Design Engineering

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 6644-6655

# Establishing of Driver's Seat Test Rig with Analyzing of Passive Seat Suspension System

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**Abstract**

The establishing and developing of a driver's seat suspension system is vital, in the last years, which has great attention from researchers and companies to gain more ride comfort and ride safety. The manufacturing process of the test rig has a high contribution because the researchers need to know how to build up the test rig that will help to undertake their research and develop it to be used later in the industry field. The test rig has been built up through creating and assembling the parts with adopted some globally applicable models. An analysis for a passive seat suspension system was carried out and a comparison between the simulation and experimental results has been done to check the validation of the test rig. It was found that the driver's seat test rig manufactured is active, suitable, and low cost. Depending on the results, this study will be recommended to use the detail of design in the manufacture of the vehicle driver's seat.

**Keyword:** driver's seat test rig, passive suspension system**,** simulation, experimental

## 1. Introduction

The driver exposed to the vibration while driving, these vibrations transmitted to human body through the suspension system of the vehicle by the driver's seat and affect the driver's psychologically and physically health safety, and that happen because the driver body connecting to the vehicle by the seat [1,2,3]. The high vibration frequencies ranges are removed by the suspension of the vehicle, and the low ranges are avoided by the suspension of seat. The human body is sensitive to the vibration in range 4-8 Hz in the vertical direction [4]. In the last decade many companies enhanced the driver's seat design to get a good performance to the seat and increase the comfortable of a driver and reduce a driver's stress during the long working hours, and so the developing of seat suspension system is a mine part of this enhances [5].

The ride comfortable and safe can be enhanced by developing seat suspension systems, which can be classify as in vehicle suspension into passive, active and semi active suspension systems.

The passive seat suspension system consists of a spring acts as storge-energy element and a damper acts as dissipate-energy element. For having ride comfortable the spring and damper coefficient

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are set usually to specific values. The limitation of the passive suspension system, it is unable to remove the high frequencies range that driver exposed to. The second type is an active seat suspension system in which the passively element springs and dampers, can be replaced or supported by control element that supplying force to the system, which is actuator. The actuators are most important part in the active system. The actuators distinguishing characteristics are reliability, low cost, low power consuming, and low noise [6] [ 7]. The active seat suspension system achieved a good vibration isolation in low frequencies.

The last type is a semi-active seat suspension system is distinguished by its passively element springs and dampers, can be adjustable, like dampers which the characteristic of damping can be modulated through applying electric field to electrorheological fluid damper (ER) or magnetic field to magnetorheological fluid damper (MR) or by modulate of fluid-flow orifices. The advantage of semi-active seat suspension system is the high reliability, low energy requirements, in addition to its cost compared to an active system, so it finds many semi-active seat suspension systems proposed in recent years [8].

The aim of this study is to build up the driver's seat test rig with reviewing all parts and modelling the passive seat test rig suspension system, and showing the performance results through validation.

2. Building up the passive seat test rig

The passive seat suspension system test rig consisting of two main units which is:

2.1 Input unit

The input unit is design to provide the system input, which is displacement. This system input is consisting of:

2.1.1 Iron steel structure frame

As was shows in the figure 1, the structure is made of two iron steel plate, upper base and Lower base with dimensions [460* 640 * 10] mm, the frame has four columns with a diameter of [80] mm for each and these columns able to support the top base by four springs to uniform distribute the seat weight.

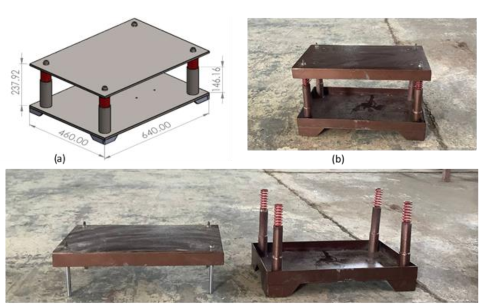

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Figure 1 a. Sketch of the frame in SOLIDWORKS program b. Duplicated picture of the frame.

c. Photograph for the upper and lower plates.

### 2.1.2 AC Motor

A three-phase electric motor was used with 3hp -380V, which is connected to the gear box in order to reduce the output cycle into 104 rpm. The electric motor was rotated the cam to get the required displacement, i.e., the system input.

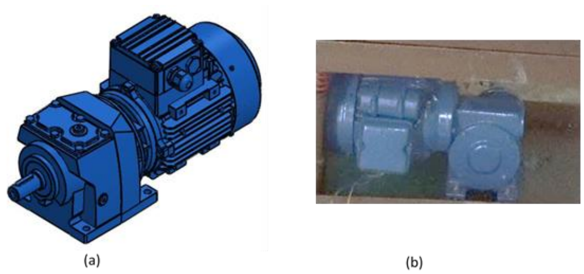


Figure 2 a. Sketch of motor in SOLIDWORKS program b. Photograph of the motor and gear box.

### 2.1.3 Cam and flower

The cam used to generate the system input signals. Figure 3 was shown the eccentric cam with a circular shape with a diameter of 100 mm, cutting by using a CNC machine, the flower diameter is 40 mm, see figure 4.


Figure 3 a. Sketch of eccentric cam in SOLIDWORKS program b. Photograph for the eccentric cam

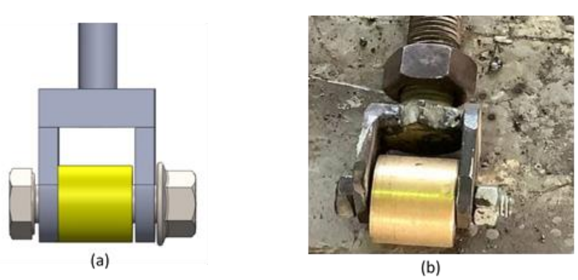


Figure 4 a. Sketch of flower in SOLIDWORKS program b. Duplicated picture of the flower.

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## 2.2 Seat structure

### 2.2.1 Seat base construction

The seat base is made of angel iron steel bar with dimensions of [ 50 * 50 * 5] mm in the form of Litter L as shown in figure 5. The seat base is connected directly with the input unit, which provides the displacement input.

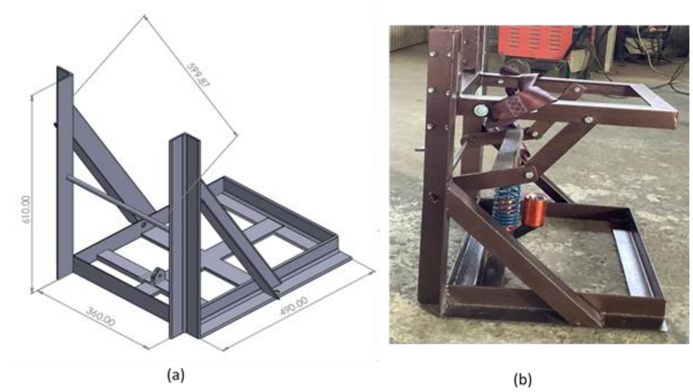


Figure 5 a. Sketch of the seat base in SOLIDWORKS program b. Duplicated picture of the seat base.

### 2.2.2 Seat pan construction

The seat pan was made of angle iron steel bar with two size of dimensions [ 50*50*5] and [ 40*40* 5] mm respectively, and they connected to the seat base by linear slider. The test dummy put on the seat pan, so a seat belt was used to secure the dummy during the test. figure (6) shows the seat pan.

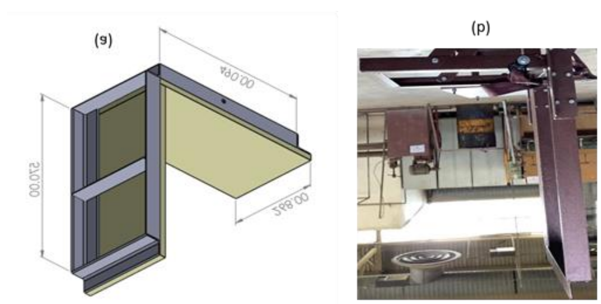

Figure 6 a. Sketch of the seat pan in SOLIDWORKS program b. Duplicated picture of the seat pan.

### 2.2.3 Shock absorber for passive suspension system

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Figure 8 shows, a GAOBIAO air shock absorber with length 200 mm from eye to eye, it was used for driver seat passive suspension system. It is consisting of coil spring and pneumatic damper. Figure 7 illustrates the spring and damper.

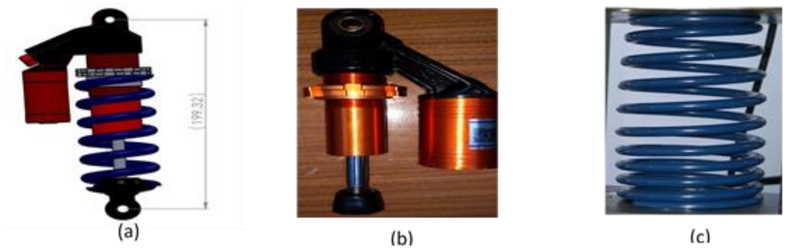


Figure 7 a. Sketch of damper and spring in SOLIDWORKS program b. Duplicated picture for the damper c. Duplicated picture for spring.

2.2.4 Linear slider

In order to achieve a vertical smooth movement of the connecting of the seat base and pan, it was used ball slide linear bearing, which consists of two parts: linear shaft part as was shown in figure 8 and the linear bearing, slide block part, as shows in figure 9 respectively.

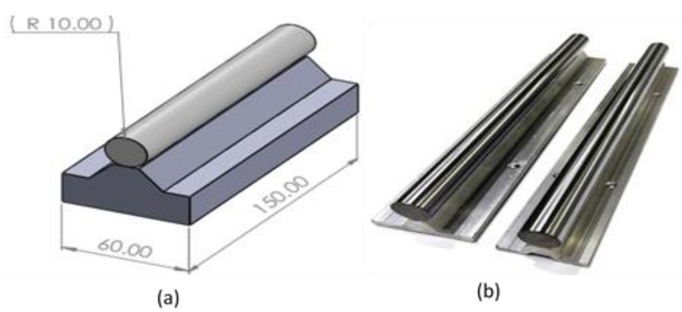


figure 8 a. Sketch of linear shaft in SOLIDWORKS program b. Photograph for the linear shaft part.

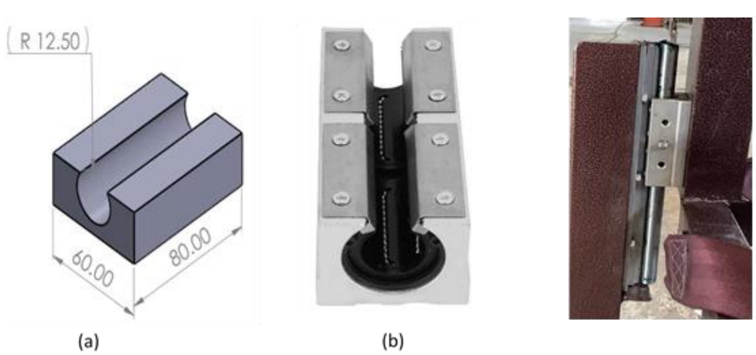


Figure 9 a. Sketch of slide block in SOLIDWORKS program b. Duplicated picture for the slide block part c. Duplicated picture for the linear slider. (c)

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### 2.2.5 Tow lever arm

The tow lever arm connected the shock absorber in the passive suspension system to the seat pan. The advantage of the tow lever arm with the suspension system is to carry the static load of the seat and the dummy test as was duplicated in figure 10.

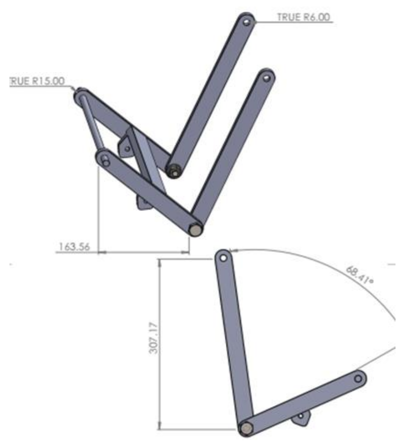


Figure 10. Sketch of two lever arms in SOLIDWORKS program.

## 2.3 Electronic parts

The base and pan seat movement towards up and down, it was resulting from provide the cam motion, the cam is directly connected to the electric motor, therefore, the displacement, velocity, and acceleration of them are measured and monitoring by using an Arduino **Uno** board, which is shown in figure 11, and the duplicated picture of a GY-VL53L0XV2 Laser Distance sensor is demonstrated in figure 12, while a GY-61 DXL335 3-Axis acceleration sensor is illustrated in figure 13. All these equipment's will be helped through using a software program.


Figure 11. Duplicated picture for Arduino Uno board.

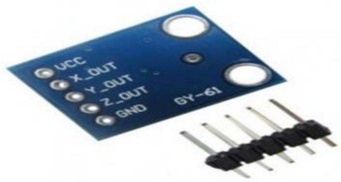


Figure 12. Duplicated picture for GY-61 DXL335 3-Axis Accelerometer.

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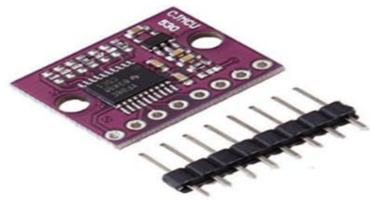

Figure 13. Duplicated picture for GY-VL53L0XV2 Laser Distance sensor.

As a result of complete establishing, the driver's seat test rig was a whole assembled as demonstrated in figure 14.

Figure 14. Duplicated picture for whole assembly of driver's seat test rig.

3. Modelling of the passive seat suspension system

The modelling of the passive seat suspension system is demonstrated in the figure 15, this model is 2 DOF and consists of two mass which is the seat base mass and the seat pan mass with spring and damper and spring (passively element) respectively.

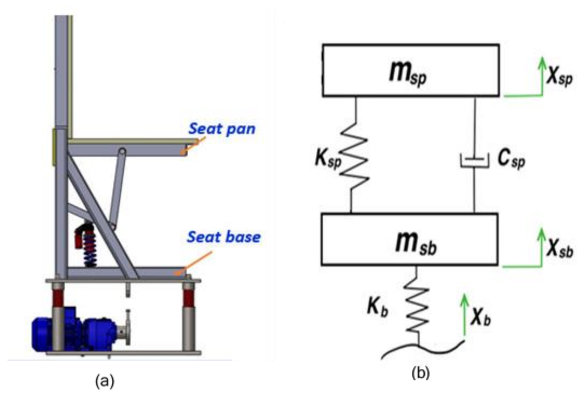


Figure 15 a. Sketch of the passive seat test rig b. Passive seat suspension system model

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The detail and model specification are shown in Table I.

Table I the description of 2 DOF model parameters

| | | | |
|---|---|---|---|
| $m_{sp}$ | Seat pan mass + driver's mass (Kg) | $k_{sp}$ | Seat suspension stiffness (N\m) |
| $m_{sb}$ | Seat base mass (Kg) | $c_{sp}$ | Seat suspension damper (N.s\m) |
| $k_b$ | Body stuffiness (N\m) | $X_{sp}$ | Vertical displacement of seat pan (m) |
| $X_{sb}$ | Vertical displacement of seat base (m) | $X_b$ | Body input (m) |

The passive seat suspension model parameters are taken from the real working driver's seat test rig. The model parameters used in the following analysis are given in Table II.

Table II The value of parameters of the passive seat suspension

| | | | |
|---|---|---|---|
| $m_{sp}$ | 58 Kg | $m_{sb}$ | 21 Kg |
| $k_{sp}$ | 20000 N\m | $k_b$ | 100000 N\m |
| $c_{sp}$ | 4000 N.s\m | - | - |

4. Mathematical model

The mathematical model of the passive seat suspension system could be defined by 2nd order degree of differential equations obtained through applying Newton's 2nd law of motion, depending on the free body diagram that was shown in figure 15. Therefore, the system dynamic behaviors could be described by the two following equations:

$$\ddot{x}_{sp} = \frac{1}{m_{sp}}[- c_{sp} (\dot{x}_{sp} - \dot{x}_{sb}) - k_{sp} (x_{sp} - x_{sb})] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\ddot{x}_{sb} = \frac{1}{m_{sb}}[- k_b (x_{sb} - x_b) + c_{sp} (\dot{x}_{sp} - \dot{x}_{sb}) + k_{sp} (x_{sp} - x_{sb})] \ldots (2)$$

Where, the parameters definition was mentioned in Table I.

5. Results and discussion

The passive seat suspension system analysis was conducted through doing the experimental test by using an Arduino **Uno** board with displacement, velocity and acceleration sensors, and a code program is prepared within MATLAB/SIMULINK environment to find the simulation system performance, the SIMULINK code is illustrated in figure 16. It is used part of sine input as system input to show the dynamic responses.

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The results are validated as comparison between the experimental and simulation results of the displacement, velocity, acceleration for seat pan as will show in the following.

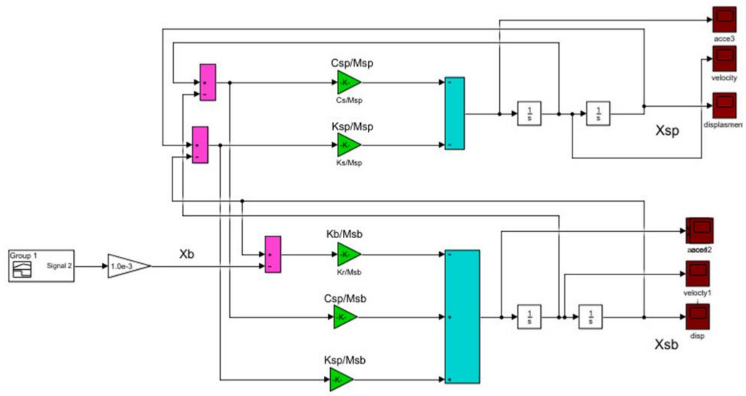


Figure 16. SIMULINK code of passive test rig model.

Figure 17 shows the system input, the eccentric cam design is used to create the input signal as same as possible to represent the real road bump. It clearly seen that there is a good agreement between the experimental and simulation results, which is urgent need to make a sensible comparison between them.

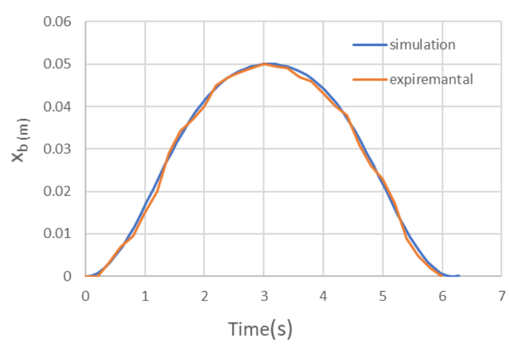


Figure 17. Experimental and simulation of system input.

A comparison of the simulation an experimental result for the seat pan displacement has been conducted as illustrated in figure 18. It is eventually seen that there is a good agreement between both.

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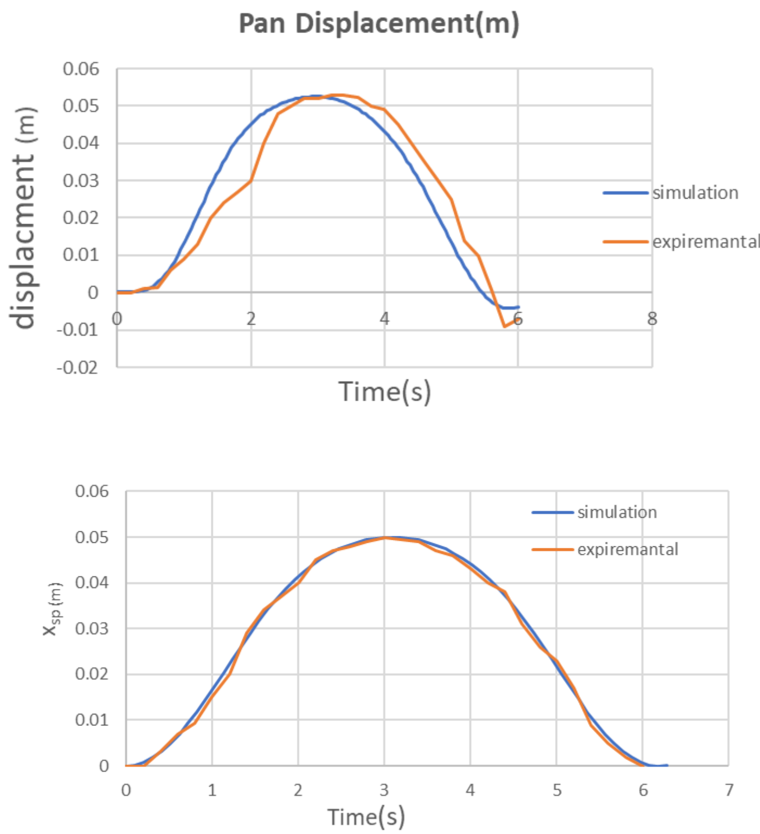


Figure 18. A comparison of experimental and simulation results of the seat pan displacement.

While the comparison of the experimental and simulation result of the velocity of the seat pan is demonstrated in figure 19, it is obviously seen that there is a good agreement between both that's mean the test rig construction used and the simulated model is an accurate and sufficient.

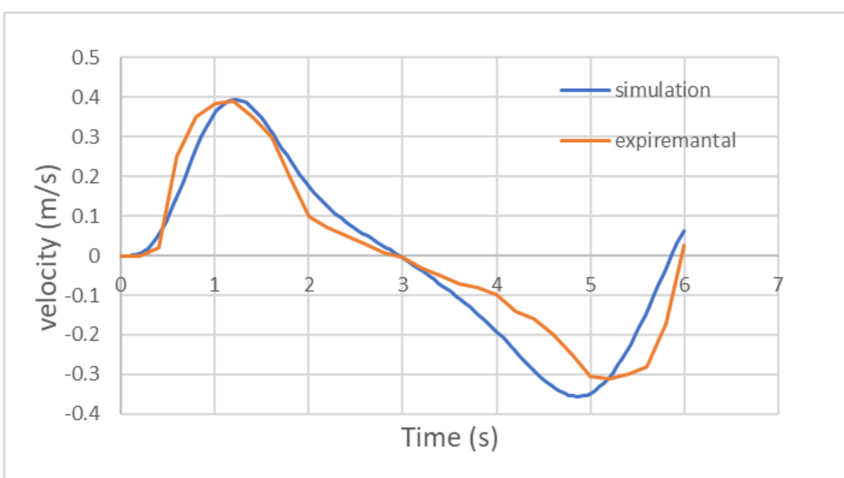


Figure 19. A comparison between the experimental and simulation results of the seat pan velocity.

Figure 20 is shown the comparison between the experimental and simulation results of the seat pan acceleration, it is vital to display the acceleration test rig behavior because they directed connected with the vibration. There is a little difference between the simulation and experimental results, that could be came from the sensor sensitive, but it is acceptable within this type of system.

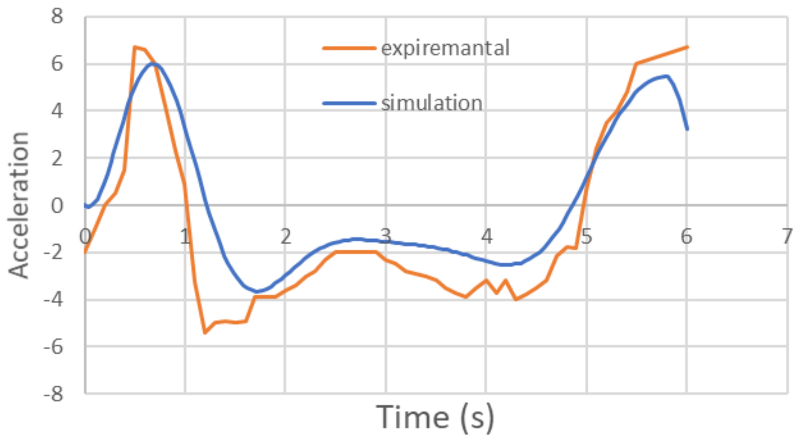


Figure 20. A comparison of the experimental and simulation results of the seat pan acceleration.

## 6. Conclusions

The main aim of this study is to highlight the designing and building of the driver seat test rig that one of the urgent needs of researchers and industrial companies within the suspension field. For system analysis response it was used an Arduino **Uno** board to measure the displacement, velocity, and acceleration of the base and pan driver seat test rig, and by using MATLAB/SIMULINK environment considering the mathematical model to check the test rig from one hand and made a comparison between the practical and simulation results. The dynamic response of the passive driver seat test rig is acceptable. It was found that there is a good agreement between the experimental and simulation results of displacement, velocity, and acceleration for the base and pan driver's seat. As a result, the design driver's seat test rig is reliable with a good performance, low cost, and practicable so it could be used to develop the driver's seat spatially for a heavy-duty vehicle. For future work, it could be a benefit to using this test rig with considering proposed controllers such as LQR or PA controller and show the active performance of the test rig.

## Acknowledgments

The authors would thank, Kerbala University, Engineering College for give them this opportunity to do this study, also they would thank, Babylon University, Technician College and the laboratory technician "Zaid" for support.

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