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CHAOS, COMPLEXITY AND SYNCHRONIZATION IN DYNAMICAL SYSTEM USING BOND GRAPH

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ABSTRACT

This paper describes a method for approaching an arbitrary parameter with initial outline, slider and simulation model, systematical and quantitative bond graph model of vehicle dynamic system. It illustrates a typical bond graph and object models using the three basic modules of the software. For brevity, only small problems are considered for simulation of vehicle dynamic system model. Bond graph techniques reveal its strength and beauty in developing a clear and simplified model for vehicle dynamic system. Fast Fourier Transform (FFT) generates discrete Fourier transform of a time-varying signal and stores it into a disk file containing discredited numerical values for all the system states, ranging over the entire simulation interval. In this paper, a vehicle dynamic Modeling and Simulation involving three partners viz., Vehicle model, Vehicle parameter and Vehicle simulator, are taken into consideration. This process consists of both modeling and simulating closely associated with each other. Vehicle dynamics is the science that studies the kinematics of wheeled land vehicles with its dimensions and benefits to mechanisms, suspensions and steering mechanisms. The dynamics of computer models of vehicles using Bond graph technique originated by H. M. Paynter, presents a tool for continuous system modeling in a graphical sense, by generalizing the physical phenomenon such as: Mechanical Dynamic System. The role of computerized modeling and simulation in engineering design continues to increase as companies are striving to gain competitive advantages by reducing the time required to move from concept to final product.

Keywords - Dynamic system model, Bond Graph, FFT, Simulator module, Chaos concept

1. INTRODUCTION

The chaos, complexity and synchronization in dynamical system show that modeling of an automobile is an important field of study [1]. Further it shows that a new modeling technique using Bond graph is becoming popular and it helps in several ways like: flexibility and extensibility of models, automatic generation and solution of the system equations [2]. Further, study shows that it could be applied for various purposes like: quick evaluation of specific features, configurations and real time running of the models for controls [3]. Simple models are desirable and found adequate, as compared to full models [4].

Four wheeled automobiles have been modeled in a variety of ways; some to study stability and controllability [5], some to study crashworthiness and other to variety of criteria like development of greener vehicles, hybrid vehicles [6], self navigating vehicles etc. The most common requirement is to have a relatively simple but responsive model in hand which may run in real- time during the vehicle operation [7].

Recent studies show that while the full blown vehicle models [8] may be needed to be used in some application like: a planer two wheeled bicycle model and even a single wheel quarter model have a role in evaluating the active ride control system of a vehicle [9]. Further, the controlling system itself may need to run a vehicle model to provide more advanced type of vehicle control. These models may also form a basis of crisis control in the event of any damage or in all functionality of the vehicle. Keeping the above observations in mind, the present paper is focused on building a two wheeled plane vehicle model and its validation and evaluation for road un-evenness. In this a Bond graph based approach has been adopted as it easily permits variety of evaluation or contributions and derives principle run time versions, if needed.

NOMENCLATURE

[A] =	System matrix
[B] =	Input matrix
[U] =	Input vector
[X] =	State vector
A =	Distance of rear wheel from C.G
B =	Distance of front wheel from C.G
C =	Complement element
H =	Height of ground excitation
I =	Flow equation junction
I =	Inertial element
Jbf =	Front Mass of the car
Jbr =	Rear Mass of the car
Jc =	Mass of the car
K_{1f} =	Front stiffness
K_{1r} =	Rear stiffness
K_{2f} =	Front stiffness
K_{2r} =	Rear stiffness)
K_{3f} =	Front stiffness
K_{3r} =	Rear stiffness
L=	Length of ground excitation
Mbf =	Front Mass of the car
Mbfg =	Front Moment of inertia of the car
Mbr =	Rear Mass of the car
Mbrg =	Rear Moment of inertia of the car
Mc =	Mass of the car
Mcg =	Moment of inertia of the car
R =	Resistive element
R_{1f} =	Front damper
R_{1r} =	Rear damper
R_{2f} =	Front damper
R_{2r} =	Rear damper
R_{3f} =	Front damper
R_{3r} =	Rear damper
SE=	Source of effort
SF =	Source of flow
TF =	Transformer
U =	Effort equation junction
V =	Velocity of the car
Vf(t) =	Front Velocity of the car
Vr(t) =	Rear velocity of the car

2. CHAOS AND COMPLEXITY DEVELOPMENT OF THE MODEL

Dynamics of an automobile with road excitation of a chaos and complexity model is shown in **Fig. 1**. The front and rear wheels of an automobile of a chaos and complexity through a suspension (spring and damper) and support parameters are estimated and responses to road excitation of chaos are studied. The heavy and the rotational (pitch) motion of the main body and suspension system are modeled. The proposed bond graph model of two wheeled bicycle type of chaos and complexity is shown in **Fig. 2**.

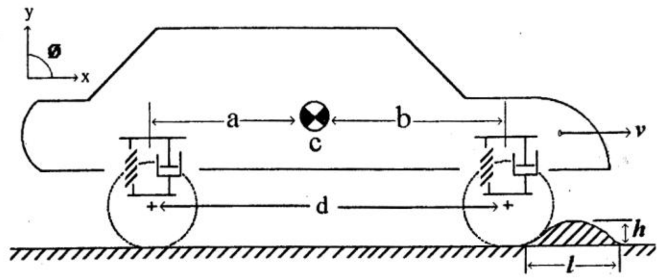

Figure 1: Dynamics of 4-wheeled car model with road excitation of a chaos and complexity

In this model, elements of spring, dampers and the configurations used are similar to one used by Kim et al [10]. These configurations are suitable for in plane study of the vehicles for road disturbances. The Bond graph based study requires transformation of model in an equivalent description. For this purpose a University developed software called SYMBOL Shakti has been used [11]. The concept of Bond graphs is based as power flow in various elements of the system. The normal 4 wheeled vehicle as mentioned above can be reduced to a 2 wheeled model and variation parameters can be identified for a front wheel or rear wheel drive vehicle.

Since the role of modeling and simulation in engineering design continues to gain competitive advantage by reducing the time required to move from concept to final product, here it is considered to examine the front and rear wheels supported on the main body of an automobile through a suspension (spring and damper). As a model complexity increases in steps with advances in computer software and hardware, the designer / engineer should remain well versed to use "proper simulation models". Proper modeling can be derived with systematic determination of the model with minimum complexity. This model describes an arbitrary parameter, initial, outline and slider, and its simulation model with an approach to systematical and quantitative method.

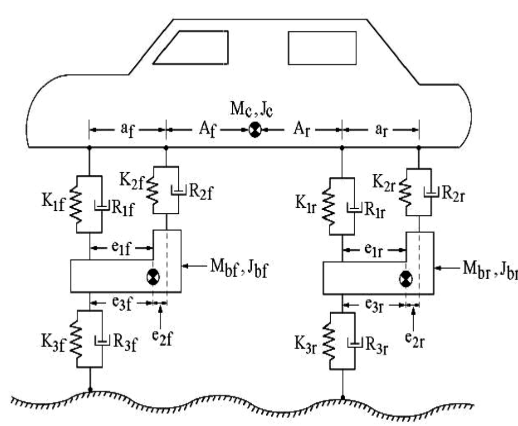

Figure 2: Chaos and complexity for two wheeled vehicle car model

In the development of proposed model, following parameters and notations are considered: the distance of rear wheel from C.G is kept 1.1m, the distance of front wheel from C.G is 0.9m, Front damper is R_{2f}, Rear stiffness is K_{2r}, Front stiffness is K_{2f}, Mass of the car is Mc, Rear damper is R_{2r}, Moment of inertia of the car is Mcg, Rear damper is R_{1r}, Front damper is R_{1f}, Rear stiffness is K_{1r}, Front stiffness is K_{1f}, Mass of the car is Jc, Front Moment of inertia of the car is Mbfg, Rear Moment of inertia of the car is Mbrg, Front Mass of the car is Mbf, Rear Mass of the car is Mbr, Rear Mass of the car is Jbr, Front Mass of the car is Jbf, Front stiffness is K_{3f}, Rear stiffness is K_{3r}, Front damper is R_{3f}, Rear damper is R_{3r}, Front Velocity of the car is Vf(t) and Rear velocity of the car is Vr(t) [12].

3. SYNCHRONIZED BOND GRAPH MODEL OF A DYNAMICAL SYSTEM

In this model Rear suspension damper is R1, Rear suspension spring is C2, Ground excitation is SF4, Heavy motion of the car is C9, Mass of the vehicle is I7, Ground excitation of the car is SF10, Front suspension is 04, Vehicle motion of C.G is I2, Front suspension Damper is R13, Front suspension spring is C14, Rotational motion of the car is I, Rotational Pitch is C18, Rotational inertia of the vehicle is I17, Rear suspension of the car is 03 as shown in **Fig 3**.

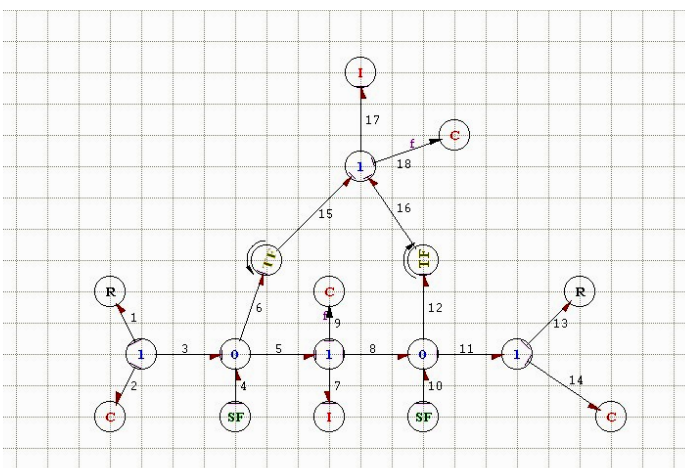

Figure 3: Bond graph Model of Dynamics of 4-wheeled car model with road excitation

Choose International from Junction display mode combo box in the module toolbar. Choose "1" icon from bond pad toolbox. Bring the mouse cursor to drawing area place it at "1" position as shown in the above figure and paste it by clicking left mouse button. This "1" is for rotational motion of the car. Similarly put another "1" icon at "1" position for vertical motion of C.G. Then choose "0" icon and place it in two places it in two places "0" and "0" for rear and front suspension of the car. Choose "SF" icon and place it in two places "SF" and "SF" for ground excitations. Next, choose line icon from Bond pad toolbox and draw a line from "SF" to "0". Similarly draw a line from "SF" to "0". Then choose another "1" and place it "1"posion. Place a "C" icon at "C" position for rear suspension spring and a "R" icon at "R" position for rear suspension damper. Similarly place "1", "C" and "R" icon at "1", "C" and "R" position for front suspension and put two "I" icons at "I" and "I" position for mass of the vehicle and rotary inertia of the vehicle respectively. Put two "C" icons at "C" and "C" position. These are two observers that observe the rotational (pitch) and heave motion of the car. Place two transformers "TF" icons "TF"and "TF" as shown in the above picture. Finally Number the bonds by selecting "Number" item options menu. Set the power direction between bonds by selecting "Power" item in options menu. Set causality by selecting "Causal" item in options menu. Activate two observers by pressing "Activation" icon. Choose flow activation from popup menu. Then the "f" will appear in the side of the corresponding bond. Now select the Modulus "specified" icon to establish symbolic name for the transformers "TF". The bond graph is shown in **Fig.4**.

The bump excitation for front wheel is:

$$y = h * \sin\left(\pi * \frac{v}{l} * t\right)$$

for $0 \leq t \leq \frac{1}{v}$ = 0, for $t > \frac{1}{v}$ and for rear wheel is = 0, for $t > \frac{d+l}{v}$ for $\frac{d}{v} \leq t \leq \frac{d+l}{v}$

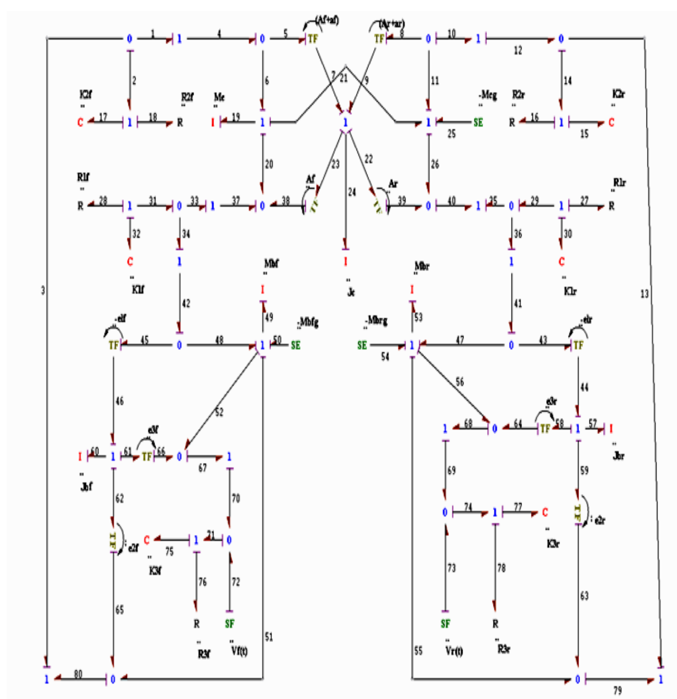

Figure 4: Bond graph model of two wheeled vehicle car model

4. DESCRIPTIONS AND PARAMETERS OF THE VEHICLE

4.1 Parameters of dynamics of 4-wheeled car with road excitation (shown in Table 1)

Table 1
Parameters of dynamics of 4-wheeled car with road excitation

Description	Parameter name	Value can be entered
Velocity of car	V	1 m/s
Height of ground excitation	H	0.1 m
Length of ground excitation	L	0.3 m
Rear damper	REAR_DM	100 n.s/m
Rear stiffness	REAR_ST	20000 n/s
Front damper	FRONT_DM	100 n.s/s
Front stiffness	FRONT_ST	20000 n/s
Mass of the car	CAR_MASS	1080 kg
Distance of rear wheel from C.G	A	1.1 m
Distance of front wheel from C.G.	B	0.9 m
Moment of inertia of car	J_CAR	250 kgm^2

Start simulator window by pressing simulated item from the process menu. SYMBOLSHAKTI simulator window will open with active document. Choose “Parameters” item from the view menu, a box appear showing all system parameters following a small square box to the left of each parameter. Parameter, initial, online, slider, and simulator etc., Here, model parameters can be specified. Set time range by selecting “Simulation properties” item from the “View” menu. Set the simulation time in seconds (say, 10) by typing in the final time edit field on Time group box and finally press Enter. Set the plot block by selecting “Plot blocks” item from the View menu. Set horizontal axis “0” for time, and two vertical axis Y[3]: Q4 for vertical “1” and Y[2]: Q8 for vertical 2. For Q4 is rocking motion of the car and for Q8 is heavy motion of the car and also plotting two vertical axis Y[3]: Q14 for vertical “1” and Y[2]: Q18 for vertical 2. For Q14 is rocking motion of the car and for Q18 is heavy motion of the car.

Now, select simulation item from the Disk menu. It will start the simulating and will prompt the end of simulation. Open graph window by selecting “Graphics Display” item from the View menu and a window will appear showing two graphs on it. Choose “Tile vertically” item from the Mode menu of this window to see two graphs in tile mode as displayed in the simulation **Figs.5** to **8**.

The upper graph shows the rocking motion of the car and the lower graph shows the heaving motion of the car. The support parameters are estimated and the response to road excitations is studied as shown in the Table 1.

4.2 Parameter of two wheeled vehicle car model (shown in Table 2).

Table 2
Parameter of two wheeled vehicle car model

Description	**Parameter name**	**Value can be entered**
Distance of rear wheel from C.G.	A	1.1 m
Distance of front wheel from C.G.	B	0.9 m
Front damper (R_{2f})	REAR_DM	100 n.s/m
Rear stiffness (K_{2r})	FRONT_ST	20000 n/m
Front stiffness (K_{2f})	FRONT_ST	20000 n/m
Mass of the car (Mc)	CAR_MASS	1080 kg.
Rear damper (R_{2r})	REAR_DM	100 n.s/m
Moment of inertia of the car (Mcg)	J_CAR	250 kg.m^2
Rear damper (R_{1r})	REAR_DM	100 n.s/m
Front damper (R_{1f})	REAR_DM	100 n.s/m
Rear stiffness (K_{1r})	FRONT_ST	20000 n/m
Front stiffness (K_{1f})	FRONT_ST	20000 n/m
Mass of the car (Jc)	CAR_MASS	1080 kg.
Front Moment of inertia of the car (Mbfg)	J_CAR	250 kg.m^2
Rear Moment of inertia of the car (Mbrg)	J_CAR	250 kg.m^2
Front Mass of the car (Mbf)	CAR_MASS	1080 kg.
Rear Mass of the car (Mbr)	CAR_MASS	1080 kg.
Rear Mass of the car (Jbr)	CAR_MASS	1080 kg.
Front Mass of the car (Jbf)	CAR_MASS	1080 kg.
Front stiffness (K_{3f})	FRONT_ST	20000 n/m
Rear stiffness (K_{3r})	FRONT_ST	20000 n/m
Front damper (R_{3f})	REAR_DM	100 n.s/m
Rear damper (R_{3r})	REAR_DM	100 n.s/m
Front Velocity of the car [Vf(t)]	V	15 m/s
Rear velocity of the car [Vr(t)]	V	15 m/s

Start simulator window by pressing simulated item from the process menu. SYMBOLSHAKTI simulator window will open with active documents. Choose “Parameters” item from the view menu, a box appear showing all system parameters following a small square box to the left of each parameter. Parameter, initial, online, slider, and simulator etc., Here, model parameters can be specified conveniently. Set time range by selecting “Simulation properties” item from the “View” menu. Set the simulation time in seconds (say, 10) by typing in the final time edit field on Time group box and finally press Enter.

Set the plot block by selecting “Plot blocks” item from the View menu. Set horizontal axis “0” for time, and four vertical axis Y[5]: 57 for vertical “1”, Y[4]: P53 for vertical 2, for Y[3]: P49 for vertical “3” and Y[2]: P24 for vertical 4. For P57 heaving motion of the car at rear suspension of the car, for P53 heaving motion of the car at front and rear suspension, for P49 rocking motion of the car at front suspension, and for P24 rocking and heaving motion the car at front and rear suspension [11].

Now, select simulation item from the Disk menu. It will start simulating and will get prompted to end the simulation. Open graph window by selecting “Graphics Display” item from the View menu and a window will appear showing two graphs on it. Choose “Tile vertically” item from the Mode menu of this window to see two graphs in tile mode as displayed in the simulation **Figs. 9** to **13**.

The upper graph shows the rocking motion of the car and the lower graph shows the heaving motion of the car. The support parameters are estimated and the response to road excitations is studied as shown in the **Table 2**.

5. VALIDATION SIMULATION AND RESULT

Simulation result is related to particular type of Indian road. This 2- wheel car model is firstly validated through comparisons of the simulated predictions with measurements obtained from the real 4- wheel vehicle running on the grounds. The simulation of 4- wheel vehicle is done from time (t) = 0 to 10 seconds and for 2-wheel vehicle from time (t) = 0 to 100 seconds. The predicted 2-wheel vehicle results are closely matching with the results of 4-wheel vehicles. The general model has augmented to include the effects of the compliant. Then the parameters describing in Table 1 and Table 2, are determined for model simulation. Actual results from the Symbolshakti software are given below in the **Figs. 5** to **13**:

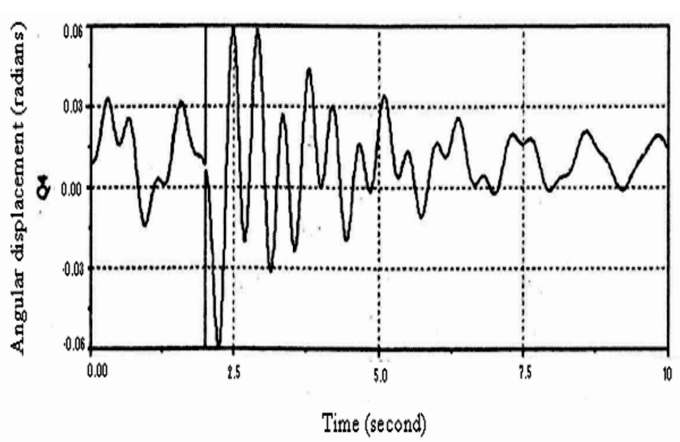

Figure 5: Rocking motion of the car at front suspension with input parameters: Angular displacement - Q4 Radians, Speed - 1m/s, Time- 100 seconds and Suspension- (Q4)

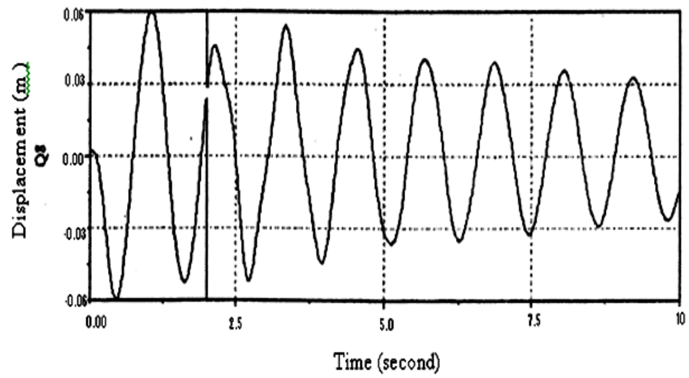

Figure 6: Heaving motion of the car at rear suspension with input parameters: Displacement - Q8 m, Speed -1m/s, Time - 100 seconds, and Suspension- (Q8)

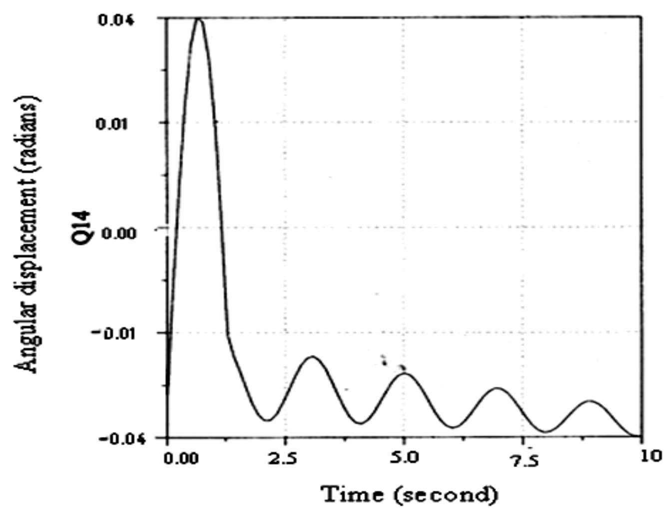

Figure 7: Rocking motion of the car at front suspension with input parameters: Angular displacement- Q14 Radians, Speed - 1m/s, Time- 100 seconds and Suspension- (Q14).

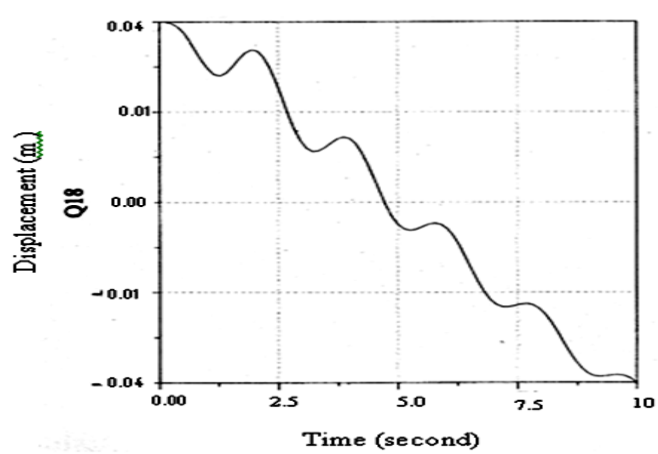

Figure 8: Heaving motion of the car at rear suspension with input parameters: Displacement- Q18 m, Speed - 1m/s, Time - 100 seconds and Suspension- (Q18)

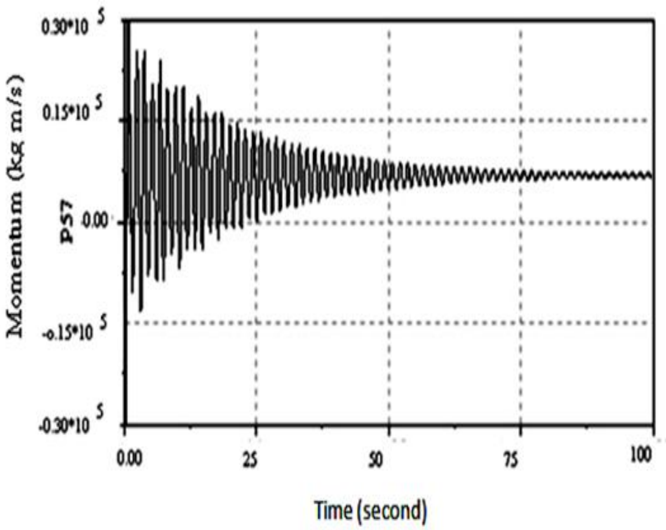

Figure 9: Heaving motion of the two wheeled vehicle car model at rear suspension with input parameters: Momentum of P57 in kg m/s, Speed - 15 m/s, Time - 100 seconds and Suspension - (P57) and Oscillation of 100 seconds

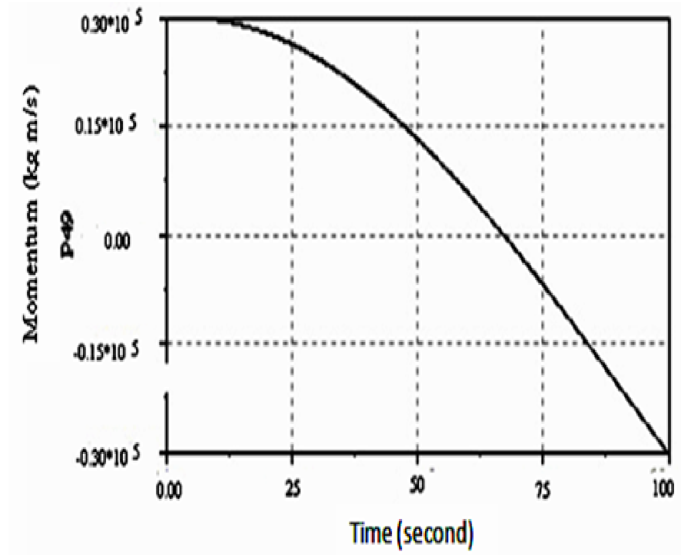

Figure 11: Rocking motion of the two wheeled vehicle car model at front suspension with input parameters as: Momentum of P49 in kg m/s, Speed - 15 m/s, Time - 100seconds, Suspension- (P49) and Oscillation of 100 seconds

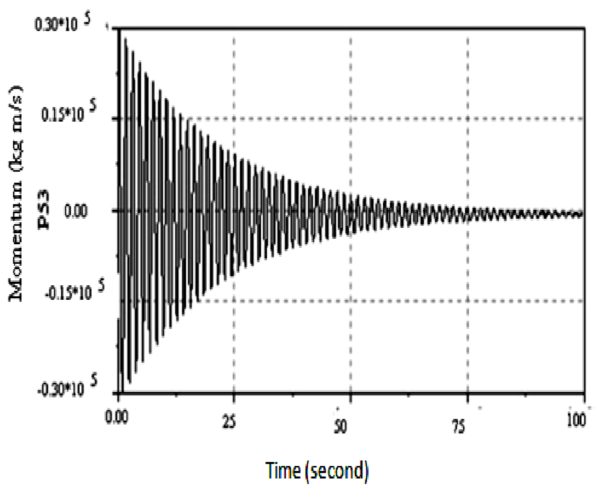

Figure 10: Heaving motion of the two wheeled vehicle car model at front and rear suspension with input parameters as: Momentum of P53 in kg m/s, Speed-15 m/s, Time- 100 seconds, Suspension- (P53) and Oscillation of 100 seconds

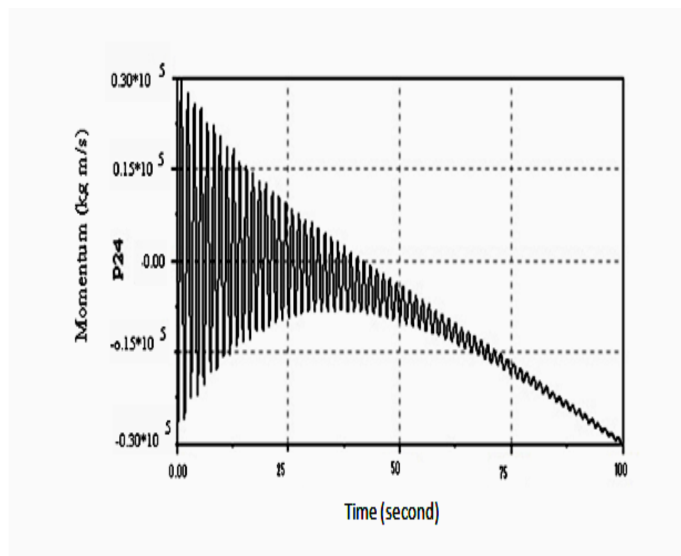

Figure 12: Rocking and heaving motion the two wheeled vehicle car model at front and rear suspension with input parameters as: Momentum of P24 in kg m/s, Speed -15 m/s, Time -100seconds, Suspension- (P24) and Oscillation of 100 seconds

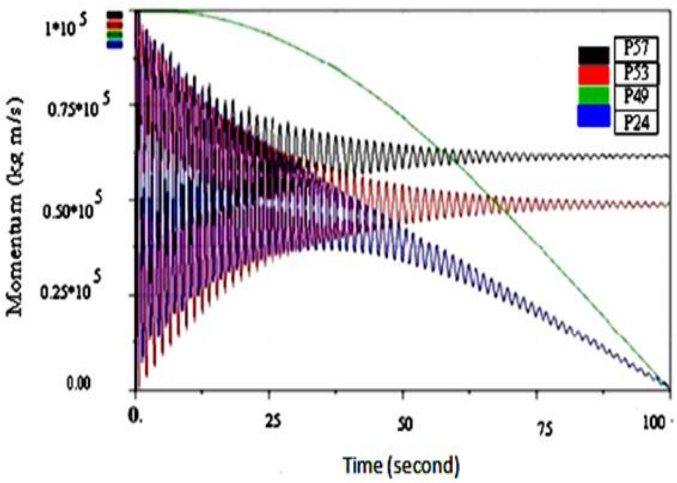

Figure 13: Combined effect of Simulation of two wheeled vehicle car model due to: (a) Heaving motion at rear suspension, (b) Heaving motion at front and rear suspension, (c) Rocking motion at front suspension, and (d) Rocking and heaving motion at front and rear suspension with input parameters as: Momentum of P57, P53, P49 and P24 in kg m/s, Speed - 15 m/s, Time – 100 seconds and Suspension- (P57, P53, P49 and P24) and Oscillation of 100 seconds

6. CONCLUSIONS

A two wheeled vehicle car model using Symbolshakti (bond graph) software has been taken into consideration and simulated to examine its usefulness under the Indian road conditions. In order to evaluate this, a typical bump has been created as an example of road variations. The model of 2-wheel car has been simulation and results are validated with 4- wheel car using Bond-graph Modeling. It has been observed that the results of two wheeled car vehicle model are very close to the results of four wheeled car model.

Thus the two wheeled car vehicle would become very popular under Indian road conditions where such bumps are predominant. The traffic hazards on Indian narrow roads can also be controlled. The cost of such two wheeled car can also get reduced in comparison to four wheel existing cars. The future studies of the two wheeled car vehicle can further be carried out with the help of bond graph model under simulating its variant conditions such as: comfort, stiffness, bumps, tyre slipage etc..

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REFERENCES

[1]. Andradottir. S. R., Healy. K. L,. Withers D. H and. Nelson B. L, 1997, Introduction to modeling and simulation, winter simulation conference Binghamton, NY 13902-6000, U.S.A.

[2]. Silva Luis, Delarmelina Diego, Junco Sergio, K. M. Sirdi Nacer, Noura Hassan,2008 Bond graph based full diagnosis of 4 wheeled vehicles suspension systems of passive suspension, Avenue Escadrille Normadie Niemen, 13397 Marseille Cedex 20, France.

[3]. Adibi-as Hadi, Rideout Geoff,2009, Bond graph modeling and simulation of a full car model with active suspenson, Faculty of Engineering, Memorial University, St. John's NL, Canada.

[4]. Creed Ben, Kahawatte Nalaka and Varnhagen, 2010, Development of a full car vehicle dynamics model for use in the design of an active suspension control system, University of California, Davis.

[5]. Tseng Hongtei Eric, Ashrafi Behrouz, 1999, The development of vehicle stability control at ford on Mechtronics, vol. 4, no.. 3, September 1999.

[6]. Milner David, Goodell Jarrett, Smith Wilford, Pozolo Mike and Ueda Jason, 2009, Modeling and Simulation of an Autonomous Hybrid-Electric Military Vehicle, World Electric Vehicle Journal Vol. 3 - ISSN 2032-6653 - © 2009 AVERE, EVS24 Stavanger, Norway, May 13-16, 2009.

[7]. Louca. Loucas S Stein , Jeffrey L and Rideout D Geoff 2000, Generating Proper Integrated_DynamicModels for Vehicle Mobility Using a_Bond Graph Formulation Automated Modeling Laboratory G029 W.E. Lay Automotive Lab,2000, Michigan.

[8]. Zoroofi Siavash, 2008, Modeling and Simulation of Vehicular Power Systems, International master's 'Program 'Electric Power Engineering 'Sweden, 2008.

[9]. Wakeham j. Keith and Geoff Rideout, D., 2011, Model complexity requirements in design of half car active suspension controllers, ASME Dynamic systems and controls conference.

[10]. Kim Hyung Min, Rideout D. Geoff. Papalambros, Panos Y and. Stein L. Jetlre, 2003 Analytical target cascading in automotive vehicle design. ASME Journal of Mechanical Design, sept-2003, V-125/48.

[11]. Symbolshakti – Mukherjee, A. and Samantaray, A., 2006, Symbolshakti user's manuals, Hightech consultants, STEP, Indian Institute of Technology, Kharagpur, India.

[12]. Mukherjee, A Karmakar, R and Samantaray, A., 2006, Bond graph in modeling and simulation and fault identification, I.K. Publishing House pvt. Ltd., Delhi.

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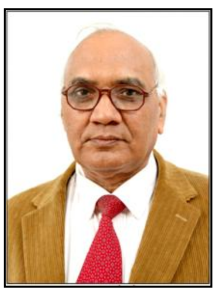
ii). Industrial Economics and Principle of Management, published by New Age International (P) Limited.

Presently he is conducting research in the area of Bond Graph under the supervision of Prof. (Dr.) M. A. Faruqi. He has published 9 National and 7 International paper in various conferences, seminar and journals. Mr. Singh is a Life Member of Indian Society of Technical Education (ISTE) India.



(Dr.) Bharat Raj Singh– received B.E. (Mechanical) degree, from SVNIT, Surat, South Gujarat University, India in 1972, M.E. (Analysis & Design of Process Equipments), from MNNIT, Allahabad University India in 1988 and Ph.D. from GB Technical University, Lucknow, India in 2011. Dr Singh has four decades experience of Industry, Administration and Academics. Served 32 years in various Government Organizations and retired as *Managing Director*, UP Rajkiya Nirman Nigam, Lucknow and 8 years in Academics at various positions as Professor, Head of Department- Mechanical Engineering., Dean and Deputy-Director and Associate Director. He was recipient of many recognitions and awards.

He is currently working as *Director (R&D)* with *School of Management Sciences, Technical Campus, Lucknow (India).*

Dr. Singh published about 56-papers in leading International, National Journals and proceedings of Conferences. Also published 5- books**:**

(i) Development and Analysis of a Novel Air Engine**;** ISBN: 978-3-8443-8171-9, Lap LAMBERT Academic Publishing, UK.

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(iv) Global Warming; ISBN:979-953-307-820-4, Full Chapter: Study of Impacts of Global Warming on Climate Change: Rise in Sea Level and Disaster Frequency, InTech Open Access Publisher, Rijeka, Croatia, (Received 18 November 2011, accepted 28 January 2012) –In press.

(v) A Hand Book on Friction Stir Welding; ISBN: 978-3-659-10762-7, Lambert Academic Publishing, GmbH & Co. KG, Germany, UK, (Received 29 Mar 2012, accepted 20 Apr 2012, published 05 Jun 2012).

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