Simulation and Analysis of the New Brake System according to Changing of the Spring and Vertical Acceleration of the Wheels

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Abstract
Moving car on rough road suddenly gets out of its way for some reason and moves to the edge of the road at the same speed. Since the most important factor in car overturning is vertical acceleration in the wheels and car speed and road conditions determine the vertical instantaneous acceleration, brake system according to change of the spring length is designed in such a way that by monitoring the instantaneous acceleration at the wheels, by interrupting the speeding up and applying the anti-lock braking, this can prevent cars overturning. By placing the sensor on rings of the spring, we can send the changing moment of the spring to the ABS control unit. The sensor which was a kind of Electromagnetic sensors providing these conditions to control the car with precise circuit design at the Simulink section in CARSIM software and three-step interface circuit between the sensor and ABS brakes at Proteus software. In Simulink software the data that is logged as input has car maneuver variables such as longitudinal speed of the car, which after processing the instantaneous information obtained during maneuvering, variables such as pressure in the wheel brake cylinders, are sent to CARSIM software as the output of the system to continue the maneuvering. At Simulink model is designed in three parts that include: designing of simulated car in the software with the existing parameters, control boxes circuit and also switch boxes for system operators which have their task. First, the car goes straight in normal maneuvers, and then it would be tested in the rugged pathways. In this condition, the success and failure of the maneuvering are checking by the equipping and not equipping the car. After these tests, the right real way would be selected and the road will be more completed by placing screws and soil shoulder and margins.

Keywords
Length Change, Control Unit, ABS, Simulink, CARSIM, Proteus, Switch Box

1. Introduction

For the car that has very high statistics in road accidents each year, the braking system is one of the vital components of the device. In recent years, many attempts has been done to control the device in certain situations by applying control systems and also studies in this section have been used, So that an Insurance Institute in the United States of America has developed researches as "new evidence about the fatal crashes of the cars before and after adding anti-lock system" that shows the

high sensitivity of this subject. The car that is out of control in the simplest and most common conditions such as straying turning from the main road perhaps causes the most casualties and irrecoverable damages. So the braking system decreases these cases to the lowest levels.
Innovative braking system has some intersection with TCS system, but the main difference is when TCS brake shows its performance on a flat road and if it goes outside of the main road, it may not be helpful to control the car. TCS system at the initial movement of the car, acceleration and turning (particularly on slippery surfaces) helps the driver [1,2]. The innovative system is an ABS complementary system such as other control systems. In this essay, the ABS brakes will be used to brake in the planning and designing of circuits with the help of simulation software CARSIM.
Basically, human being is looking for designing smart devices to increase the control operation factor. Smart cars are not excluded from these ideas and many researchers have tried in this way. We can mention a group of engineers from Toyota Laboratory (Hiroshi Ano, Toshi Hiko Suzuki , Keiji Aoki, Arata Takahashi and Gavanaj Sugi Moto) which have provided useful researches in the field of "neural network control for automatic brake control system" [3] in 1993. Also lots of efforts have been done in the field of automatic braking systems in industrial and academic centers [4].
When the car is turning to prevent overturning, by detecting potential possibility of overturning car, preventive brake process will be activated automatically. This example is an activity that Hans and his colleagues published in their published book [5,6].
The factors that can cause getting out of the main can be derived driving at high speed in sharp turns (used maneuvers in this article), slippery of the path or drowsiness of the driver and so on. In such cases, if the car speed is high, we can imagine what will happen next. When the car reaches the ups and downs on the roadside and passing them by adding a vertical acceleration of the car wheel to its acceleration, the initial speed significantly increases and by the way, if it encounters more ups and downs, the possibility of car overturning will be increased. This brake system will activate the ABS system by applying control process on the vertical acceleration.

2. Designing Simulation Model

The used software in this article is Carism that is strong car simulation software. Many major automakers have chosen it as a tool for designing and testing their projects and compared the results of the software with actual results. We can name Mitsubishi, Toyota, Volvo, Ford, Honda, GM and… that use the software to predict the dynamic behavior of the car. The Carsim software is used between the control strategy and design phases of the development cycle and product design.
Simulink software that can be used to simulate dynamic systems is a subset of the MATLAB software that has several libraries in various fields of electrical and mechanical courses. One of the valuable features of Carsim software is its connection with Simulink software which in this article we try to use this feature.
With the help of this software, data connection and simulated action have been shown well, so that the car speed and the speed of each wheel plus braking force are provided as the input of Simulink from CARSIM analyzer. Control and operation blocks which are designed in Simulink, calculate suitable braking force for car for a complete stop and show how independent speed of the wheels which based on slippery amount of each wheel at road surface increase and the optimized anti-lock brake force generated by Simulink, re-apply as an input Carsim. So according to the vertical

acceleration or speed of the car wheels, the ripples that could overturn a car is used as standard to cut the throttle and braking.

Today many countries have safety electronic stability control system on their new cars. In US, almost all cars sold after September 2011 equipped with ESC and are in full compliance with the requirements of FMVSS 126 published in 2007. These requirements are a copy of the ECE R13H which runs in Europe and many Asian countries. In both requirements, a test procedure is defined by using a driving maneuver as the Sine with Dwell. Thus, automakers depending on the country aim to export need to simulate one of these two test procedures. Of course for accepting a car, a combination of simulation and test will be done. Shortly after the release of 126FMVSS in 2007, the Department of Mechanical Simulation provided explanations and examples of its Carsim analyses, and then automakers validated related simulation maneuver of stability control with this software. In order to perform this analysis, the user should have Basic familiarity with software and VehicleSim analyst and should have studied advanced documented procedures with VehicleSim instructions. Examples provided in this section contain simplified type of desired testing in other words, steady-state circular turning to achieve the car understeer gradient.

Simulink model for this article is taken from the ABS model. The changes that need to be created are incorporating the instantaneous vertical acceleration of each wheel in Simulink inputs that are CARSIM supply systems. In fact, the vertical accelerations represent the ups and downs and make the signal to activate the ABS system (Figure 1).

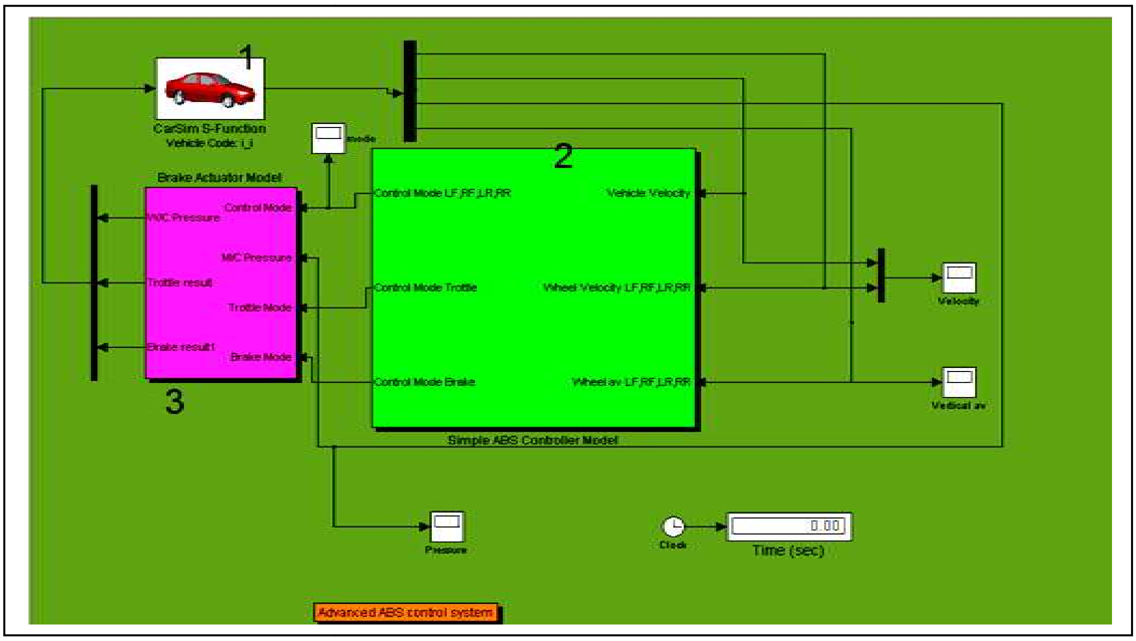


Figure1. Simulink model of anti-lock brakes after applying necessary changes

Model Simulink (1) in Figure 1, is designed with 10 variable maneuver includes longitudinal speed of the wheels (four variables), longitudinal car speed, control brake input and vertical wheel acceleration (four variables) which are taken as input data and after processing the information obtained in maneuver, sent to the CARSIM software 6 variables include brake cylinder pressure in the wheel, accelerate and braking constant to continue the maneuver. In fact, The Simulink model has artificial intelligence roll to control the car to prevent the overturning on the road. The designed system can prevent cars overturning by monitoring the instantaneous acceleration at the wheels, by interrupting the speeding up and applying the anti-lock braking.

In the control box (2) in Figure 1 necessary decisions would be taken for wheel brake cylinders, accelerator and brakes according to the wheels slippery and their vertical acceleration, and in the operator box (3) necessary instructions will send to Carsim as Simulink output.

A complete control brake system circuit has three inputs and three outputs (Figure 2).

In this example, if the vertical acceleration at each of the wheels be more than the gravity acceleration (g = 9.81) interrupting accelerate command and applying brake pedal force has been issued and anti-lock brake force to each of wheels will be send depending on the vertical acceleration of each wheel. In other words, this model completes anti-lock braking system for car stability control in unpaved surfaces.

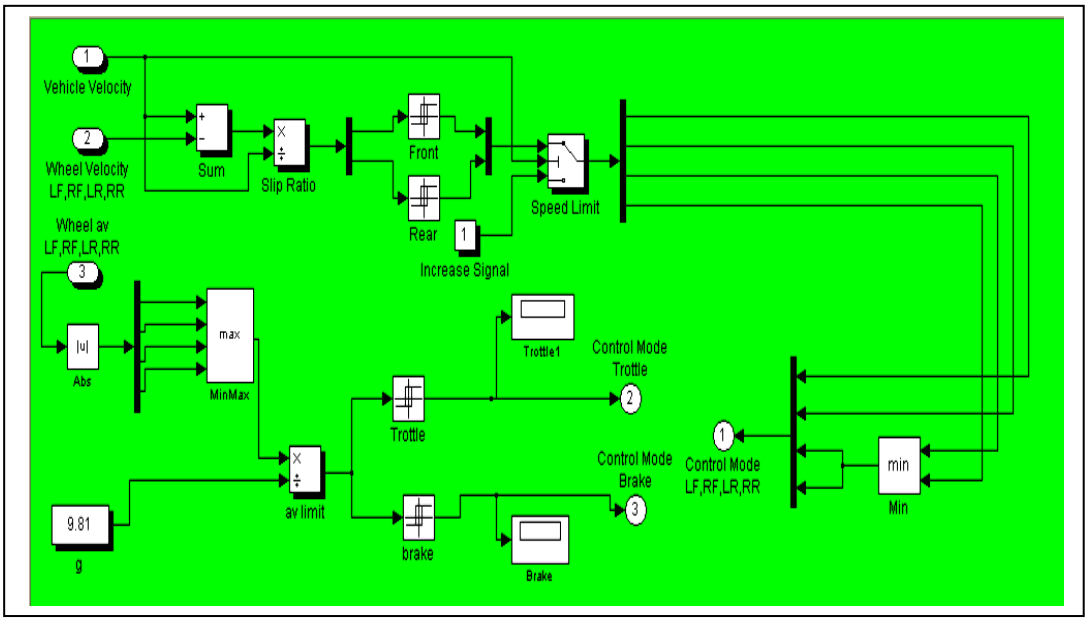


Figure2. Control box circuit

The Simulink operator box circuit with four inputs and three outputs signals is such as Figure 3. Output (1) sends cylinder pressure to the Carsim for anti-lock braking as matrix 4 and two other outputs are for accelerator and brakes to keep the car maneuver simulation.

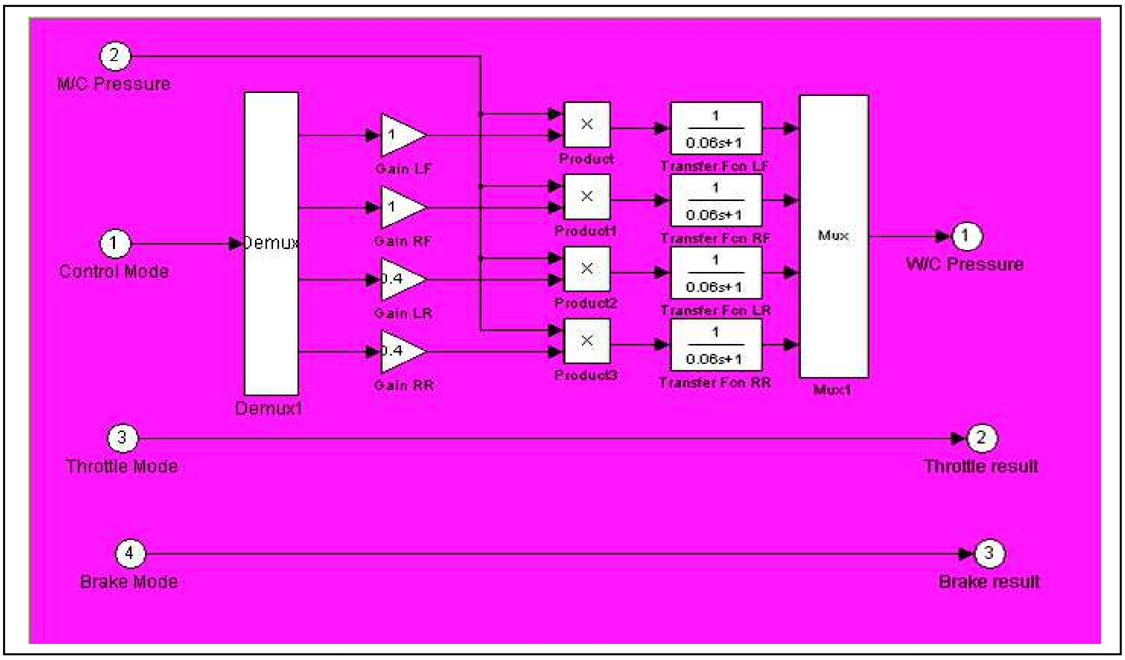
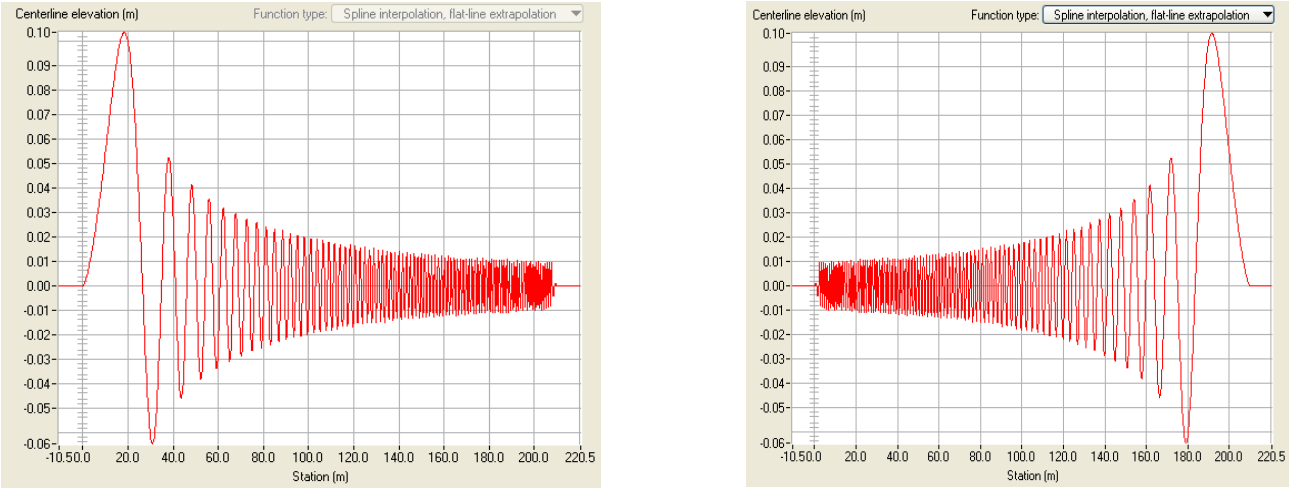


Figure3. Operator box circuit

Undulating sinusoidal type in both increscent and decrescent amplitude were studied. Switching car status from road to the cross-road is more similar to increscent state (Figure 4a) and the possibility of car overturning in ups and downs is similar to decrescent (Figure 4b). In the figure, the place of ups and downs and the height of center line of the road are declared. So the direct road with defined roughness and friction have undulating sinusoidal in modeled Carsim and all car, road and maneuver procedure conditions except mentioned system are completely identical. Car speeds are considered 80 kilometers per hour, the car is equipped with a brake control system start up by receiving the vertical instantaneous acceleration signals caused by unpaved road, and pass unpaved path and after passing unpaved surfaces continues with the same speed of 80 kilometers per hours; While other cars have been overturned by extending the unpaved amplitude in the middle of path.



(b) (a)

Figure4. designing of increscent and decrescent undulating sinusoidal (station- central line height)

The mentioned test simulation is done in Carsim software by using the link ability of MATLAB Simulink software.

The road with a hairpin is a section of test and here assumed that the driver drowsiness decreases the speed of the car, also does not control steering wheel and directly goes into the shoulder of the road. Maneuver path is selected by entering the coordinates of longitude and latitude that are located on the central line of the path as a part of a road in the road geometry. The entire route is about 300 meters that the car's position at the time of entering soil shoulder is on the second screw (Figure 5).

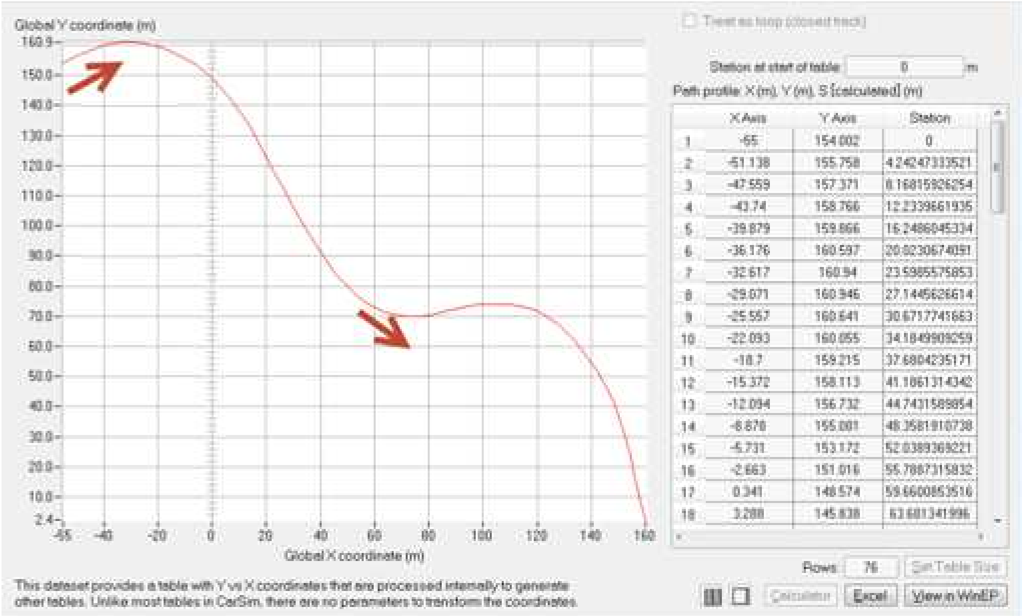


Figure5. Selecting car maneuver path and road and soil shoulder conditions

In fact the goal is that by getting into the shoulder and facing unpaved roads the car stop command will be issued by using car stability control system and be stopped before overturning in ups and downs area (Figure 6).

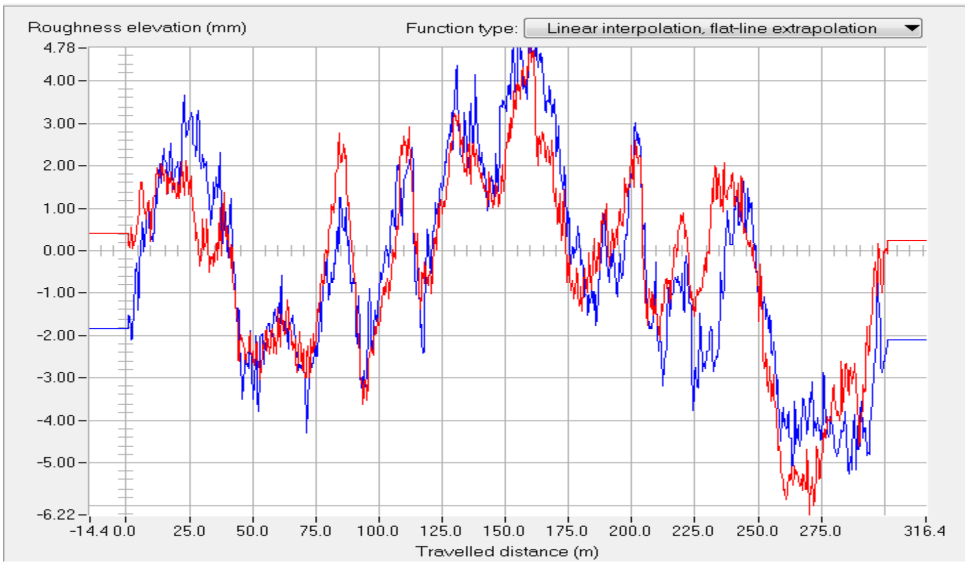


Figure6. Selecting the usual road roughness from the library of the software for designed path

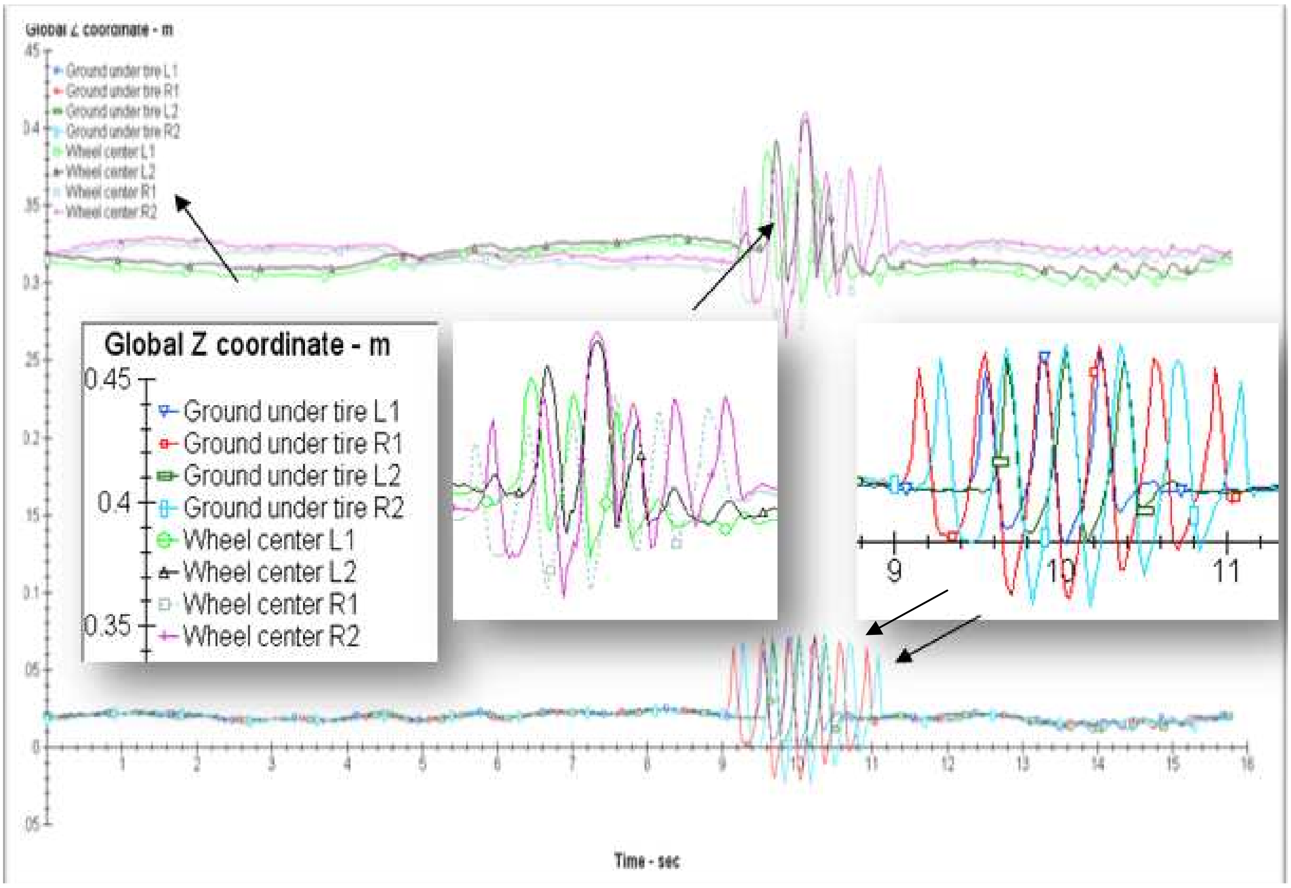


Figure7. Roughness of the road under the wheels of a car while crossing the road and vertical distance of the wheels center from the plane in a successful maneuver (Time - height of the wheel center till ground)

In a successful maneuver path roughness and the height of the center of the wheels to the road surface were examined and as is clear from Figure 7, between 9 and 11 seconds roughness is shown at the bottom of the chart and the vertical distance from the surface of the wheel center is shown in the top of the chart (about 0.34 meters). This maneuver is for a path that would get rough after the ninth second and the car passes it after two seconds.

We repeated analysis for different cars and different initial velocity and unpaved conditions. According to the detection of wheel vertical acceleration in maneuver as the independent unpaved variable, all effects of the car and the road are dependent variable and impact the value and direction of the created instantaneous acceleration.

Weight and the class of car, type of propulsion, and quality of tires are effective in the result of analysis. The results of 6 different classes of cars with different specifications, features and maneuverability are investigated. Designed Simulink algorithm is successfully operated for 4 cars and prevents it from their overturning. However, studies have shown that stability control algorithm for each car is just for its own, and can be easily designed with more analysis for any car.

In this model, the effect of unpaved and velocity is seen in the applying vertical acceleration of car wheels. In fact, as regards the algorithm is designed based on the independent variable of vertical acceleration, and it does not affect further because of initial velocity of car and unpaved of the road.

The created Carsim and Simulink models can be able to simulate the result of maneuver of different car classes with defined specifications, at different types of roads with different unpaved and geometry. Designed control system sends signals when it is necessary to cut off the accelerating and applying the brakes and control car stability under difficult circumstances.

Circuit in the ISIS of Proteus software has been simulated with introduced components in the library. The software is specially for simulating microcontroller circuit sand, in addition to drawing and simulation; it can make a PCB in ARES. As mentioned, this circuit provides the connection between the sensor and ABS brake system (Figure 8).

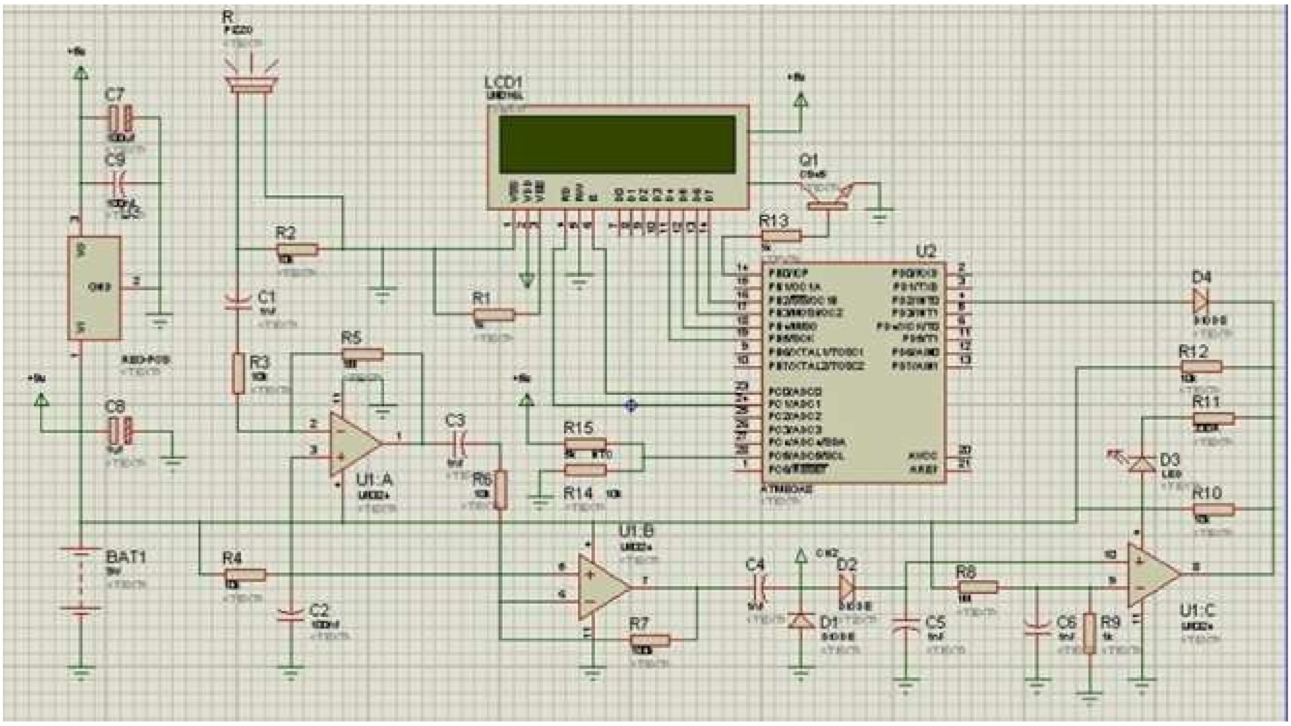


Figure8. The control ABS circuit in Proteus software

By observing the following graphs and image, it will be a good help to understand this article.

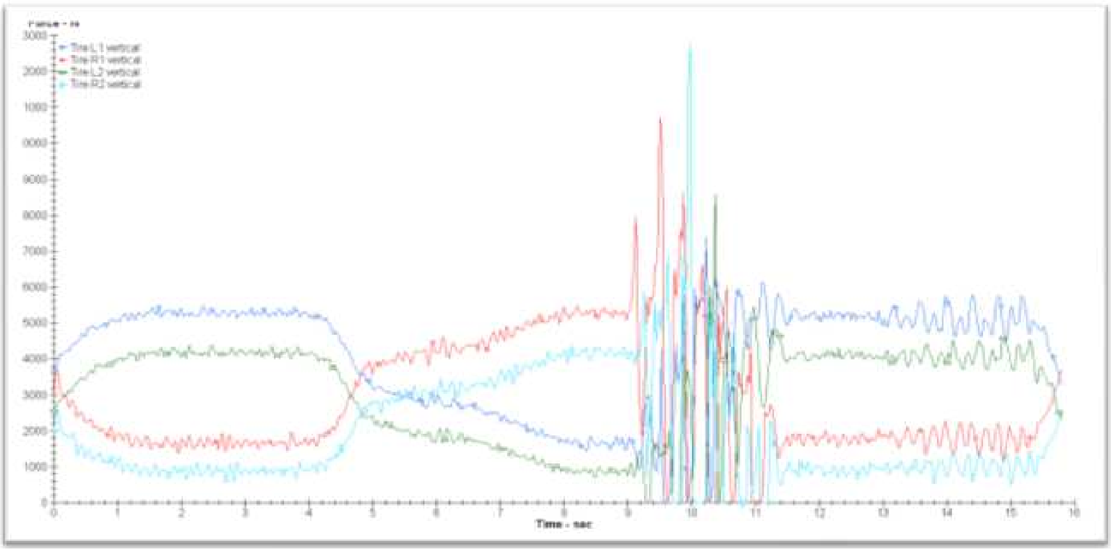


Figure9. Changes of the vertical force on the tires from the road in a successful maneuver (force-time)

In Figure 9, the perpendicular force on tires from the road is shown by a successful maneuver. As the forces specified in seconds from zero to five, the car is normally passed from the first screw and in the fifth second the forces acting on the wheel will be equal somewhat but in the second screw because of car that is out of control, it goes on unpaved path which is visible in the from 9 to 11 seconds. The car that is equipped with a control system successfully passes these damping force wheels after 12 seconds.

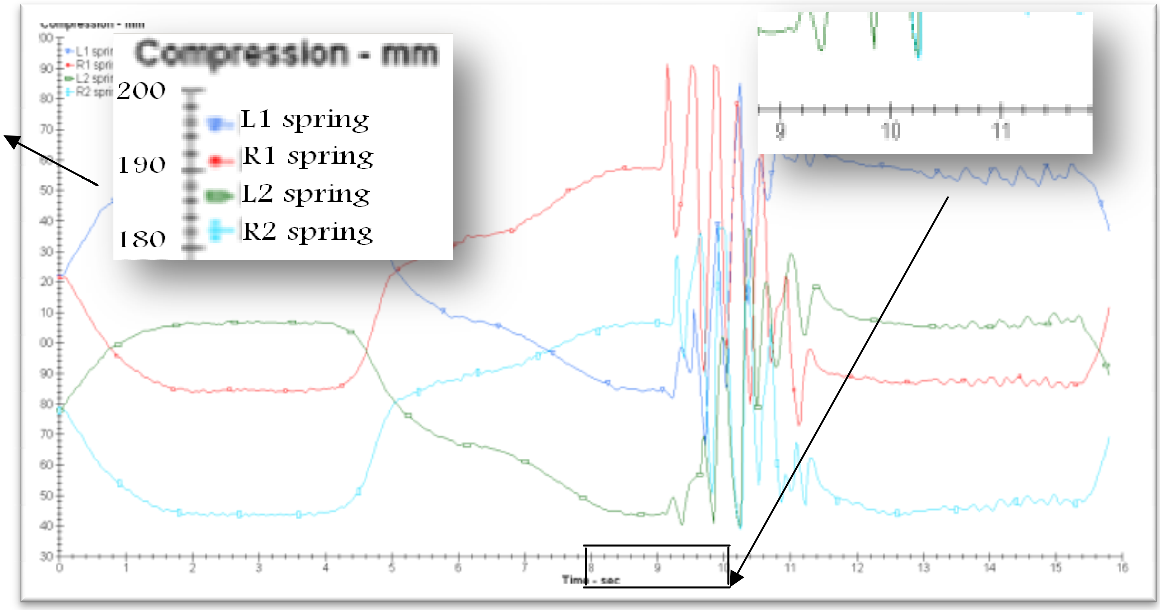


Figure10. The amount of dampers compression in a successful maneuver (time – spring compression)

The amount of dampers compression is also somewhat similar to the previous figure that can be seen in Figure 10.

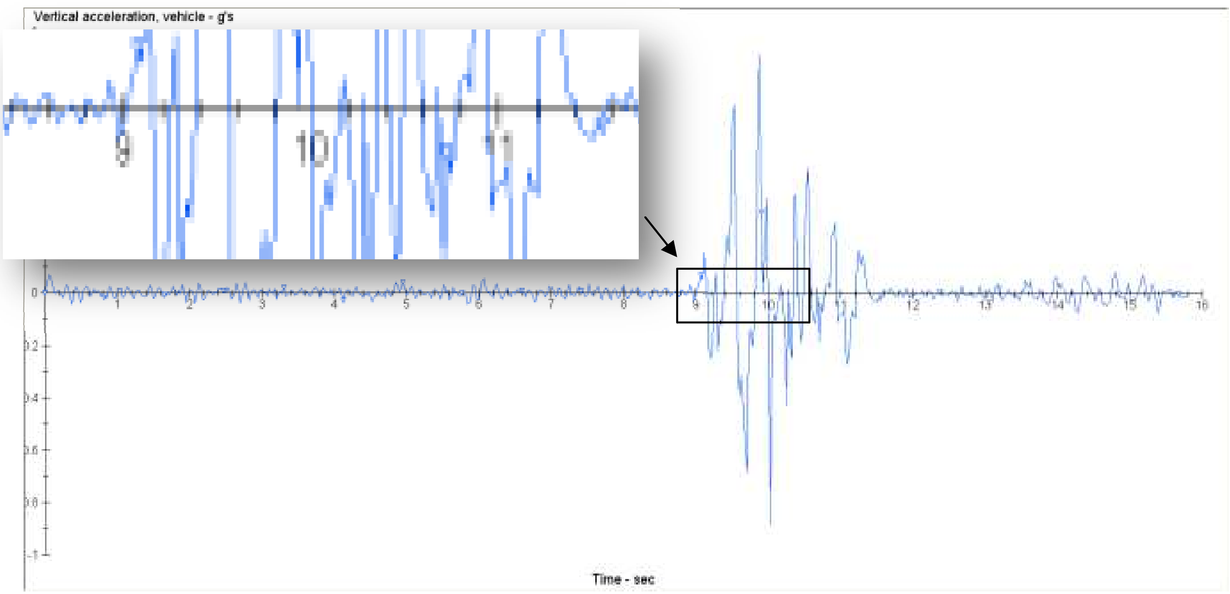


Figure11. The central vertical acceleration changes of mass of car in a successful maneuver (Time – vertical car acceleration)

In Figure 11 the central vertical acceleration changes of the mass of car show that between 9 and 11 seconds when the central vertical acceleration changes the mass of car which has been swung and after that it will reach equilibrium state.

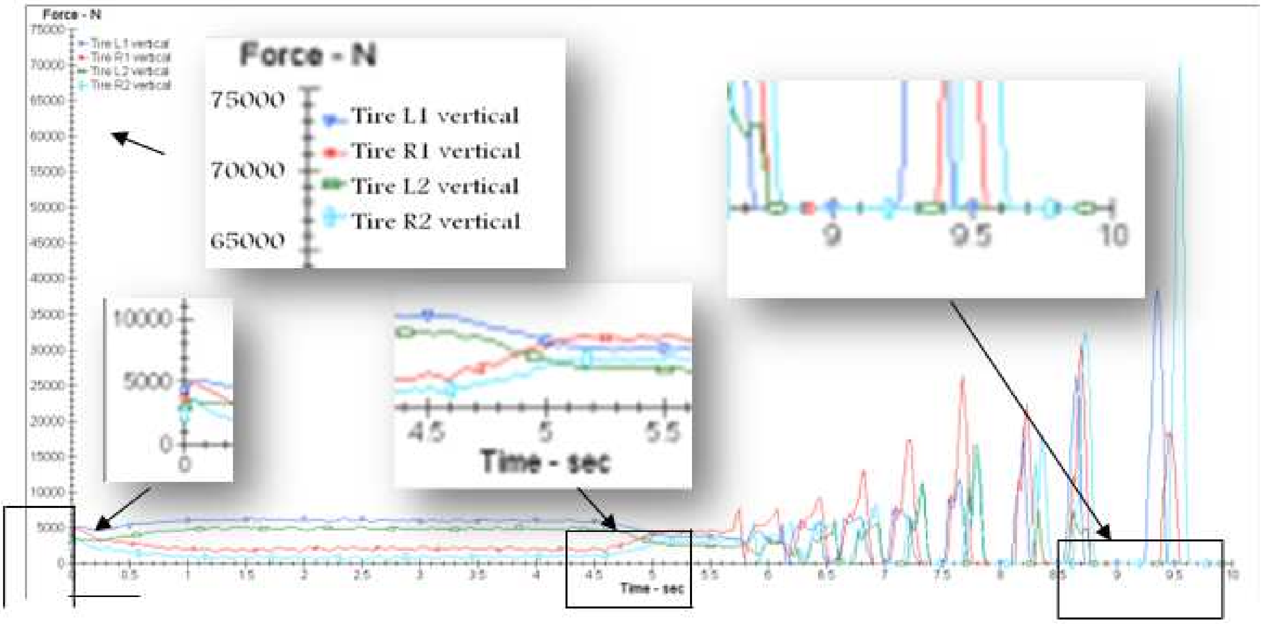


Figure12. The changes of vertical force on tires on the road in an unsuccessful maneuver (time-force)

Figures 12 to 14, which had been applied in an unsuccessful maneuver use plot of the changes of vertical force on tires on the road and the amount of dampers compression and also vertical acceleration changes in the center of car mass. The only difference is that the car doesn't have control system and obtained different results. The plot of Figure 12 looks like a successful maneuver till 5 seconds, when passing through the second screw but after 6 and 7, driver was not able to control the car and the vertical force is becoming more and more.

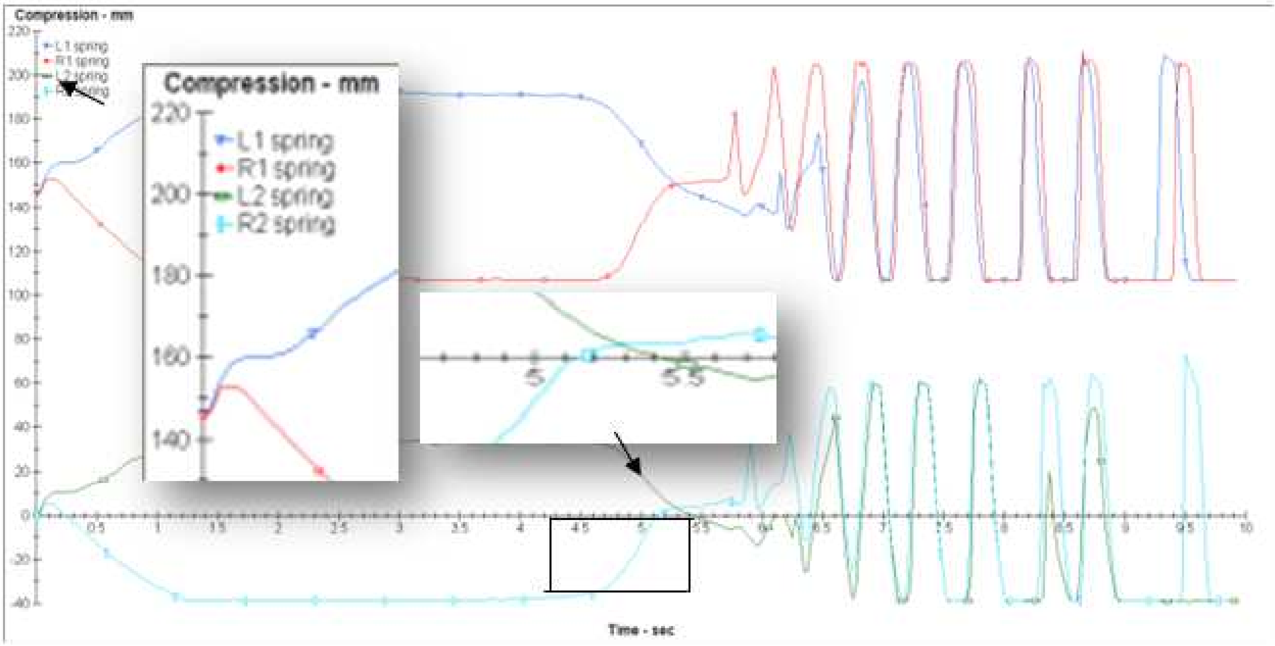


Figure13. The amount of dampers compression in an unsuccessful maneuver (Time- spring compression)

About Figure 13, it can be also said that the spring compression continues due to ups and downs to prevent car overturning. In this plot such as the plot of Figure 10, the spring compression are usual in 5 and 6 seconds, and as soon as the car get out of the road it will compress, but the difference of this plot is in the continued compression of the compression until the car is overturning.

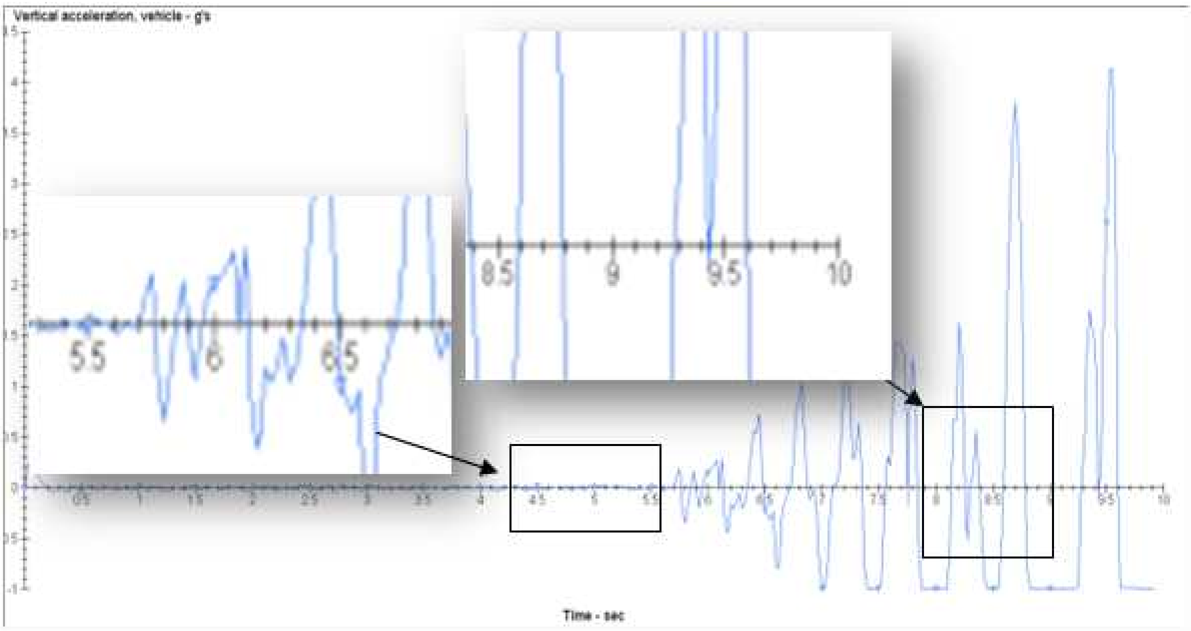


Figure14. The changes of vertical acceleration of the center of car mass in an unsuccessful maneuver (Time – car vertical acceleration)

Vertical acceleration changes in the center of car mass in an unsuccessful maneuver (Figure 14) is in such a way that when the car gets out of the road in 6th second, it will be much more. In this plot, the rising of car acceleration is clear from initial acceleration and vertical acceleration.

In Figure 15, reviewed plots are displaying with immediate images of maneuver of two cars, one equipped with a control system (blue) and other without control system (red). As seen in this figure, the cars ride at a specific speed until reaching the roadside after the equipped car with speed control system decreases its speed a little but the other one continues its way with the same initial velocity and enters unpaved path of the road. Finally the first car slows down due to path conditions but car without control system will have a different fate.

Vertical acceleration comparison at center of car mass in a maneuver can be seen in Figure 16 by using control system and without using the control system. In this Figure, car without control system (blue line) loses its balance since leaving the paved road up to 10th second and overturns, but the car that is equipped with a control system (red line) continues unpaved path until restores the balance.

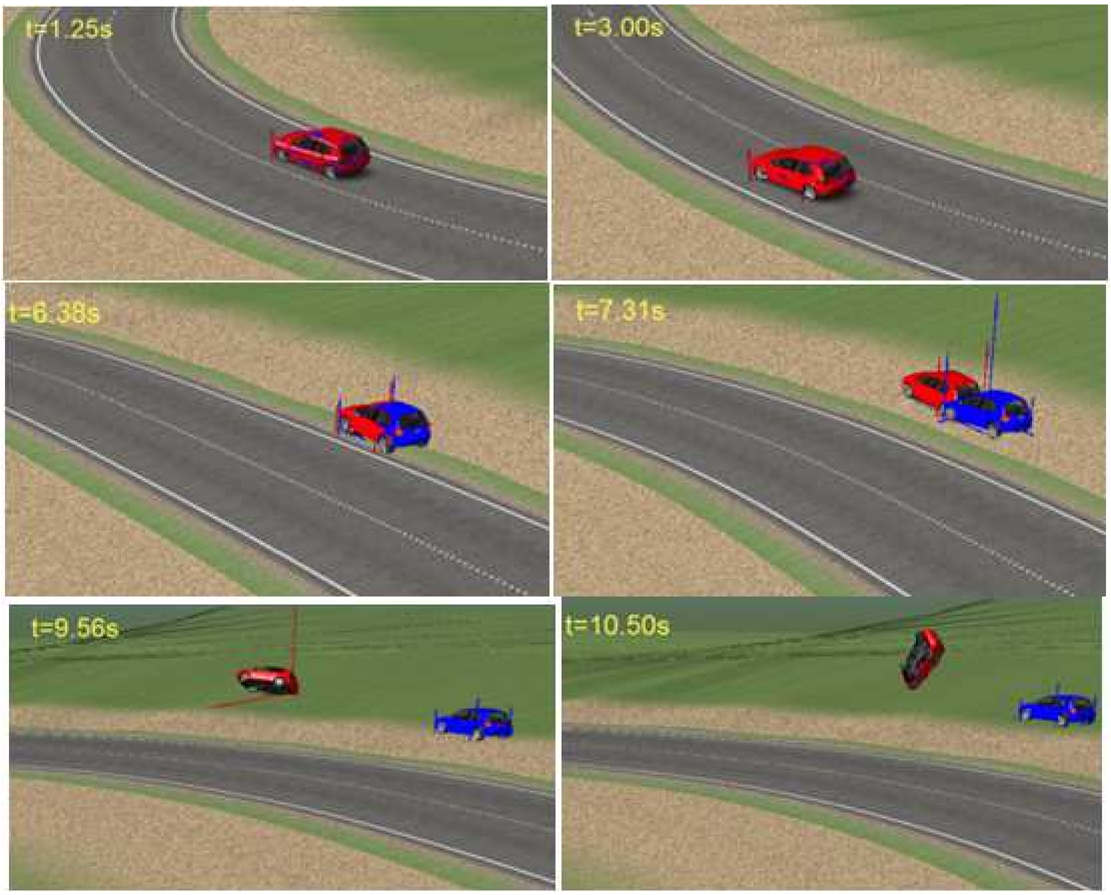


Figure15. The Comparison of simulation results with a car equipped by control system and without control system

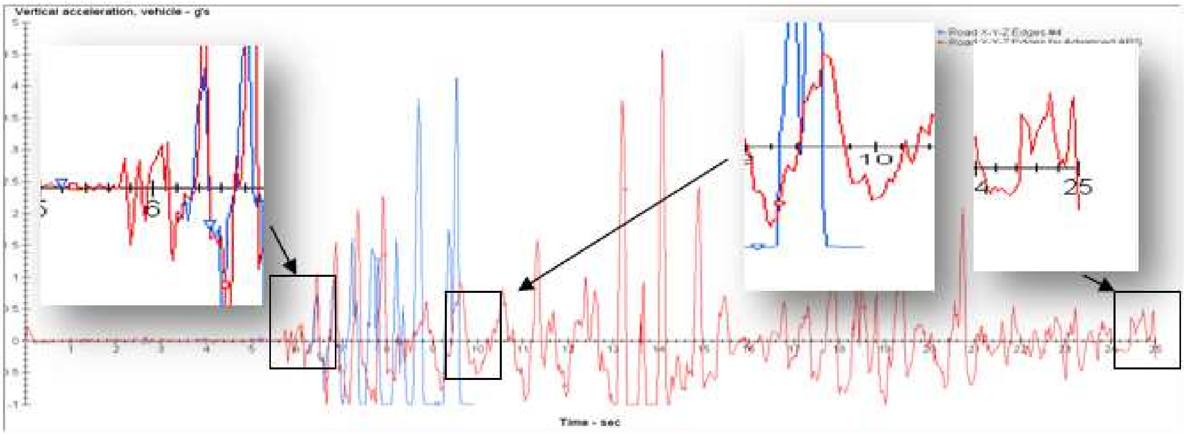


Figure16. The comparison of the vertical acceleration changes in the center of car mass in maneuver with and without using of control system - red line is equipped with a control system and the blue line is without control system

3. Conclusion

According to necessary researches to study the response of the suspension system in the face of unexpected unpaved road in driving, the maneuver car analysis had been done by using "Carsim" software. The software will be used between control strategy and design phases, in a developed cycle and product design.

The results of this section can be expressed in three stages:

1. In the first step, the goal is car maneuver analysis with an initial velocity and getting out of the road suddenly.

At this stage, we try to extract plots of suspension system response to unpaved.

2. In the second stage, the main sections of Simulink model are mentioned. In the complete control brake system circuit if vertical acceleration in any wheel increases from gravity acceleration, the interrupting accelerate and applying brake pedal force command will be issued. Operator box circuit of system with defined input and output signals, brake pressure at the wheels will be controlled and applied to wheels due to ups and downs and make a brake.
3. In the third stage, by adding braking conditions to the created model, change of speed control conditions to stop the car will be examined. The repetitions of this step will be done for studying the dynamic behavior of the car with different initial conditions and facing to various unpaved and finally all obtained data will be collected as a database to determine how the performance of the system brakes circuits is appropriate which will be used in the Simulink section of Carsim.

After modeling different parameters in the software, including car parameters such as height of the car to the road surface, control box, operator box and the path and also test and simulation models, favorable results were obtained. In this plot it is clearly seen that in the car without control, system cannot stand versus the ups and downs, and after a few seconds it will be overturned and if the car be equipped with a control, system will be successfully completed. By comparing the plots of the spring compression and the vertical force exerted on the wheel and also central vertical acceleration of car mass in successful and unsuccessful maneuvers, we can conclude that the car which is out of control will be able to be controlled with a high percentage by equipping the control system.

Because of inaccessibility to the engine control unit (ECU) car stopping command occurs from the ABS with the help of another designed circuit. The circuit in Proteus software is designed in ISIS circumstance.

4. Abbreviations

-Anti-lock braking system (ABS)
- A car simulation software is designed and developed by Mechanical Simulation Co (CARSIM)
-Traction Control System (TCS)

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