Ride Comfort Sensitivity Analysis Of Portal Axle Using Adams/Car

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Abstract

Ride comfort had been developed by satisfying many requirements from engineering design guides, CAE (computer aided engineering) and vehicle testing. So that, this work is an investigation on the ride behavior of the portal axle. Test results showed that damper and air spring geometries cause the bounce motion which affects the passengers' sensation of discomfort. Therefore, vehicle has been modelled and developed ride comfort using Adams/Car. The studies show that the damper and air spring attachment points are one of the sensitive parameter to affect the ride comfort characteristics. Therefore, damper and air spring “x” and “y” attachment points have been selected as a design variable.

Keywords: Portal Axle, Parameter Optimization, Suspension Analysis, Adams/Car, Low Floor Bus

Özet

Sürüş konforu, CAE (bilgisayar destekli mühendislik), araç testleri ve mühendislik tasarım kılavuzları ihtiyaçlarına cevap verecek şekilde geliştirilmiştir. Bu nedenle, bu çalışmada, portal aksın sürüş davranışı üzerine etkileri incelenmiştir. Test sonuçları, amortisör ve havalı yay geometrilerinin, yolcuların konforsuz hissedeceği rahatsız sıçrama hareketine neden olduğunu gösterdiği için Adams/Car kullanılarak aracın sanal modeli oluşturulup sürüş konforu geliştirilmiştir. Çalışmalar, amortisör ve hava körüğü bağlantı noktalarının sürüş konforu karakteristikliğini etkileyen duyarlı parametrelerden biri olduğunu gösterdiği için amortsiör ve hava körüğünün "x" ve "y" bağlantı noktaları dizayn değişkenleri olarak seçilmiştir.

Anahtar Kelimeler: Portal Aks, Parametre Optimizasyonu, Süspansiyon Analizi, Adams/Car, Alçak Tabanlı Otobüs

1. Introduction

The comfort level of a vehicle is one of the most important factor in a vehicle's subjective evaluation. Vehicle ride analysis isused to design the suspension to ensure that passenger comfort. There are two basic types of elements in conventional suspension systems that define the performance of the suspension. The elements are springs and dampers; the role of the spring in a vehicle's suspension system is to store the energy and support the static weight of the vehicle, while the role of the dampers to dissipate vibrational energy and to control the input from the road that is transmitted to the vehicle [1].

Increasing in spring stiffness is not an option as its specification is governed by other vehicle performance such as handling, stability etc. Hence, a detailed study has been performed to understand the governing design variables. Damper and air spring “x” and “y” attachment points have been selected as a design variables. Before ride analysis, full vehicle has been modelled using Adams/Car and model has been validated by physical test. Simulation results and physical test results has been shared as comparative.

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2. Correlation of the Adams/Car Model

When vehicle suspension is modelled, some requirements listed below have been considered.

- System structural compenents (links, arms, hub, knuckle etc.) are represented as rigid elements.
- Some of the inertias and masses that are unknown have been selected from Adams library.

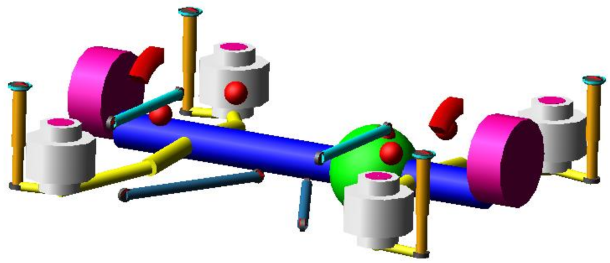


Figure 1. Adams/Car Model of the Portal Axle

Experimental correlation is essential in the development of analytical simulation models. A methodology applied for correlating a bus model. Crossing over a known dimensions of bump is one of the correlation tests. Therefore vehicle is crossed over the bump for physical test and Adams/Car simulation. Test Equipments have been listed below.

- GPS datalogger (VBOX)
- Accelerometers
- Displacement Transducers
- Datalogger with video recorder (Video VBOX)

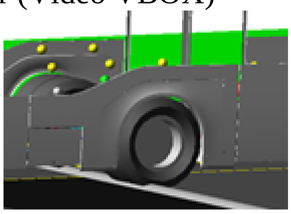
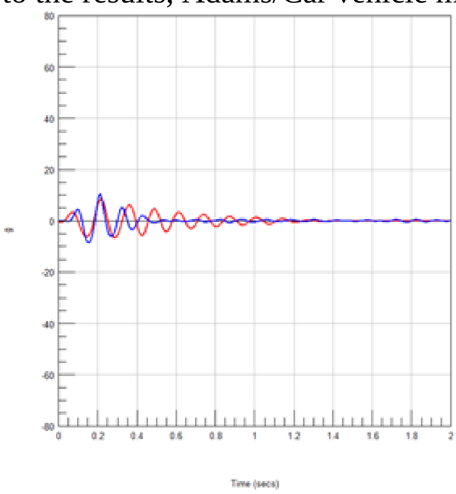


Figure 2. Vehicle Passed Over the Bump

Physical test and Adams/Car simulation results have been illustrated below as a comparative. According to the results, Adams/Car vehicle model is definitely act as a real vehicle.



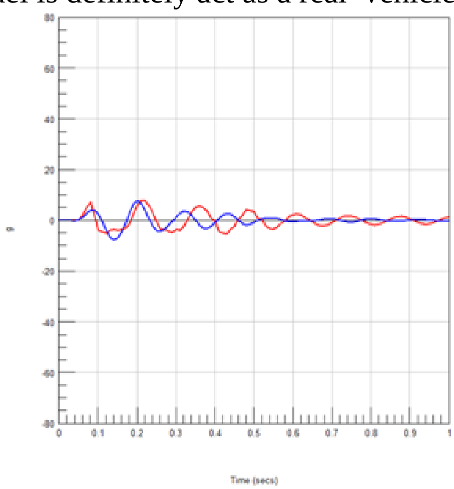
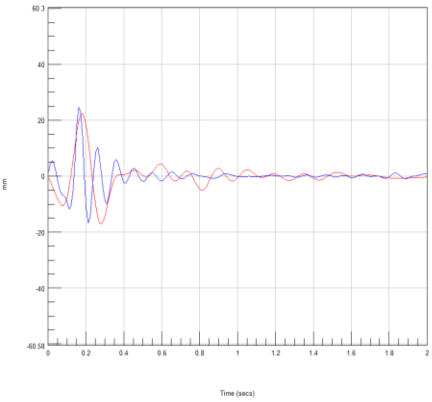


Figure 3. Left Rear Axle "z" Acceleration Value

Figure 4. Right Rear Axle "z" Acceleration Value



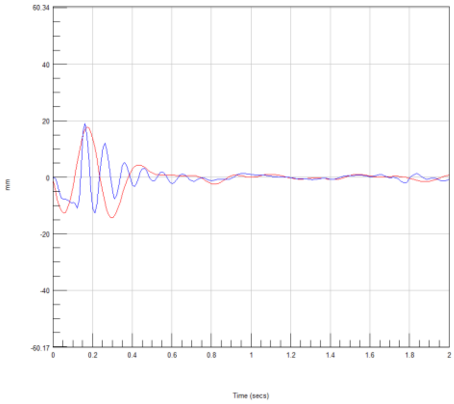


Figure 5. Left Rear Axle "z" Displacement Value

Figure 6. Right Rear Axle "z" Displacement Value

3. Adams/Car Sensitivity Analysis

Kinematic and Compliance (K&C) characteristics are the critical attribution to evaluate suspension performance. Therefore, the wheel parameters of the vehicle which affect vehicle's ride performances were simulated and analyzed [2]. It is necessary to be reduced bounce motion. Therefore, wheel vertical displacement has been selected design output. Full vehicle model has been run under different roads. Then, rear left and right wheel vertical displacement which are depend on the time have been shared below. Simulation result has given the same result with full vehicle analysis.

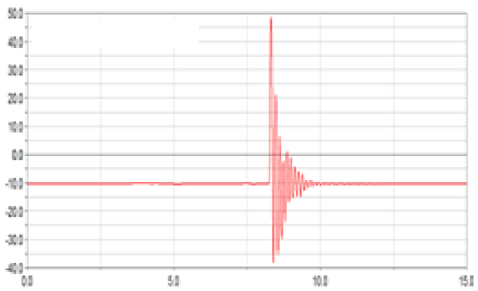


Figure 7. Left Wheel Center Displacement Value

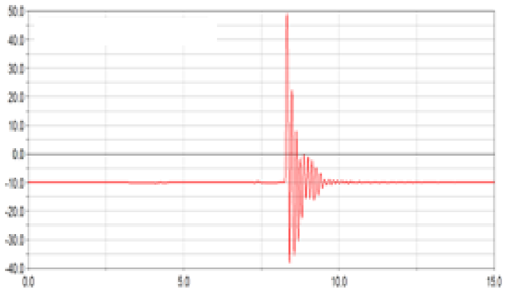


Figure 8. Right Wheel Center Displacement Value

A wheel-travel analysis allows to look at how the characteristics of a suspension change throughout the vertical range of motion of the suspension.

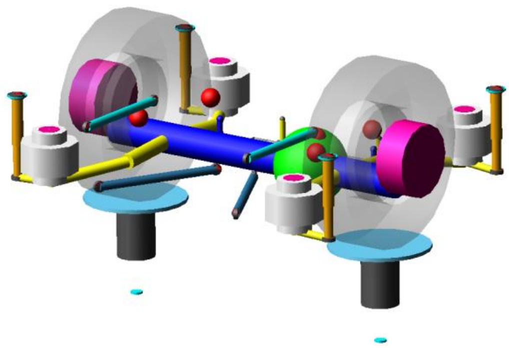


Figure 9. Adams/Car Suspension Analysis

The upper limit of wheel-center displacement relative to the input position is 58 (mm) and the lower limit of wheel-center displacement relative to the input position is -28 (mm).

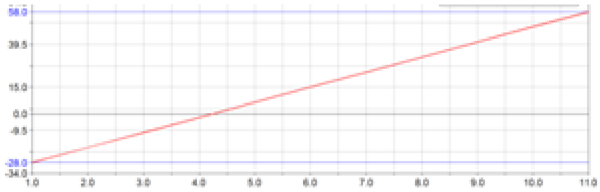


Figure 10. Wheel Center Bump and Rebound Values

As seen on the Figure-10 magnitude of the compression and de-compression of the axle while testing has similar results with the Adams/Car simulation. Coordinates of the displacement transducer is transferred to Adams/Car model. The magnitude of the displacement value on the this coordinate is shown on the Figure-11 and Figure-12

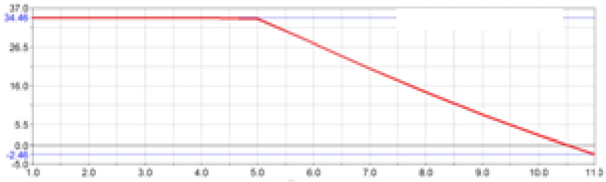


Figure 11. Left Wheel Center Displacement Value

In the simulation, the value of the displacement on the left rear axle is 36,92mm.

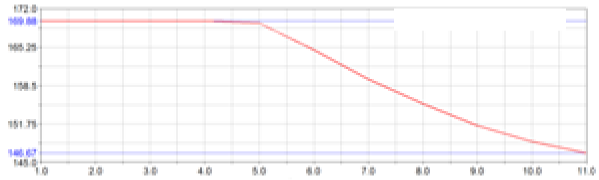


Figure 12. Right Wheel Center Displacement Value

Again in the simulation, the value of the displacement on the right rear axle is 23,21mm.

4. Parameter Optimization

Most used method is for decreasing the compression, to increase the stiffness of the air spring or compression ratio of the damper to solve the problem. On the other hand increasing this parameters has negative effect on the driving comfort [3]. For this reason we worked on another method. Mounting of the air spring and damper coordinates were changed step by step between “-40mm” and “+40mm” on the x and y axis. To have minumum displacement, new coordinates have been optimised. For this optimisation, we used Adams/Insight module and performed 256 steps.

4.1. Coordinate change on the “x” axis for Damper

Rows of the optimisation table is described below:
f_34 : Left rear damper (hpl_shock_to_frame)
f_44 : Left front damper (hpl_shock_to_frame_2)
f_35 : Right rear damper (hpr_shock_to_frame)
f_45 : Right front damper (hpr_shock_to_frame_2)

Minumum and maximum values of the x coordinates of the damper mount and left axle displacement is shown in the Table 1 below:

Table 1. Minumum and Maximum "x" coordinates for Damper Mount

Coordinate	Minimum Value (mm)	Normal Value (mm)	Maximum Value (mm)
Left Rear Damper	6542.5	6582.5	6622.5
Left Front Damper	5077.5	5117.5	5157.5
Right Rear Damper	6542.5	6582.5	6622.5
Right Front Damper	5077.5	5117.5	5157.5

The coordinates calculated to have minumum displacement values of the axle are

Left rear damper (f_34.x) : 6622.5 mm
Left front damper (f_44.x) : 5157.5 mm
Right rear damper (f_35.x) : 6595.8 mm
Right front damper (f_45.x) : 5130.8 mm

These factors are varied one by one keeping other factors constant[7]. Figure 13 shows a set of graphs for current experiment.
We can say that the left front, right rear and right front dampers show an irregular distribution. Displacement value has been increased after declining trend. We can say that left rear and left front dampers attachment points are very important and the most effective parameters, whereas right rear and right front dampers attachment points are slightly less important.

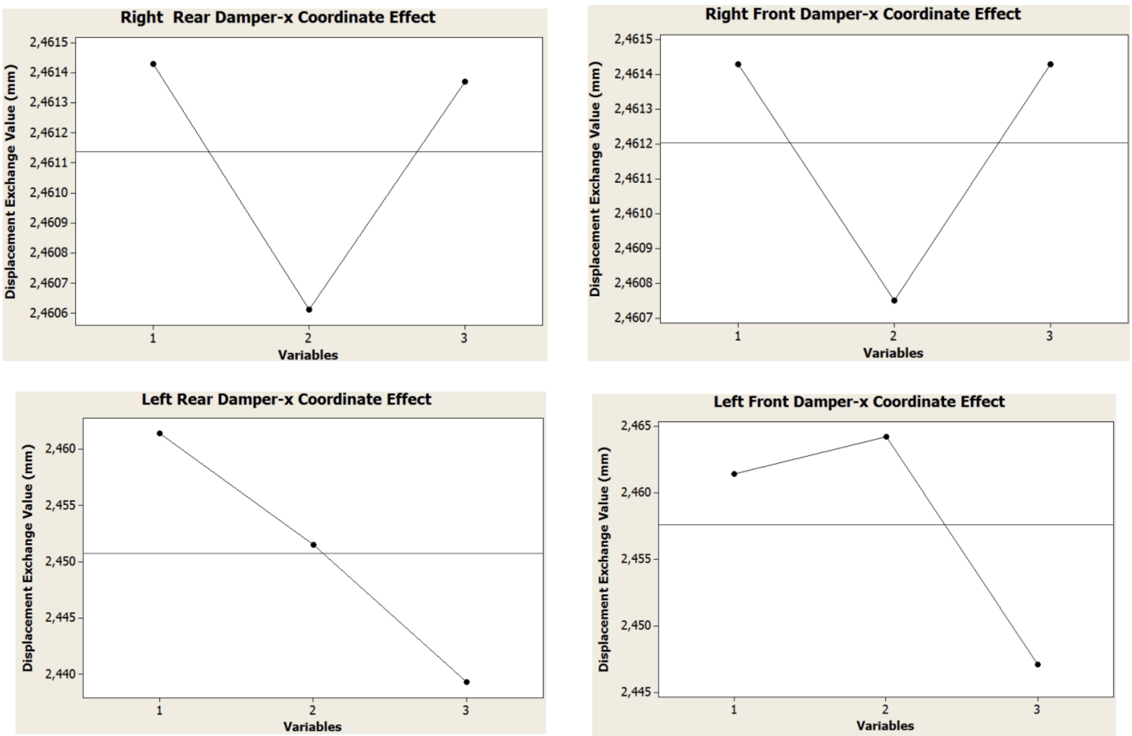


Figure 13. Effects of the Damper "x" Parameters

4.2. Coordinat change on the "y" axis for Damper

Minumum and maximum values of the y coordinates of the damper mount and left axle displacement is shown in the Table 2 below:

Table 2. Minumum and Maximum "y" coordinates for Damper Mount

Coordinate	Minimum Value (mm)	Normal Value (mm)	Maximum Value (mm)
Left Rear Damper	-1022	-982	-942
Left Front Damper	-1022	-982	-942
Right Rear Damper	942	982	1022
Right Front Damper	942	982	1022

The coordinates calculated to have minumum displacement values of the axle are:

Left rear damper (f_34.y) : -942 mm
Left front damper (f_44.y) : -1022 mm
Right rear damper (f_35.y) : 1022 mm
Right front damper (f_45.y) : 1022 mm

These factors are varied one by one keeping other factors constant. Figure 14 shows a set of graphs for current experiment.
We can say that the change of the y coordinates of the left front damper is increasing displacement value. We can say that left rear and right front dampers attachment points are very important and the most effective parameters, whereas right rear damper attachment point is slightly less important.

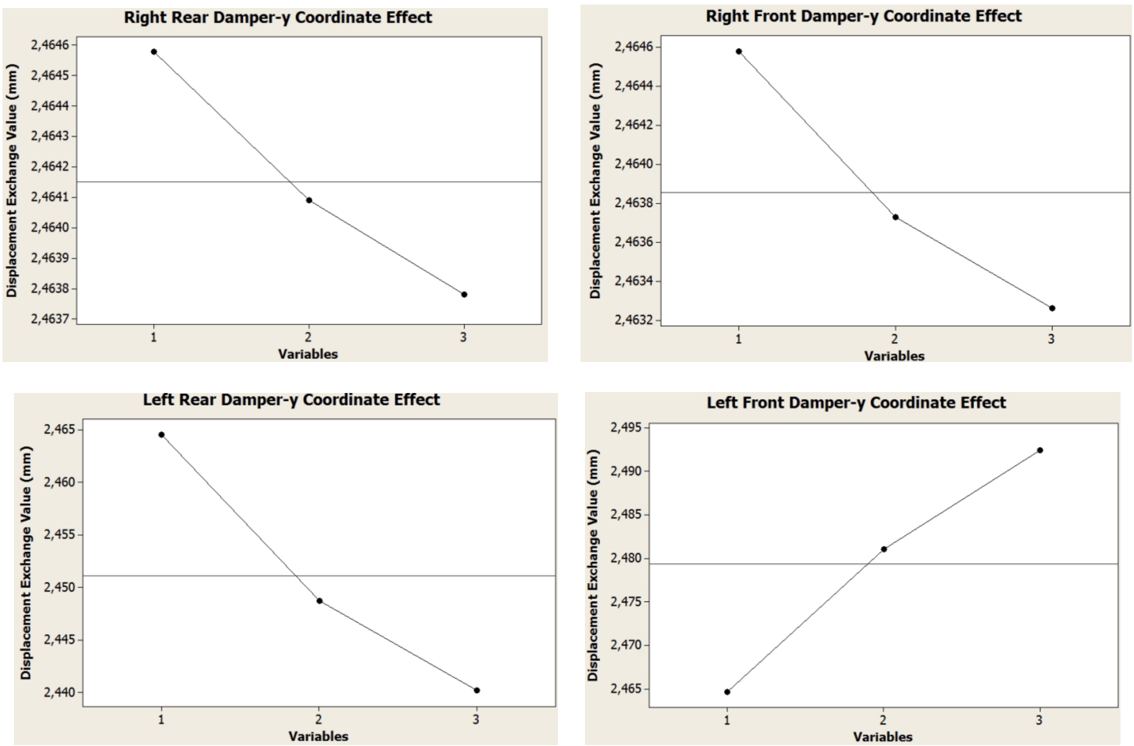


Figure 14. Effects of the Damper "y" Parameters

4.3. Coordinat change on the "y" axis for Air Spring

Rows of the optimisation table is described below:

f_32 :Left Rear Air Spring (hpl_upper_spring_mount)
f_24 :Left Front Air Spring (hpl_upper_spring_mount_2)
f_33 :Right Rear Air Spring (hpr_upper_spring_mount)
f_25 :Right Front Air Spring (hpr_upper_spring_mount_2)

Minumum and maximum values of the y coordinates of the air spring mount and left axle displacement is shown in the Table 3 below:

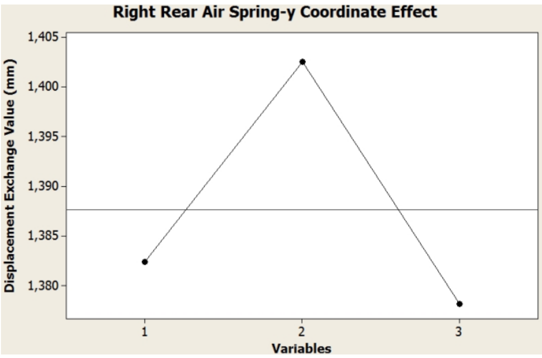
Table 3. Minumum and Maximum "y" coordinates for Air Spring Mount

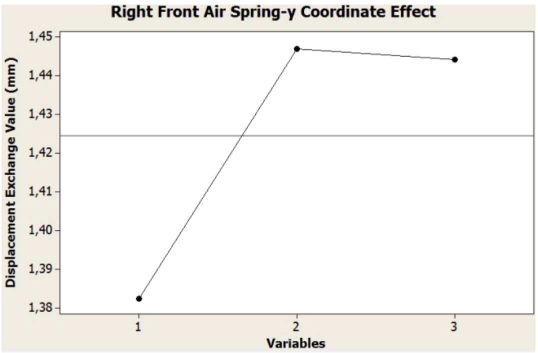
Coordinate	Minimum Value (mm)	Normal Value (mm)	Maximum Value (mm)
Left Rear Damper	-813	-773	-733
Left Front Damper	-813	-773	-733
Right Rear Damper	733	773	733
Right Front Damper	733	773	733

The air spring coordinates calculated to have minumum displacement values of the axle are:

Left Rear Air Spring (f_32.y) : -733 mm
Left Front Air Spring (f_24.y) : -759.66 mm
Right Rear Air Spring (f_33.y) : 733 mm
Right Front Air Spring (f_25.y) : 733 mm

These factors are varied one by one keeping other factors constant. Figure 15 shows a set of graphs for current experiment.
We can say that the left rear, right rear and right front dampers show an irregular distribution. Displacement value has decrease after upward trend. We can say that left rear and right rear dampers attachment points are very important and the most effective parameters.





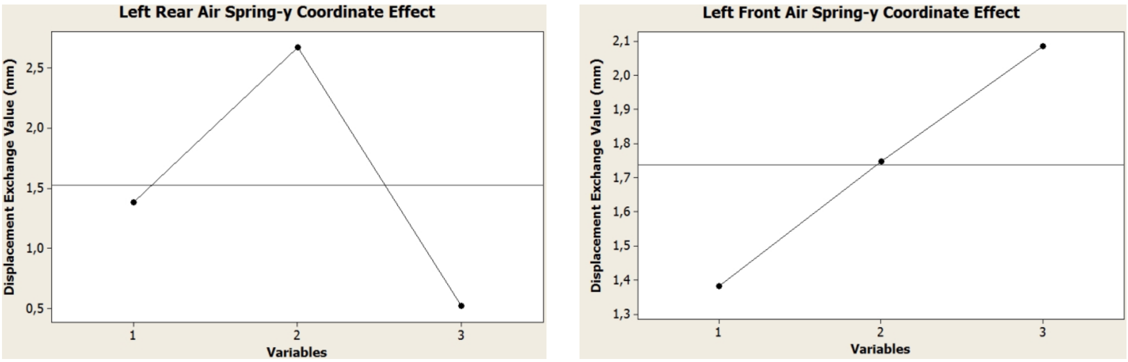


Figure 15. Effects of the Air Spring "y" Parameters

4.4. Coordinat change on the "x" axis for Air Spring

Minumum and maximum values of the x coordinates of the air spring mount and left axle displacement is shown in the Table 4 below:

Table 4. Minumum and Maximum "x" coordinates for Air Spring Mount

Coordinate	Minimum Value (mm)	Normal Value (mm)	Maximum Value (mm)
Left Rear Damper	6555	6595	6635
Left Front Damper	5065	5105	5145
Right Rear Damper	6555	6595	6635
Right Front Damper	5065	5105	5145

The air spring coordinates calculated to have minumum displacement values of the axle are:

Left Rear Air Spring (f_32.x) : 6635 mm
Left Front Air Spring (f_24.x) : 5091.67 mm
Right Rear Air Spring (f_33.x) : 6581.67 mm
Right Front Air Spring (f_25.x) : 5091.67 mm
These factors are varied one by one keeping other factors constant. Figure 16 shows a set of graphs for current experiment.
We can say that the all of the parameters show an irregular distribution. Displacement value has increased after declining trend. We can say that left rear and left front dampers attachment points are very important and the most effective parameters, whereas right front damper attachment point is slightly less important.

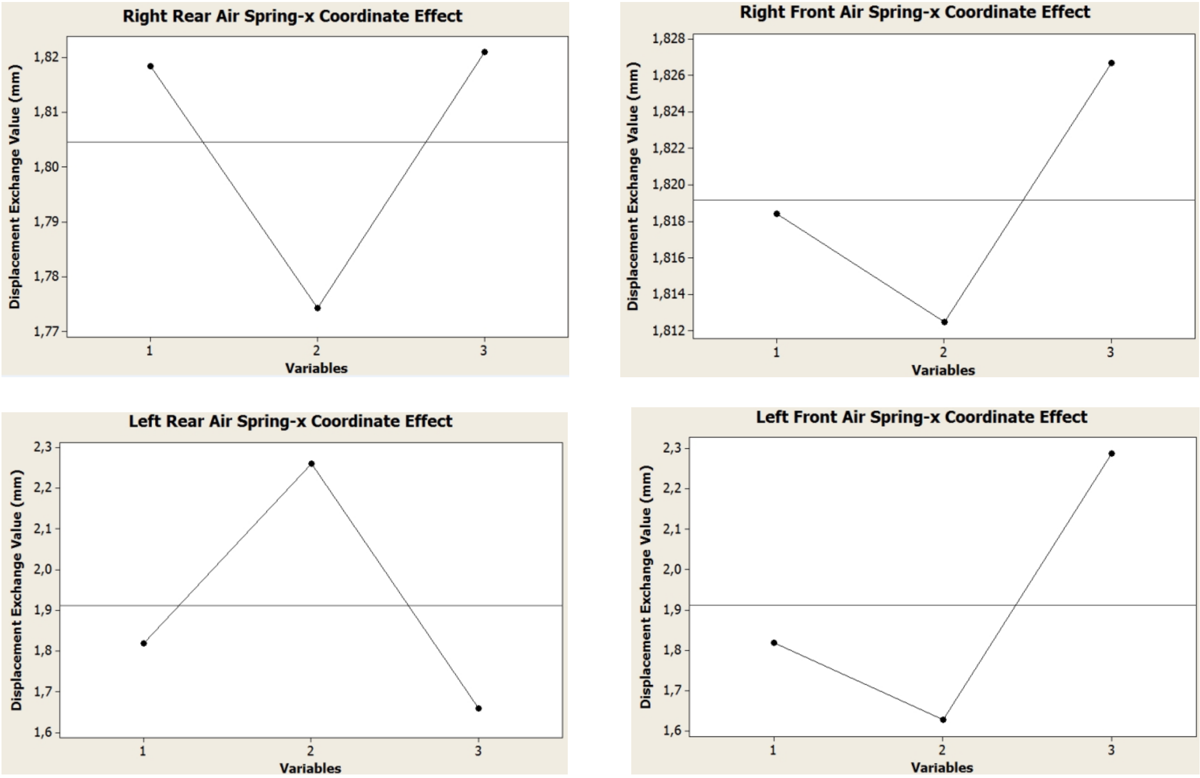


Figure 16. Effects of the Air Spring "x" Parameters

5. Results

In conclusion, change on the x and y mounting coordinates of the air spring and damper optimised and effect of the parameters shown in this study. The most effective method to increase driving comfort is to change y coordinate of the air spring. Changing of the damper coordinates on the x axis and y axis are slightly less important. The most important two parameters have been shown in figure 17, 18, 19 and 20 as to interact with one another [7].
Levels of factors are represented as three separate lines. Figure 17 shows interaction between factors left rear and left front air spring "x" attachment points. Legend of plot displays the levels of factor left rear air spring point. The levels of factor 'left rear air spring' are plotted as three separate lines. The horizontal scale (X axis) shows the levels of the second factor 'left front air spring'. The vertical scale (Y axis) is in the units of response displacement value.

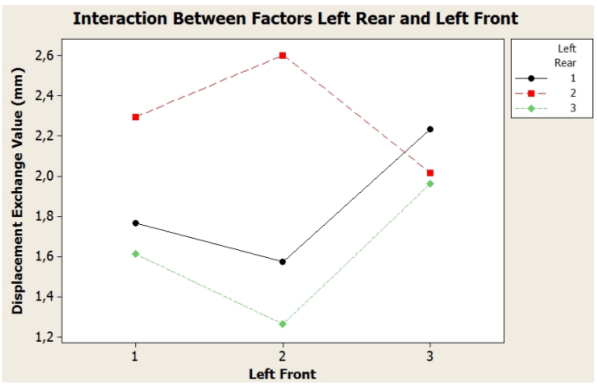


Figure 17. Interaction between factors left rear and left front air spring "x" attachment points

Levels of factors are represented as three separate lines. Figure 18 shows interaction between factors left rear and right rear air spring "y" attachment points. Legend of plot displays the levels of factor left rear air spring point. The levels of factor ‘left rear air spring’ are plotted as three separate lines. The horizontal scale (X axis) shows the levels of the second factor right rear air spring’. The vertical scale (Y axis) is in the units of response displacement value.

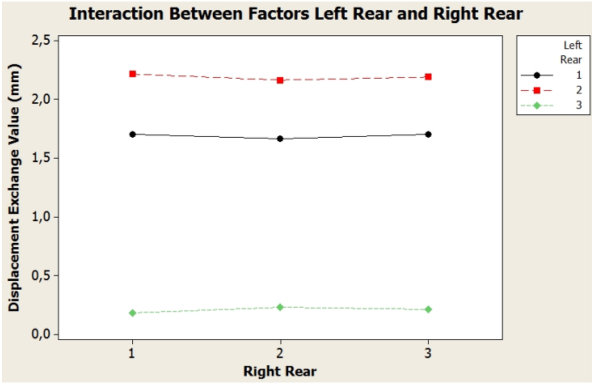


Figure 18. Interaction between factors left rear and right front air spring "y" attachment points

Levels of factors are represented as three separate lines. Figure 19 shows interaction between factors left rear and left front damper "x" attachment points. Legend of plot displays the levels of factor left rear damper point. The levels of factor ‘left rear damper' are plotted as three separate lines. The horizontal scale (X axis) shows the levels of the second factor 'left front damper’. The vertical scale (Y axis) is in the units of response displacement value.

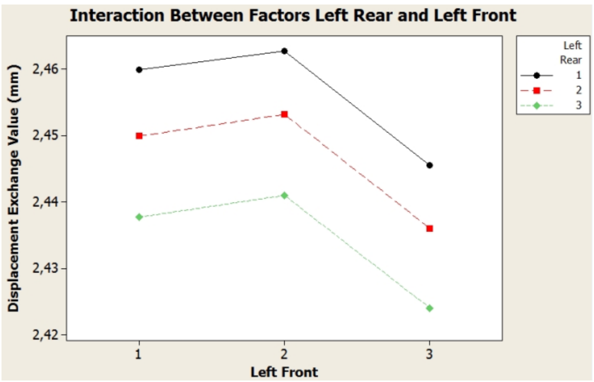


Figure 19. Interaction between factors left rear and left front damper "x" attachment points

Levels of factors are represented as three separate lines. Figure 20 shows interaction between factors left rear and right front damper "y" attachment points. Legend of plot displays the levels of factor left rear damper point. The levels of factor ‘left rear damper' are plotted as three separate lines. The horizontal scale (X axis) shows the levels of the second factor 'right front damper’. The vertical scale (Y axis) is in the units of response displacement value.

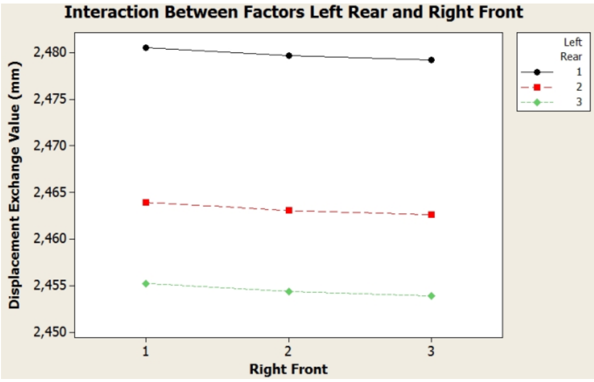


Figure 20. Interaction between factors left rear and right front damper "y" attachment points

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