ANALYTICAL VIBRATING SOLUTIONS OF THE NEW DESIGNED CAR WITH THE COMPARISONS

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ABSTRACT

A very latest designed BMW focusing on the following features; a new body shape, the body shape analysis, a particular chassis design for the designed car, the analysis of installed chassis into the car body, the regarding and relevant calculations with reference to the resulted diagrams, the accurate consequences of the calculations and finally the analysis of the resulted calculations.

KEYWORDS: *Damper, Chassis, Lagrange's Equations, Wheels & Mesh body*

I. INTRODUCTION

The presenting article involves a designed BMW automobile including a designed particularly specific chassis. The assumed as well as considered issue in the field of mechanical vibration theories can help in order to create a defined and distributed reaction to both the surroundings and chassis. [1] The sketched chassis includes the springs and the dampers to rectify both the estimated strokes to the engine and the chassis. This will help the approximately focused strokes into the bumper or engine converted to a distributive energy over the whole surroundings and compartments of automobile. The condition of the pre-stroked forces at both front and rare section of chassis as well as the function of the dampers including the installed spring in the design are stated by the charts and analytical solutions. The Lagrange's vibration equations of the design system were expressed. Having solved the calculated equations and achieving the b factors, the efficiency of the strokes to the front and rare of the car body and the repealing of the strokes caused by the dampers and the springs will be argued. [2] The major issue here is the rate of the efficiency and damping of the stroked forces to the applied system on the car body and the returning function of the absorbed forces on the body which therefore the strokes and the system efficiency under this circumstance is superiorly illustrated in the scheme by an undisputed superior rate. There is a flowchart consists of the designing process, the designing analysis, and the former performed process to the finalized output process which illustrated on Figure 1.

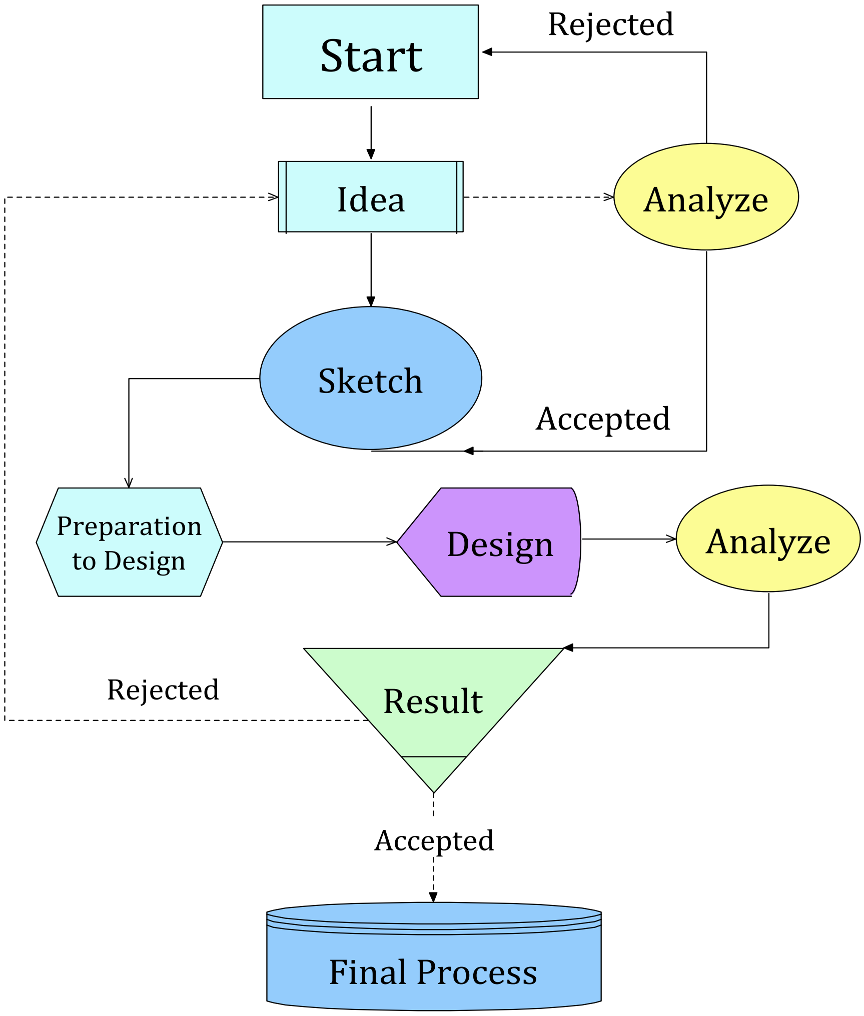

Figure 1. The schematic flowchart of the design processing with the details of portions

The automobile whole body was basically designed from BMW designs (with the combination of I8 concept and coupe 6 Series) to finally create a make accurately between the mentioned makes by two applications such as; 3D MAX and SOLID WORKS. [3] Besides a new particular and suitable designed chassis and fit in the front of the car which the detailed information is illustrated on Figure 2 accordingly.

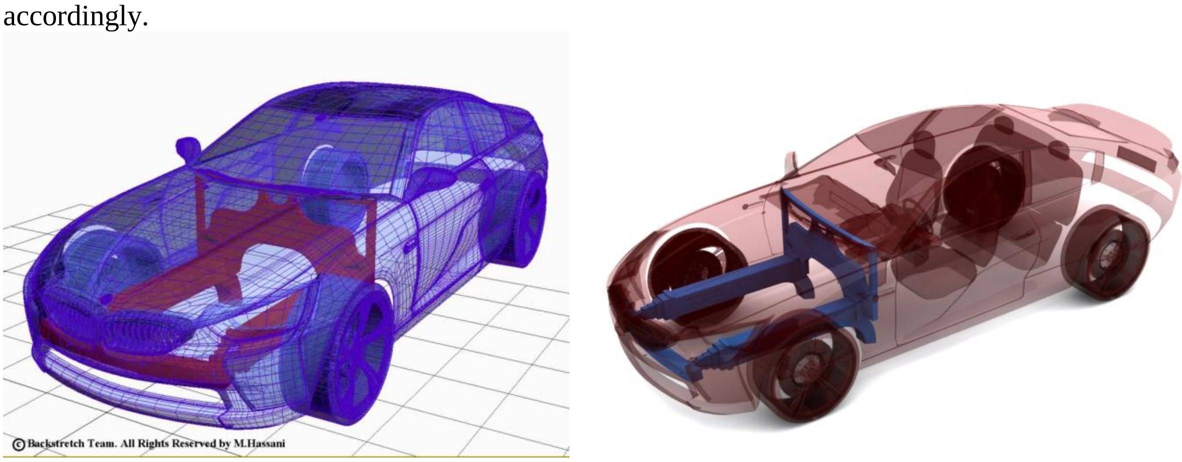

Figure 2. (a) The illustrated design on the meshed body and the chassis **(b)** The demonstration of the whole contained chassis including the details

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The SOLID WORKS where applied due to the designing for the mentioned chassis and the 3D MAX applied to design of the body shape. In order to demonstrate how the body structure at the front in the condition of brunt forces is changeably transitional is figured and illustrated on Figure 2 by the meshed lines right after performing the brunt forces to transit toward to the front.

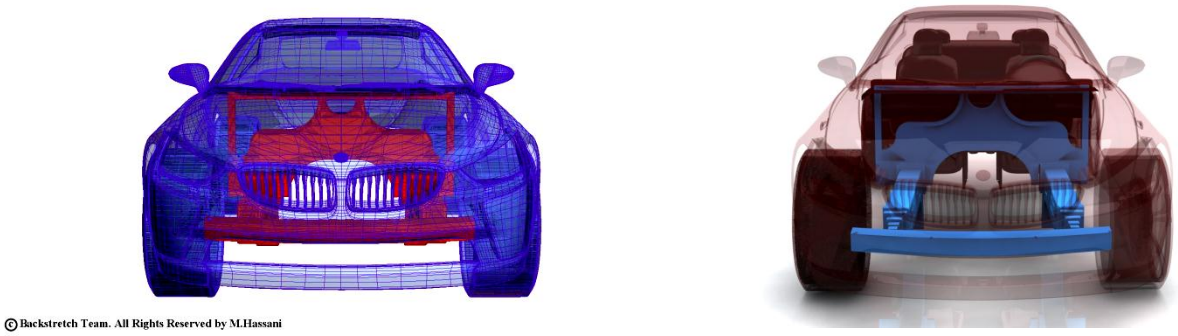

Figure 3. Illustration of the designed body in accord with the designed chassis [3]
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The horizontal vibration strokes are technically limited and distributed to the car sides and rare part to excessively diminish the proportion of transited vibration strokes. It is noticeable that the similar mechanical design is concerned to the chassis at the rare part of the automobile which is found on Figure 3. The calculations as well as vibration equations have accurately and analytically resulted in following sections on the article.

II. Car Suspension and Structure Model

II.1 Mathematical Formulation

A quarter car model used in Figure 4 is used to define a new suspension control law;

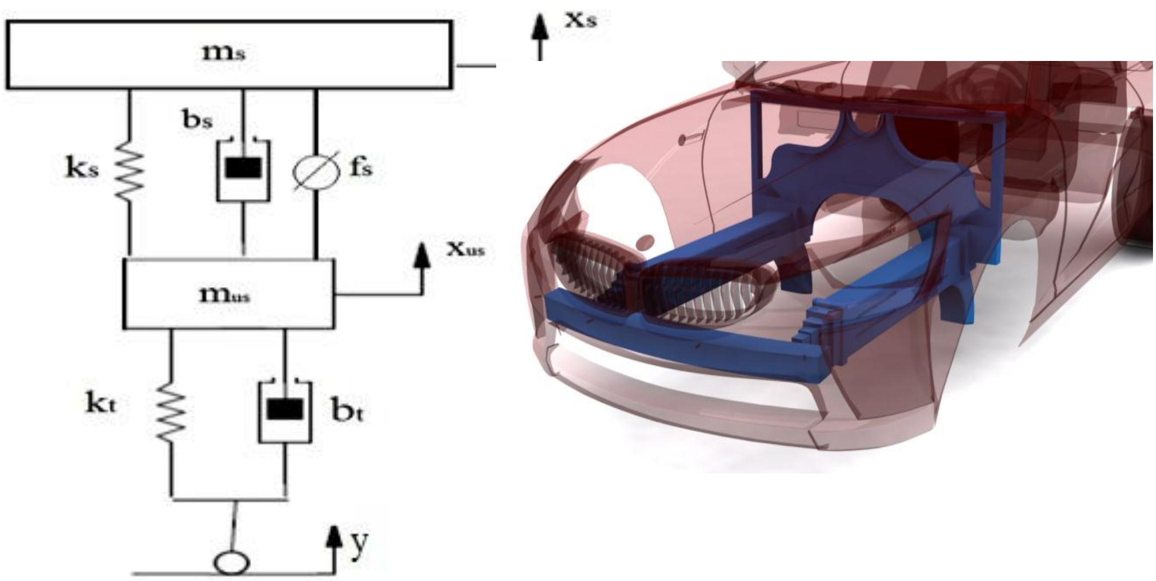

Figure 4. (a) Active suspension system law **(b)** Whole perspective of the designed car including the proposed chassis

The sprung mass m_s represents the car chassis, while the unsprung mass m_{us} represents the wheel assembly. The spring, K_s, and damper, b_s, represent a passive spring and shock absorber that are placed between the car body and the wheel assembly, while the spring K_t and the damper b_t serves to model the compressibility of the pneumatic tire. The variables X_s, X_{us} and r are the car body ravel, and the road disturbance, respectively. The force f_s, in the unit of KN, applied between the sprung and unsprung masses, is controlled by feedback and represents the active component of the suspension system. If the dynamics of the actuator be ignored and assume that the control signal be the force f_s, also defined $x_1 = x_s$, $x_2 = \dot{x}_s$, $x_3 = x_{us}$ and $x_4 = \dot{x}_{us}$, then the following is then the state-space description of the quarter car dynamics.

$$\dot{x}_1 = x_2 \quad \textbf{(1)}$$

$$\dot{x}_2 = -\frac{1}{m_s}\left[k_s(x_1 - x_3) + b_s(x_2 - x_4) - f_s\right] \quad \textbf{(2)}$$

$$\dot{x}_3 = x_4 \quad \textbf{(3)}$$

$$\dot{x}_4 = \frac{1}{m_{us}}\left[k_s(x_1 - x_3) + b_s(x_2 - x_4) + b_t(x_4 - y) - f_s\right] \quad \textbf{(4)}$$

II.2 EQUATIONS OF MOTION

The applied quotations in this research consist of Lagrange's equations as well as other nonlinear calculations so as to introduce the applied and designed system. [4] The generalized nates $x(t)$ and $\theta(t)$ are applied to describe the system vibration. The system used to define and analyze is shown by Figure 5.

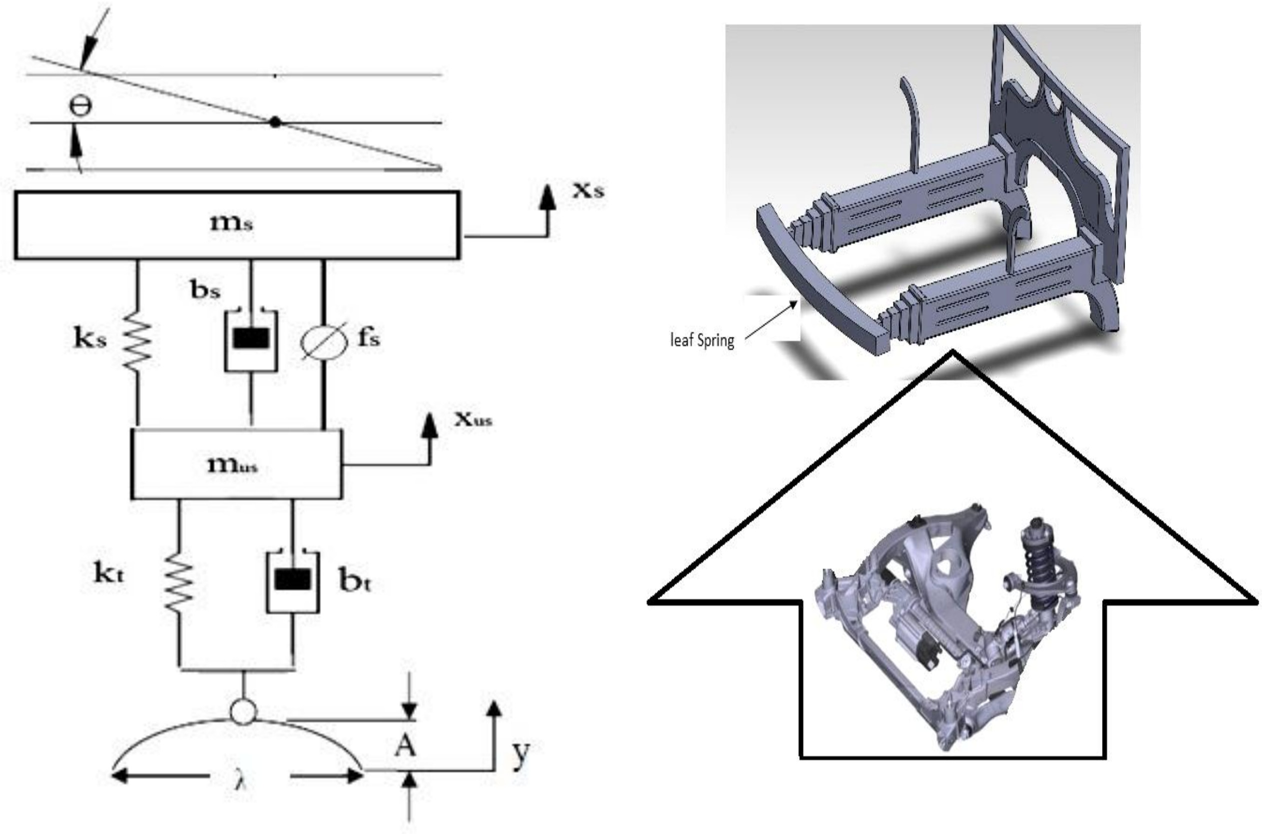

Figure 5. (a) Schematic system motion of the tire in the ramp situation
(b) Chassis and the information of the portions

It is noticeable that the car elastic model illustrates the dampers and springs system which had assisted to write dynamical equation process.

As it is fairly shown and considerable, the assumed resulted equations have been precisely calculated. Also the elastic dynamical model of the body is represented on Figure 6.

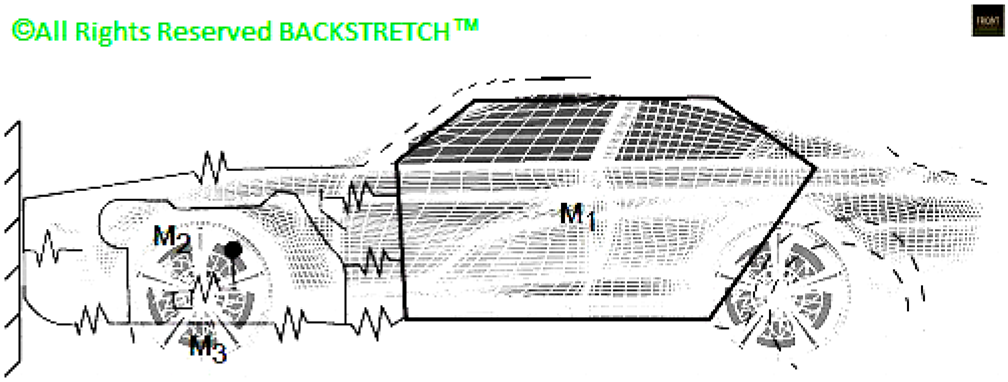

Figure 6. Elastic model of the whole body structure
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M_1 represents the whole body mass, $M_2 = M_s$ and $M_3 = M_{us}$. Also the simulation of the elastic model of body which consists of the dampers, springs, engine system and the body mass are illustrated on Figure 7. The considering issue here is the sequence of the springs and dampers arrangement in the suspension system complex.

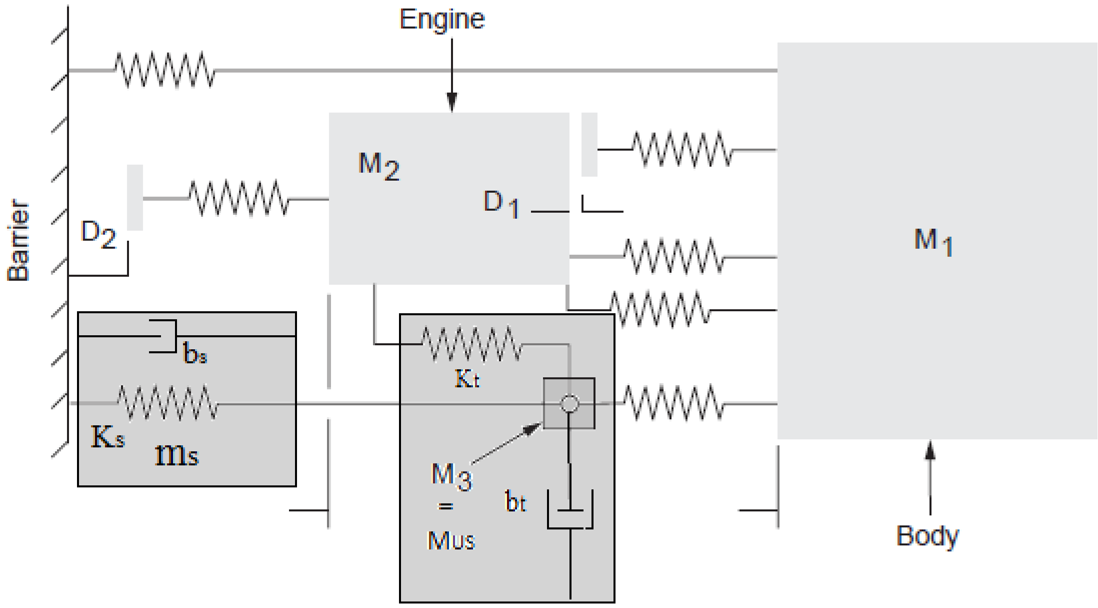


Figure 7. Simulation of the Elastic Model of Body [7]

As it is imagined on Figure 7 the whole complex works accurately when the active and passive results of the vibration equations are to be bilaterally equal. In order to reach the mentioned issue, it is required to solve and analyze the vibration equations into the system.

II.3 Mathematical Calculations

The kinetic energy according to the Euler Equation is as the following:

$$T = -\frac{1}{2} m_{us} \dot{x}_{us}^{2} - \frac{1}{2} m_s \dot{x}_s^{2} + \frac{1}{2} J \dot{\theta}^{2} \qquad \textbf{(5)}$$

The potential energy demonstrated in Equation 2 as:

$$U = \frac{1}{2}k_t(y + x_{us} + l\theta)^2 + \frac{1}{2}k_s(y + x_s + l\theta)^2 \quad \textbf{(6)}$$

Rayleigh's dissipation function demonstrates viscous dissipation in the dampers is:

$$Q = \frac{1}{2}b_t(\dot{y} + \dot{x}_{us} + l\,\dot{\theta})^2 + \frac{1}{2}b_s(\dot{y} + \dot{x}_s + l\,\dot{\theta})^2 \quad \textbf{(7)}$$

The Lagrange notation $L = T - U$ evaluated by (1) and (2), and the both including with (3) substituted in (4) and (5) have the equations of the automobile motion obtained. [6]

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{x}}\right) - \frac{\partial L}{\partial \dot{x}} = \frac{\partial Q}{\partial \dot{x}} \quad \textbf{(8)}$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \dot{\theta}} = \frac{\partial Q}{\partial \dot{\theta}} \quad \textbf{(9)}$$

The application of Equations 4 and 5 yields:

$$(m_{us} + m_s)\ddot{x} + (b_t - b_s)\dot{x} + (lb_s + lb_t)\dot{\theta} + (k_t + k_s)x + (lk_s + lk_t)\theta = k_t y + k_s y + b_t\dot{y} + b_s\dot{y} \quad \textbf{(10)}$$

$$J\ddot{\theta} + (b_s l - b_t l)\dot{x} + (l^2 b_s + l^2 b_t)\dot{\theta} + (k_2 l_2 - k_1 l_1)x + (l^2 k_t + l^2 k_s)\theta = k_s l y + k_t l y - b_s l\dot{y} + b_t l\dot{y} \quad \textbf{(11)}$$

The equation of motion can also be shown in matrix form as:

(12)

$$\begin{bmatrix} m_{us} + m_s & 0 \\ 0 & J \end{bmatrix}\begin{bmatrix} \ddot{x}(t) \\ \ddot{\theta}(t) \end{bmatrix} + \begin{bmatrix} b_t + b_s & lb_s - lb_t \\ lb_s - lb_t & l^2 b_s - l^2 b_t \end{bmatrix}\begin{bmatrix} \dot{x}(t) \\ \dot{\theta}(t) \end{bmatrix} + \begin{bmatrix} k_t + k_s & k_s l - k_t l \\ k_s l - k_t l & l^2 k_t + l^2 k_s \end{bmatrix}\begin{bmatrix} x(t) \\ \theta(t) \end{bmatrix} = \begin{bmatrix} k_t & k_s \\ -k_t l & k_s l \end{bmatrix}\begin{bmatrix} y_t \\ y_s \end{bmatrix} + \begin{bmatrix} b_t & b_s \\ -b_t l & b_s l \end{bmatrix}\begin{bmatrix} \dot{y}_t \\ \dot{y}_s \end{bmatrix}$$

Having solved the equation 12 by either the accessible Mathematics Software or Cayley Hamilton theorem which was applied to the calculation above, the final calculation resulted in b coefficients in the system which its analysis illustrated on Figure 8. The arrangement of the calculation operations is figured on chart 1.

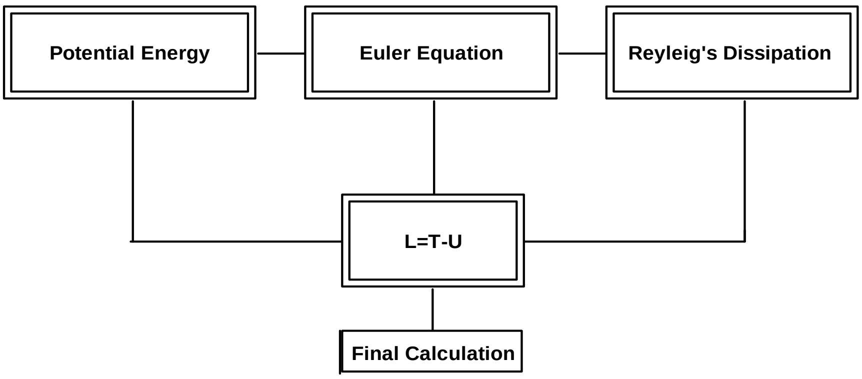
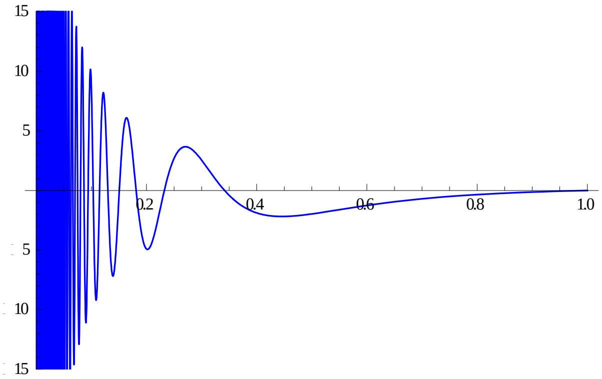
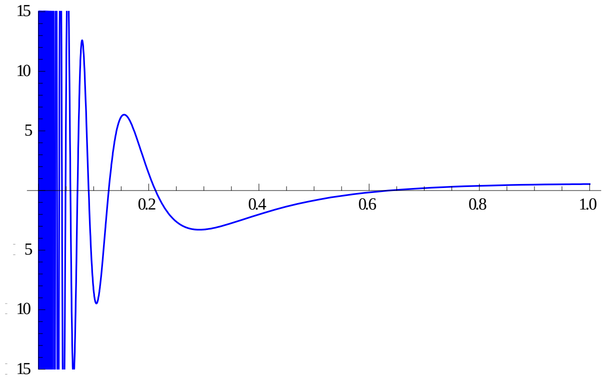


Chart 1. Arrangement calculation operations

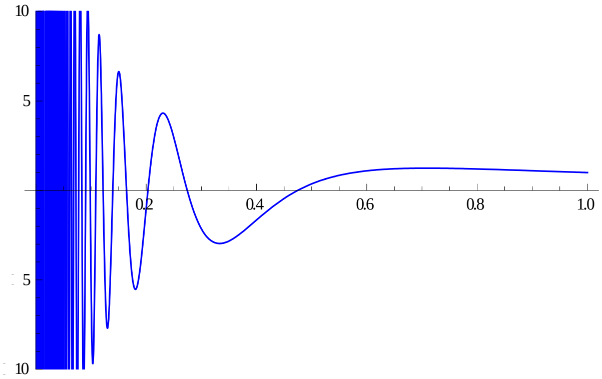
Having solved the matrix above, the bs coefficients are calculated and demonstrated as the followings:



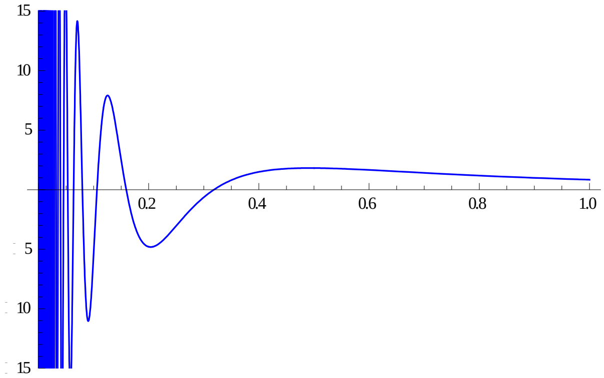
(a) First stage of adapting the chassis and applied forces Which striked to the chassis through the interval [0.2, 0.88]



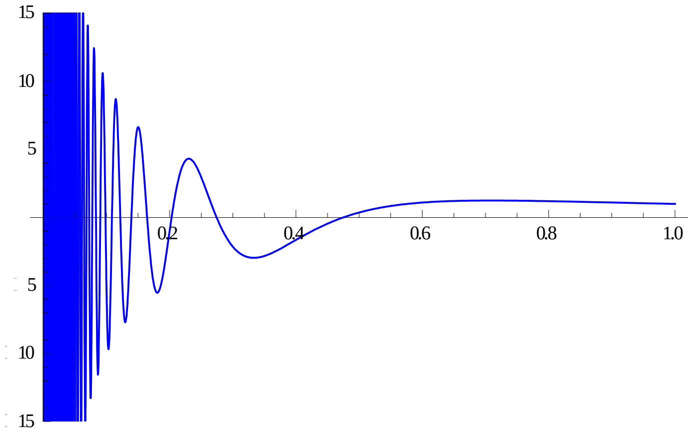
(b) Second stage with the maximum impact on the chassis through the interval of [0.6, 1.0]



(c) Third stage which is related to the reversing of the applied Forces and the functional time of impact started from 0.43 sec



(d) Final adapting process and the ultimate impact of the applied tension



(e) Final stage of damped suspension system

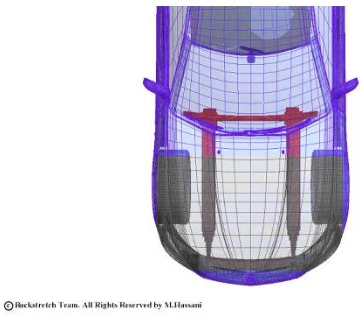
Figure 8. The state of dampers adaptation in the brunt forces condition through the interval of [0, 0.1] second sequentially illustrated

In addition to the obtained b coefficients, which are related to the system motion, are derived from Lagrange's equations which illustrate the springs and dampers vibration of the car suspension system. Besides all the designed dampers and springs in this research attentively calculated as the b coefficients similarly, this research sequentially as well as accurately proves the calculations on dampers and springs installed right before the front and rare bumpers are connected to chassis, remarkably resulted in similar coefficients, as well. As the consequence of the argumentation above, the purpose of

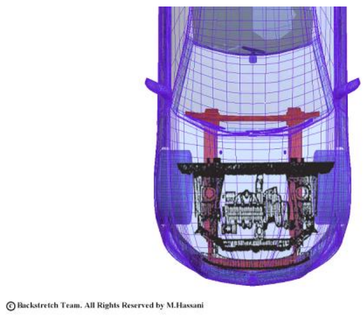
the attained diagrams illustrated on Figure 8 are technically stated each situation process of the suspension system actions.

III. CONCLUSIONS

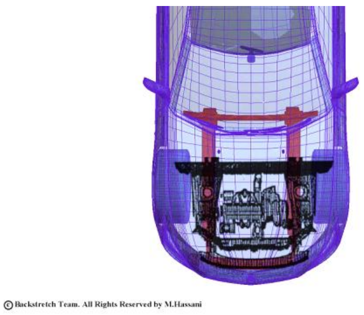
The main idea of the design is exclusively inspired and then innovated from the characteristics of the mechanical behaviors on concepts. One of the cases through thousands of the pursued researches is the car and the actions of the suspension system in the situation of the brunt forces acted by the external and accidental obligations. Accordingly, as the suspension system is noticeably taken granted for designing which practically impacts mainly the dissipation of the stroked forces on the car body. The final process of installing chassis on the engine and the adjusted comparisons of the engine dimensions with reference to the designed chassis in this study are illustrated on Figure 9.



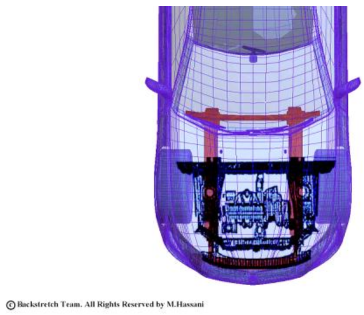
(a) The primary installed chassis



(b) The designed chassis including the detailed engine Information



(c) The completed design on car body and chassis



(d) The whole perspective of the body

Figure 9. Process of adjustable comparisons of the engine dimensions with reference to the designed chassis

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