent constant flow junction and one is represent constant effort junction, C are represent the stiffness of suspension spring Ks and tire stiffness Kt, R is represent damper in suspension system Cs. I, are represent body sprung mass and unsprung mass of the car, TF are represent transformation of energy in one step to the next step continuously and SF are also represented source of flow of the car.SE are represented source of effort. The symbol of GY is a gyrator to represent the effort converted to flow and also flow to effort these conversion according to condition. I, are also the represent the mass of the vehicle. IW, IX, IY are mass moment of inertia of the vehicle from centre of gravity. IY represent C.G point of the car and front wheel also represent by him, Iwis a front rotational part and IX to represent internal part of the vehicle. 0_{YS} front seat represent. Similarly 0_y represent front left and right suspension from C.G. C40 and C45 front tire stiffness right and left.

From fig (3.2). To describe the following numeric values, where m_s is the mass for the vehicle body, I_S is the mass moment of inertia for the vehicle body, m_{u1} and m_{u2} are the masses of the front/rear wheel respectively, c_{s1} and c_{s2} are the damping coefficients of front/rear suspension respectively,k_{s1} and k_{s2} are the spring stiffness front suspension respectively k_{t1} and k_{t2} are the stiffness of front/rear tires respectively, x_s is the vertical displacement of the vehicle body at the centre of gravity,0_s is the rotary angle of the vehicle body at the centre of gravity, x_{G1} and x_{G2} are the vertical displacement of the front//rear wheels, x_{r1} and x_{r2} are the irregular excitations from the road surface,x_{r1} and x_{r2} are the vertical displacement of the vehicle body at the front suspension location ,I_1 and I_2 are the distance of the front/rear suspension location, with reference to the centre of gravity of the vehicle body, and $I_1 + I_2 = I$

IV. SIMULATION RESULTS

Simulation is a powerful technique for solving a wide variety of problems. Simulation helps to learn about a real system, without having the system at all. In the real system, Computer simulation can compress the performance of a system over years into a few minutes of computer running time. Simulation models are comparatively flexible and can be modified to accommodate the changing environment to the real situation. The dynamic behavior of the car through bond graphs technique and simulator SYMBOLS-shakti® software. To find the deflection at various speed model developed is simulated. The parameters used for simulation is presented in table 4.1. The main interest of study is to evaluate passenger ride comfort response taking suspension displacement.

Simulation gives value of deflection of suspension. The model gives non optimal result due to severe wheel hop that result in vehicle instabilities. For a particular road the variation of suspension with speed depends upon the irregularity (bump) and its parameter.

Table 4.1 simulation parameter of half car front suspension system

Sprung mass	718.583 Kg
Front unsprang mass	100Kg
Rear unsprang mass	100Kg
Moment of inertia $I_{z\,z}$ (X-Y)	1460.769 Kg-m^2
$I_{Y\,Y}$(X-Z)	1739.092 Kg-m^2
I_{xx} (Z-X)	413.239 Kg-m^2
Stiffness of suspension spring	25.30KN/m
Stiffness of tire	182.47KN/m
Damper force	2958N-m/sec
Front track width	1.40m
Road roughness	1 KN/m

V. RESULT AND DISCUSSION

Simulation results are presented in this section. Results are also presenting in summarized table and graphical form in Table 4.1 is obtained after simulating the computational model. The different figures in the simulated results obtained at various speed the various speed taken for simulation are 20km/hr,50km/hr,60km/hr,80km/hr,100km/hr. this parameter analyzed suspension displacement.

Bond graph based modeling of various systems of automobiles has been carried out in large number of investigations, reported in literature. The present work attempts to model a car suspension through a half car model approach. when the vehicle goes over a bump . Efforts have been concentrated on evolving the model, as once the model is obtained a variety of results can be obtained.

From fig.(5.1 to 5.5) is the results obtained from simulation of computational model develop using bond graph. The results show relation between suspension displacement and time at various speed of the vehicle.

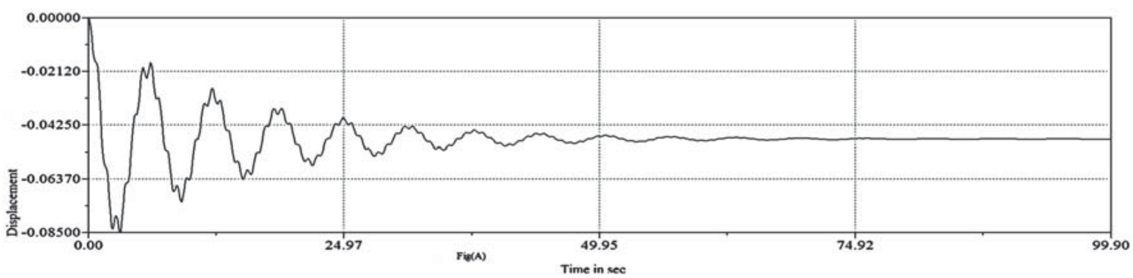

Fig. 5.2 (a) Displacement Vs time at 20 km/h

At 20km/hr speed the displacement of the front suspension 84mm and then after some time they are slowly smooth with respect to time and after 72 sec the vehicle moved freely or smooth on the road.

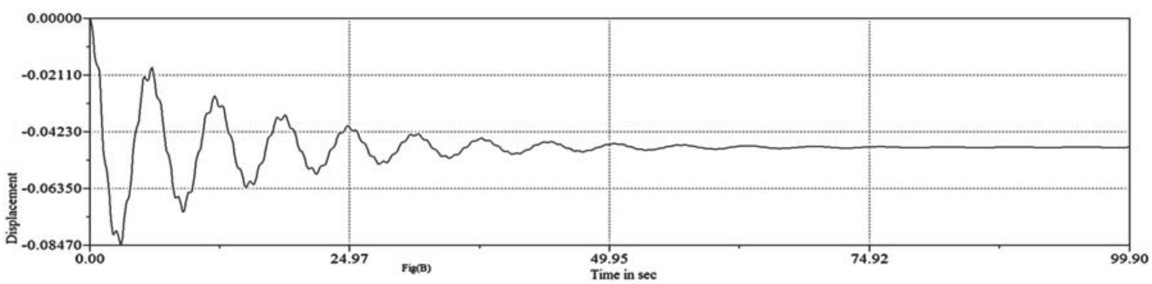

Fig.5.3 (b) Displacement Vs time at 40 km/hr

Again simulate. At 40km/hr speed the displacement of front suspension 77.50 mm after 60 sec it smooth.

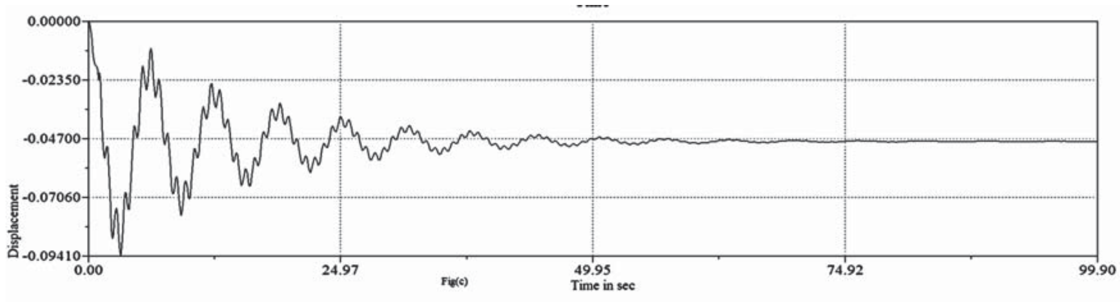

Fig.5.4 (c) Displacement Vs time at 60 km/hr

Similarly simulate. At 60km/hr speed the displacement of front suspension 87mm with some times increases the displacement of front suspension of 94mm and then slowly smooth after 55 sec.

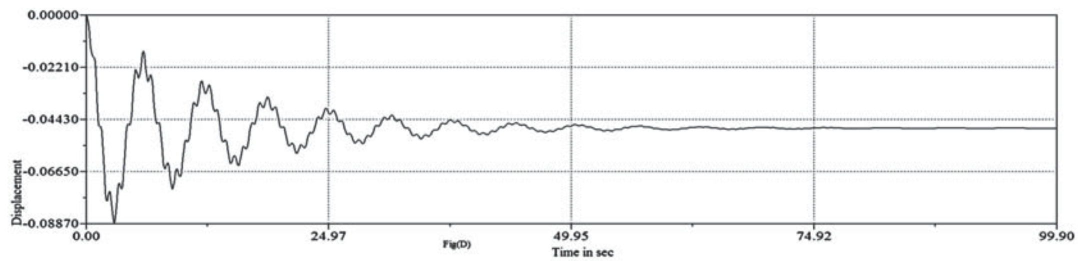

Fig. 5.5 (d) Displacement Vs time at 80 km/h

At 80km/hr speed the displacement of front suspension 77.60mm it again increased 87.70 then it reduced slowly after the 55 sec.

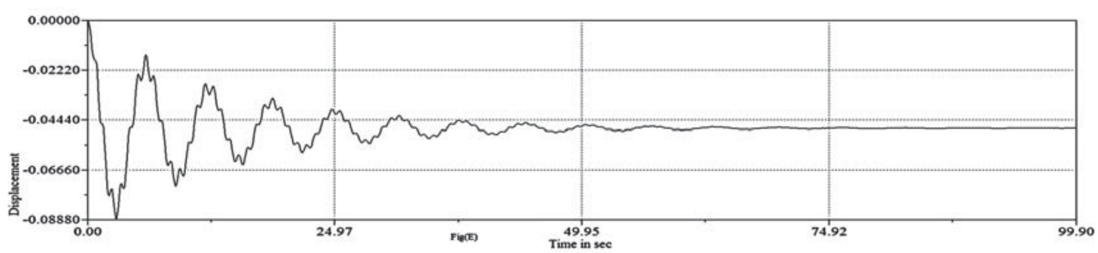

Fig .5.6 (e) Displacement Vs time at 100 km/hr

At 100km/hr speed the displacement of front suspension is 74mm again its increased and after some time smooth of 55sec, after 100km/h the value are repeated again to again so we stop the next simulation. Graph also illustrate that at 100km/h speed displacement is lower than the 20km/h speed.

VI. CONCLUSION

Automobiles continue to be central to present day human activities and a vast literature exists on their evolution and adaptation. However, the pace of developments has not slowed down. Newer tools such as Bond graphs make it possible to model more and more complex systems. The efforts here examine the modeling of automobile suspensions especially that may be useful in future to bring in active control systems etc. A half car model of a conventional suspension using Bond graphs has been created first for modeling have of a car as it passes over a bump on the road. A few results have also been obtained more results from the model created can be obtained by giving relevant *inputs.* A computational model has been in this work through bond graph modeling. One may use this model to determine the amplitude of vibration at various speed by simulating the model on the symbol shakti sonata software. Any manufacturer can evaluate comfort ride condition of his vehicle at the design stage. Manufacturer also gives speed range 60km/hr-80km/hr as a cru sizing range. Results obtained from our model also in the same direction.

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