



Graphical user interface (GUI) for design of passenger car suspension system using random road profile

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Abstract

In this paper, an Interactive approach has been introduced for the design of Passenger car suspension system subjected to random road profile, by building a graphical user interface (GUI), using Matlab/Guide has been presented. The aim of the work is to show the importance and usefulness of the developed GUI in designing and describing the dynamic behavior of car suspension system for different design criteria. Common problems in the field of design of suspension systems for the quarter-car passive model are analyzed. The result shows that the designed GUI is very convenient for engineers, analysts, and designers of car suspension systems.

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Keywords: Car suspension system; GUI; Design; Random road profile; Quarter car model.

1. Introduction

Study and design of car suspension systems are an important part of automotive engineering. Passive suspension systems have wide use in passenger vehicles but they cannot effectively sustain vehicle comfort under different road profiles without the help of a computer design tool for the analysis of these systems. The systems with more than two degrees of freedom required more analytical and computational efforts. In order to help engineers to likely solve these kinds of systems, numerically, they have to master a suitable programming environment. An essential design and analysis of suspension systems can be handled using software like Matlab. MATLAB (Matrix Laboratory) is a commercially suitable software package developed in the seventies by Cleve Moler, [1], for numerical computations, especially matrix manipulations. Now days, it is a high-level technical computing language and interactive environment, for algorithm buildings, results visualization, results analysis, and numerical analyses, widely used in academic and in sectors [2]. The analysis capabilities, flexibilities, reliability, and powerful graphics make Matlab the most used software package by engineers and scientists [3]. Matlab represent an interactive tool with a lot of good and accurate built-in mathematical functions. The functions provide good solutions to many mathematical and engineering problems such as matrix manipulation, static and dynamic systems, etc. In this work, the use of Matlab as a programming tool to design and build a graphical user interface (GUI) for the analysis of car suspension system can be carried out using MATLAB/GUIDE environment [4].

2. Mathematical model of quarter car suspension system

Car suspension systems are always modeled as two degree of freedom quarter-car suspension model, shown in Figure 1 [5]. The model consists of a quarter-car body and a wheel connected with a suspension system. The suspension system consisted of spring and damper elements, and considering the tire as a spring in contact with the road profile.

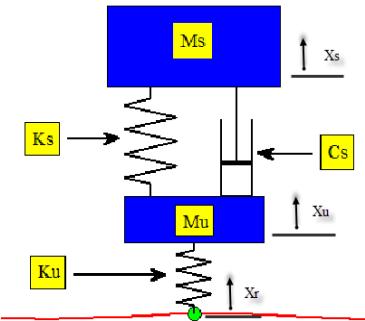


Figure 1. A two degree of freedom quarter car suspension model [5].

The dynamic equations of this model can be written as follows:

$$\begin{aligned} m_s \ddot{x}_s + C_s (x_s - x_u) + K_s (x_s - x_u) &= 0 \\ m_u \ddot{x}_u - C_s (x_s - x_u) - K_s (x_s - x_u) + K_u (x_u - x_r) &= 0 \end{aligned} \quad (1)$$

where, \$m_s\$ represent the 1/4 car body mass, and \$m_u\$ is the wheel mass. \$K_s\$ and \$K_u\$ are the stiffness of the suspension car body and the car tire respectively. \$C_s\$ is the damping constant. \$x_s\$, \$x_u\$, and \$x_r\$ are the vertical displacements of the car body, tire displacement, and road displacement respectively.

3. Design and analysis

The design and analysis of quarter-car suspension model is carried out using Matlab through direct implementation of model design parameters as given in equation (1). Three design criteria were used in the development of the GUI that were, as designed, for handling, and for comfort criterion. Each criterion required different design parameters which are suitable for the analysis. The damping coefficient of suspension system was varied from initial values to up to an optimum value to suggest an optimized value for each design criteria.

The procedure described above is implemented in the development of a Matlab GUI. The developed GUI were used to design and analyze the sensitivity of the suspension system to the variation of different design parameters. The GUI provides plots to the position, velocity, and acceleration of the car and the tire after the car hits a random road profile, as well as animating the response of the suspension system.

4. Results and discussion

An important task is to find the value of the damping coefficient \$C_s\$ that makes; the car passengers have maximum comfort. Car passengers are always sensitive to body mass acceleration and displacements. In this work, a quarter-car suspension model of a Peugeot 206 passenger car has been considered to the analysis using the developed GUI. The data required for the analysis is obtained from the Peugeot Website [6], as follows:

$$M_s = 1360/4 \text{ Kg}, M_u = 25 \text{ kg}, K_s = 24000 \text{ N/m}, K_u = 192000 \text{ N/m}, C_s = 850 - 4000 \text{ N.m/s}.$$

The analysis start by running a script file called main a popup menu will be shown as in Figure 2.

The user asked to choose one of the design criteria shown in the menu. For as design criterion, the window shown in Figure 3 will appear, in which the required information for the analysis will be inserted. The default values are the values of the Peugeot 206 passenger's car which is chosen as a case study in this work. By keeping the default values or inserting new data, in the above window, as in the figure above, and pressing the Go button, the analysis starts showing an animation of the movements of the suspension system due to the given data for five seconds, as shown in Figure 4. Then the analysis results are shown in Figures (5, 6 and 7) respectively. Figure 5 shows the relative displacement of the tire and car body due to the random road profile for the considered as designed criterion. It is obvious from this figure that the deflection of the car body has higher amplitude than the tire. While Figure 6 shows the positions, of the tire and car body. A Similar conclusion can be drawn, for this figure, that the amplitude of the position of the car body is higher than tire. Figure 7 shows displacement, velocity, and acceleration of the tire and car body due to the road input, and it was clear that a similar conclusion can be drawn also for the behavior. This indicates the need for further analysis by changing the damping coefficient, to reduce the body deflection to an acceptable level which maintains the comfort of the passengers. Starting such an analysis, using the developed GUI, with different damping coefficient values can be done by choosing another criterion such as for handling criterion, will generate the output shown in Figures (8, 9, and 10) respectively. Those Figures show clearly that by changing the value of the damping coefficient, the amplitude and settling time of the car body deflection, position, and other

parameters such as displacement, velocity, acceleration were reduced. Carrying out further analysis by using of comfort criterion, the results are generated and shown in Figures (11, 12, and 13) respectively. Those Figures show better behavior for the considered design criterion for the suspension system comparing with the other criteria. It is obvious from the behavior of the design parameters such as velocity, acceleration, and deflection, which affects the comfort of the passengers, was improved for this criterion, which is the most used criterion for the analysis and design of passive car suspension systems.



Figure 2. The main GUI menu.

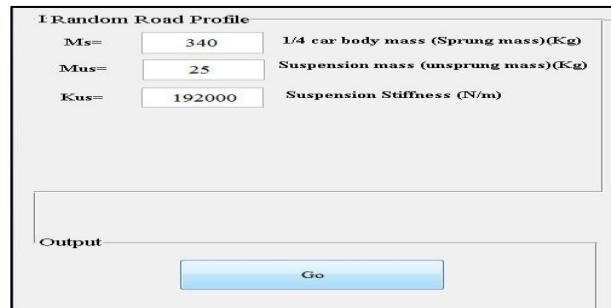


Figure 3. The main window for the required data.

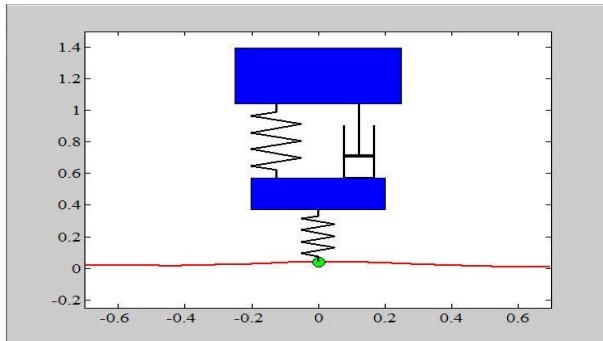


Figure 4. Suspension system due to the random road profiles.

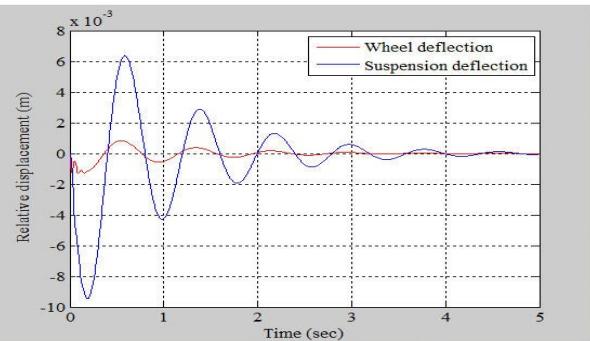


Figure 5. Relative displacement of wheel and suspension deflections for as designed criterion.

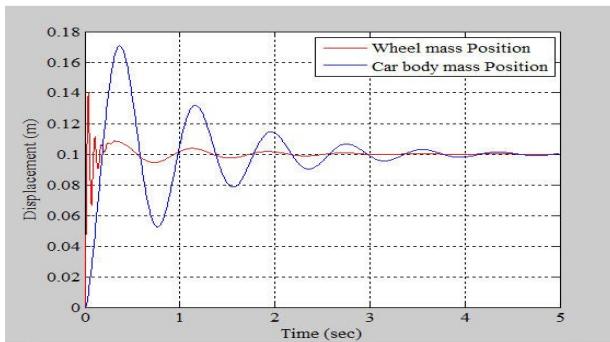


Figure 6. Wheel and Car Body Mass Position for as designed Criterion.

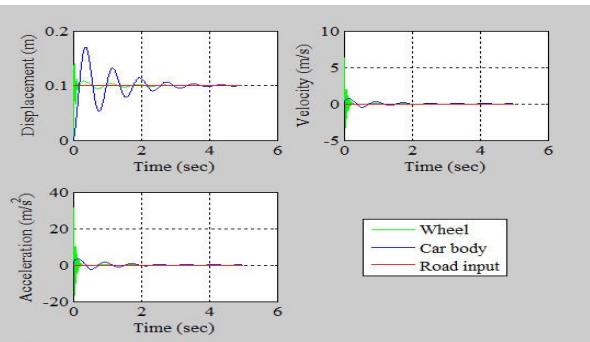


Figure 7. Displacement, velocity and acceleration of the suspension system for as designed criterion.

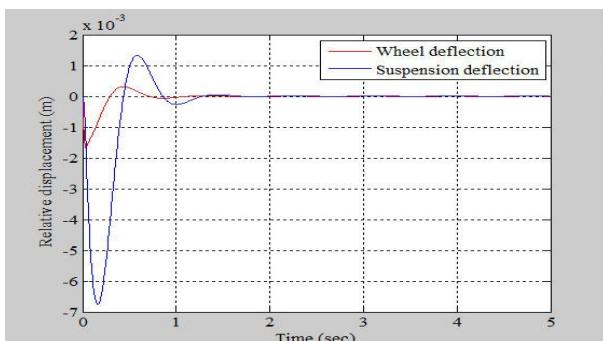


Figure 8. Relative displacement of wheel and suspension deflections of for handling criterion.

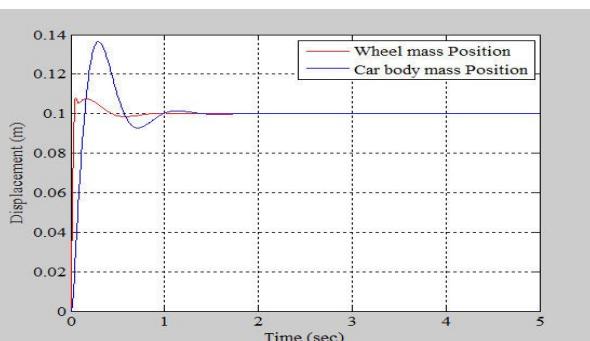


Figure 9. Wheel and car body mass position of for handling criterion.

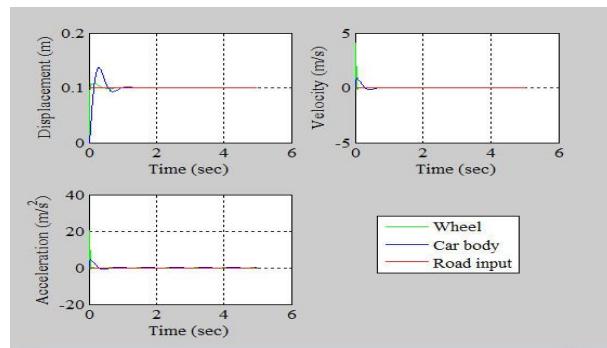


Figure 10. Displacement, velocity and acceleration of the suspension system of for handling criterion.

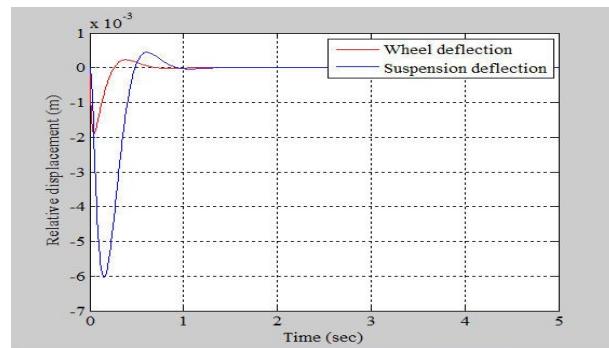


Figure 11. Relative displacement of wheel and suspension deflections of for comfort criterion.

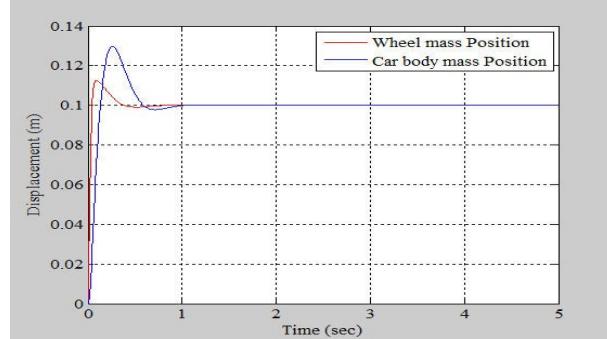


Figure 12. Wheel and car body mass position of for comfort criterion.

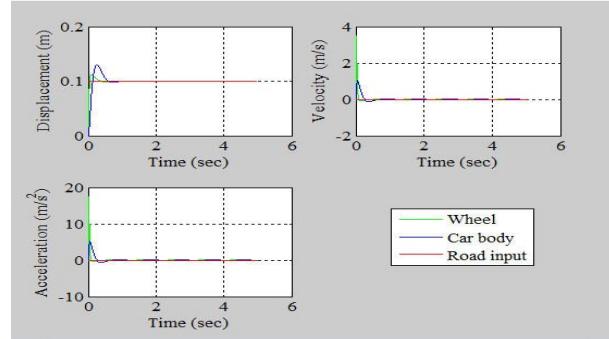


Figure 13. Displacement, velocity and acceleration of the suspension system of for comfort criterion.

5. Conclusions

The main objective of this work is to show how useful the developed GUI for engineers and analyst involves in automotive technology. The damping behavior of the suspension system has to be optimized in accordance to other parameters like body mass, wheel mass, tire stiffness, suspension stiffness and road input. The analysis provided in this paper simulated using displacement, velocity and acceleration response of car body and wheel masses with different design criteria were considered as good achievement. Finally, the case presented in this work shows the simplicity, efficiency, and reliability, of the developed GUI as a design tool for car suspension system.

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