**16th International Research/Expert Conference**
**"Trends in the Development of Machinery and Associated Technology"**
**TMT 2012, Dubai, UAE, 10-12 September 2012**

# MATHEMATICAL AND COMPUTER MODELING AND THE DIFFERENCE BETWEEN LINEARITY AND NONLINEARITY

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## ABSTRACT
*In this paper through MathCAD's we have analysed nonlinear differential equations of second order of a mechanical system that responds to a vehicle. Reduction is made in the order of differential equations where from four second-order equations, eight first order equations are made. Solving the system of differential equations is done in MATLAB. It issued a comparison of the results of a nonlinear model and the simplified linear.*
**Key words:** vehicle, model, system, equation, linear, non-linear, MathCAD, Simulink.

## 1. INTRODUCTION
This paper will discuss the results obtained from the system of linear equations and nonlinear which will compare and will present graphically. On review we take a model with four degrees of freedom, which corresponds to a passenger vehicle and who also moves through the uneven road which is described by the expression:

$$x_0 = 0.1 \cdot \sin(0.25 \cdot t) \ [m].$$

Given:

$c_g$=80000 [N/m]; $c_{s,amI}$=45000 [N/m]; $c_{s,amII}$=30000 [N/m]; $b_{am}$=4500 [Ns/m]; M=1680 [kg];
$m_{b,I}$=50 [kg]; $m_{b,II}$=40 [kg]; $J_C$=3500 [kg/m$^2$]; $L_1$=0,9 [m]; $L_2$=1,1 [m].

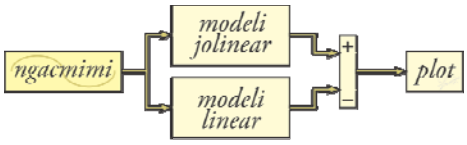



*Figure 1. The Chart used in analysis of the difference between linearity and non-linearity*

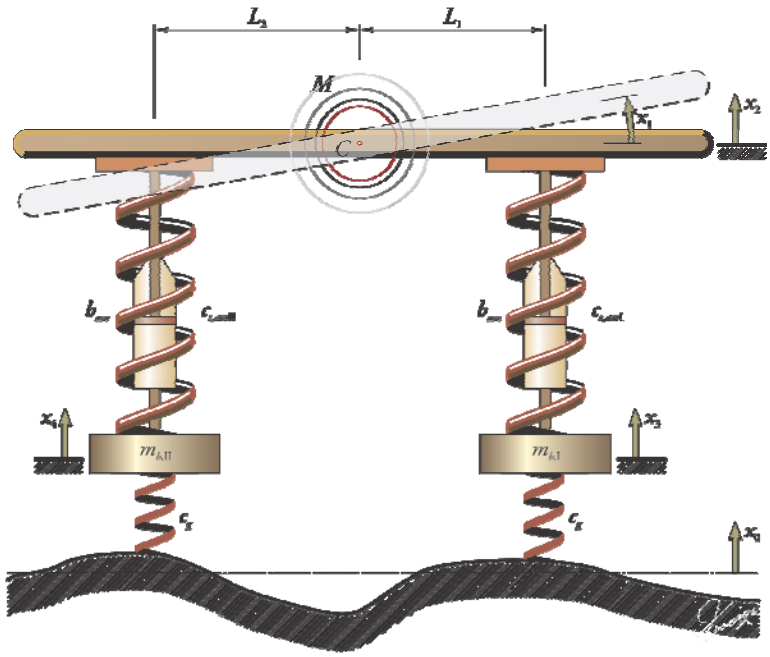



*Figure 2. Mechanical Model of a vehicle*

## 2. DEVELOPMENT OF DIFFERENTIAL EQUATIONS

Lagrange equations of second order, for oscillations of the system, in this case will look like:

$$\frac{d}{dt}\left(\frac{\partial E_k}{\partial \dot{x}_j}\right)+\frac{\partial E_p}{\partial x_j}+\frac{\partial D}{\partial \dot{x}_j}=Q_j;\ \text{where } j = 1, 2, 3 \text{ and } 4.$$

With the help of MathCAD software using Lagrange equations of the second order, we can draw four differential equations of the second orden.

## 3. THE SYSTEM OF DIFFERENTIAL EQUATIONS

After substitutions and decreasing order of the differential equations will acquire eight differential equations of the first order. To realize the solution of nonlinear model in MATLAB/ Simulink we have to write equations of the form:

$$dx_1 = x_5; \qquad dx_2 = x_6; \qquad dx_3 = x_7; \qquad dx_4 = x_8.$$

$$dx_5 = \frac{-1}{J_C}\cdot\{c_{s,amI}\cdot[x_2 + L_1\sin(x_1) - x_3]\cdot L_1\cos(x_1) -$$
$$- c_{s,amII}\cdot[x_2 - L_2\sin(x_1) - x_4]\cdot L_2\cos(x_1) +$$
$$+ b_{am}\cdot(x_6 + L_1\cdot x_5 - x_7)\cdot L_1 - b_{am}\cdot(x_6 - L_2\cdot x_5 - x_8)\cdot L_2\};$$

$$dx_6 = \frac{-1}{M}\cdot\{c_{s,amI}\cdot[x_2 + L_1\sin(x_1) - x_3] + c_{s,amII}\cdot[x_2 - L_2\sin(x_1) - x_4] +$$
$$+ b_{am}\cdot[2x_6 - x_5(L_1 + L_2) - x_7 - x_8]\};$$

$$dx_7 = \frac{-1}{m_{b,I}} \cdot \left\{ c_{s,amI} \cdot \left[ x_2 + L_1 \cdot \sin(x_1) - x_3 \right] + c_g \cdot \left[ x_3 - x_0(t) \right] - b_{am} \cdot \left( x_6 + L_1 \cdot x_5 - x_7 \right) \right\};$$

$$dx_8 = \frac{-1}{m_{b,II}} \cdot \left\{ c_{s,amII} \cdot \left[ x_2 - L_2 \cdot \sin(x_1) - x_4 \right] + c_g \cdot \left[ x_4 - x_0(t) \right] - b_{am} \left( x_6 - L_2 \cdot x_5 - x_8 \right) \right\}.$$

This way, we'll construct the chart for the simulation and analysis of the difference between the linear and non-linear system.

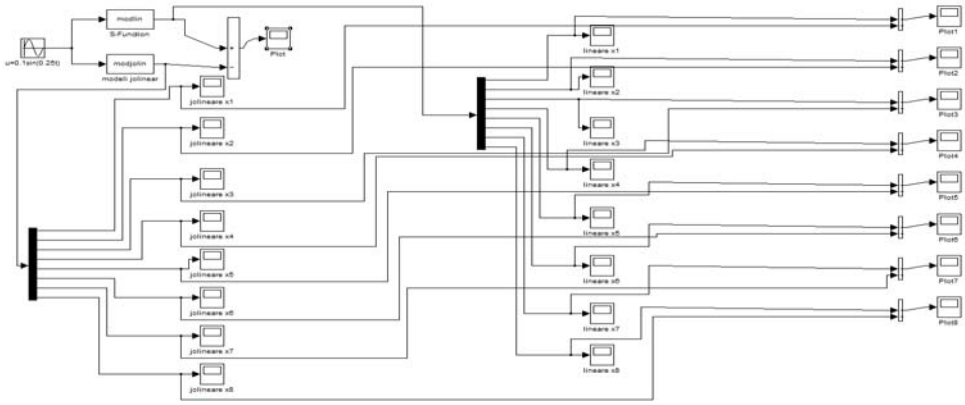
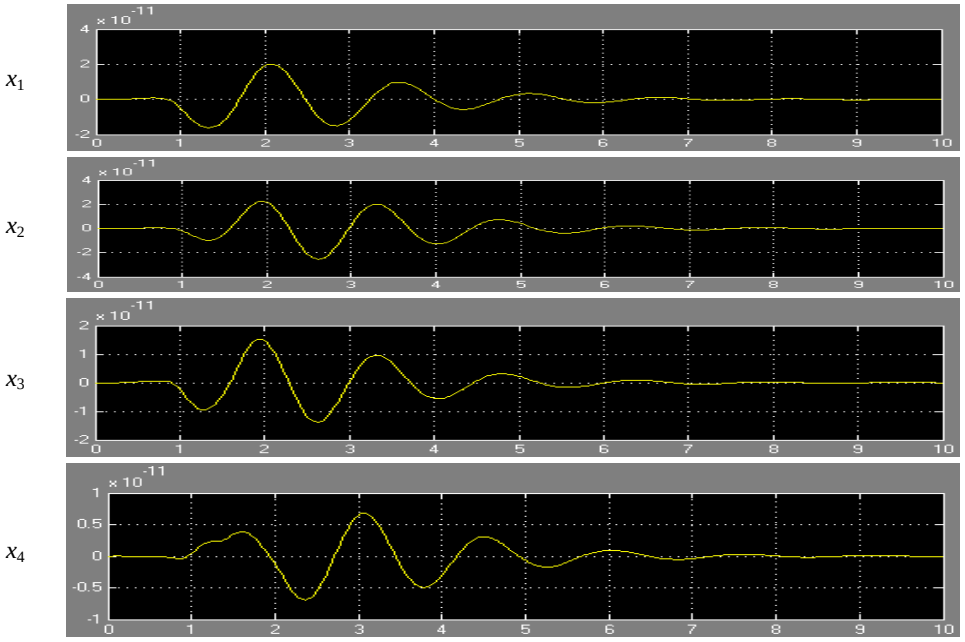


*Figure 3. The chart developed for the simulation*

Now, we'll present the difference between the linear and non-linear model.



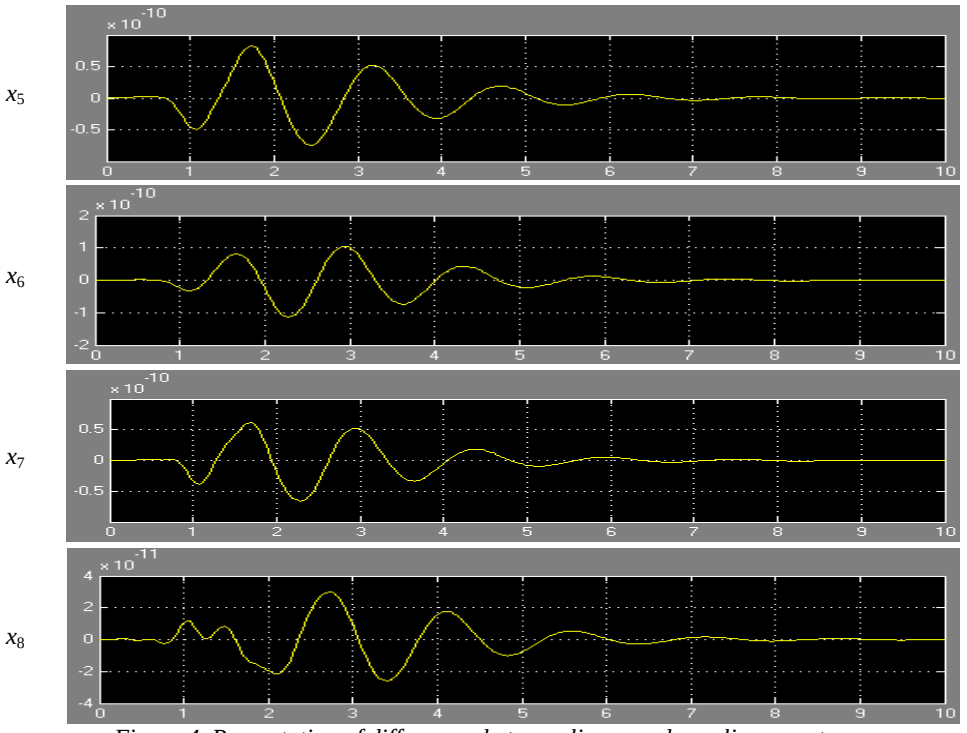
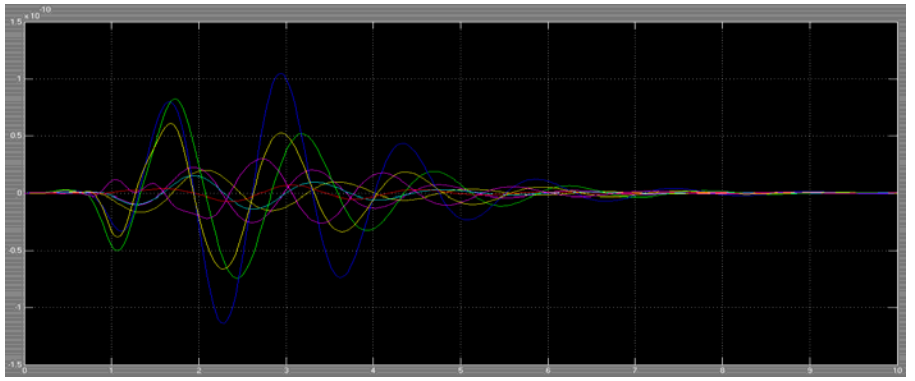



*Figure 4. Presentation of differences between linear and non-linear system*

## 4. CONCLUSION

In this paper we take a concrete example of a vehicle which moves with constant speed in a way that is not flat sinusoidal shape. We have discussed a topic which contains more calculating difficulties and we introduced the change that occurs between linear and nonlinear solucion even though the lower order is almost impossible to estimate without the support of information technology. All changes have given in a diagram as follows.



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