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Analysis of Vehicle Dynamics Motion on Performance Spring Under Vehicle Ride Condition

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Abstract: Analysis of the dynamics of vehicle motion on performance spring under vehicle ride conditions. The absorber parameters studied include a standard spring-damper system and a performance spring-damper system. The aim of this experiment to study sprung and unsprung behavior on various spring stiffness, to develop data acquisition system (DAQ) which can provide vehicle ride motion, and to analyze suspension performance testing during ride condition. The study was conducted using an Arduino Uno microcontroller as the processing unit and an accelerometer sensor as the input device. The output of the experiments was the acceleration measurements. The experiments were run in ride conditions, at speeds of 10 km/h, 15 km/h, and 20 km/h. The study used experimental approachs, the experimental setup consists of Arduino uno as the processor unit to measure the vertical acceleration of the vehicle. The vehicle dynamics data was collected and analyzed for both standard spring damper system and performance spring damper system. The data collected during the experiment was analyzed to determine the effect of different absorber parameters on the dynamics of the vehicle. The results of this study prove the unsprung acceleration from performance spring up to 2 g in the negative direction at 20km/h. The vertical acceleration of the vehicle with the performance spring is higher at the sprung mass, which has the potential to negatively impact the vehicle's ride comfort which is the average improvement of vehicle with standard spring are -12.48% at 10 km/h, -11.17% at 15 km/h and -11.41% at 20 km/h. The results show that the standard spring-damper system can improve ride comfort and that the choice of absorber parameters can have a significant impact on the dynamics of a vehicle. Overall, the understanding of how absorber parameters affect the dynamics of a vehicle under standard road conditions and provide a new perspective on how absorber parameters can be optimized for improved ride comfort.

Keywords: Arduino Uno, DAQ, Ride Comfort

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1. Introduction

Issue related to vibration are not unusual in driving comfort. There are many caused and effect of vibration on driving experiences. Vehicle user may face the problem while driving according to un-comfort driving cause by vibration. In the vehicle dynamics, By Vaibhav Dwivedi in Indian institute technology Kanpur, frequencies from 13 to 22 Hz are dominant on the lower control arm. Most suspensions are designed to transfer the frequency band between 1 to 2 Hz only. So that condition of resonance on the human body is to be controlled to maintain the passenger ride comfort [1].

Driving comfort are important for vehicle users. There is a need and desire in the modern era for passenger vehicles with robust systems and superior riding qualities. In order to fulfil customer demands and remain competitive, the automobile industry may benefit from effective suspension design. auto industry. While choosing a suitable vehicle target level, hard points, system architecture, bushing rates, and spring rates, as well as considering the structural integrity of each component and the vehicle dynamics assessment of the design results, take up a significant amount of time during the process of designing a vehicle suspension spring. To evaluate the suspension spring design for enduring the frequent road-induced disturbances without early-stage failure and offering smooth vehicle ride features, these activities demand significant human labour, resources, and time. According to ISO 2631-1 standard, the risk of vertebral injuries in the lumbar area is significantly raised if the human body is continually subjected to vibrations between 0.5 and 80 Hz. This might result in the nerves attached to these segments malfunctioning [1].

1.1 Arduino Integrated Development Environment (IDE) software

The integrated development environment (IDE) software enables developers to rapidly create new applications by seamlessly integrating into the setup process. IDE features are designed to assist developers in organizing their workflow and solving problems within their defined parameters. The IDE examines the code in real time, thus promptly identifying any bugs resulting from human error. Furthermore, IDE software supports C and C++ programming languages and provides numerous common input and output procedures. The Arduino programming language, known as Sketch, has undergone updates to facilitate easier code comprehension for beginners. The Arduino IDE, developed using the JAVA programming language, encompasses the C/C++ library, simplifying input and output tasks. It is a modified version of processing software specifically tailored for Arduino programming. Programs written using Arduino software are referred to as sketches, which are composed in a text editor and saved with a corresponding file extension. The text editor within the Arduino software offers convenient features such as cutting, copying, and searching/replacing, thereby facilitating code composition [2].

1.2 Vehicle Dynamic Motion

Evaluation of the vehicle's variables, such as slip angle, lateral acceleration, and rotational speed, is done for two transient and steady states while analyzing how to handle the automobile in various directions. The amount of roll center height, amber angles, Kester, totals, and toe in and out may be significantly altered by the suspension system geometry, which has an impact on how the vehicle handles. Two transient and stable states are included in the analysis of how the automobile is handled in each direction. Vehicle models with suspension systems are also used for this purpose to assess handling dynamics. The impacts of the suspension and tire systems are included

In a vehicle rollover prediction model that has been presented in [3]. The findings of this study demonstrate that altering the settings of the suspension system can enhance vehicle stability conditions by modifying the amount of lateral acceleration during various maneuvers. It has been found in earlier research that improving handling and positioning of wheels on the road holding by taking geometric aspects into account helps reduce variations in wheel angles [4]

2. MATLAB Simulink Data collection

Analysis of vehicle dynamic motion need come out with programming which is Arduino Uno programming and MATLAB Simulink. All sensor need to be installed to the vehicle after calibrate at sprung and unsprung location.

2.1 Spring damper selection

A spring damper is a mechanical device that is used to support loads and absorb energy through the motion of a spring. It consists of a spring and a damper, which work together to provide both support and damping in a mechanical system. The spring stores energy when it is deformed, while the damper dissipates energy through viscous friction. When a load is applied to the spring damper, the spring stretches and the damper slows the motion of the spring, resulting in a smooth and controlled response.

This experiment began with different spring damper of vehicle which is using Perodua Myvi 1.3L. The different spring which is using standard spring damper and performance spring damper. As shown in Figure 1 and Figure 2 the illustration shape of spring damper. Firstly, the experiment will conduct with standard spring damper to measure vehicle dynamic motion which include ride motion and handling motion by guide with speed has been set up.

Figure 1: Standard Spring

Figure 2: Performance Spring

2.3 Road and Speed Test

Road selection in this experiment are using road in Universiti Tun Hussien Onn Malaysia (UTHM) campus Pagoh shows in Figure 3. There are have straight road use for ride condition for experiment. By using Perodua Myvi The choice of road surface can have a significant impact on the ride conditions of a vehicle hit the speed bump. Different road surfaces have different levels of grip and smoothness, which can affect the vehicle's stability, and comfort.

Figure 3: Road for testing

To assess the performance of different spring damper setups when encountering bumps at various speeds, a controlled experiment was conducted. The test vehicle was equipped with two types of spring damper combinations: the standard spring damper setup and the sport spring damper setup. The experiment involved hitting a standardized bump at speeds of 10, 15, and 20 km/h. A speed choosed according to according to national speed limits through the bump limited at 20 kmh. The vehicle's suspension system was initially fitted with the standard spring damper setup. Vertical acceleration data was collected using precise sensors strategically placed within the vehicle. To ensure accuracy and consistency, multiple runs were conducted at each speed, and the average vertical acceleration values were recorded. The standard spring damper setup was chosen to serve as a baseline for comparison.

Following the data collection with the standard spring damper setup, the sport spring damper setup was installed on the vehicle. The same process was repeated, conducting multiple runs at each speed and recording the corresponding vertical acceleration data.

Table 1: Speed selection

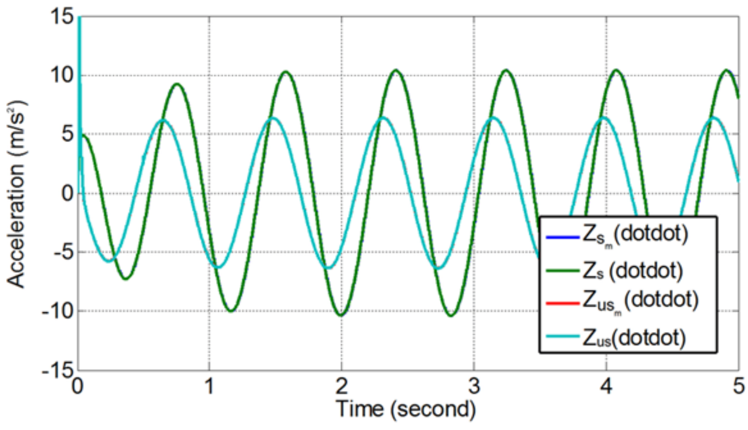
Speed (km/h)	Condition
10	Ride and bump
15	Ride and bump
20	Ride and bump

3. Results and Discussion

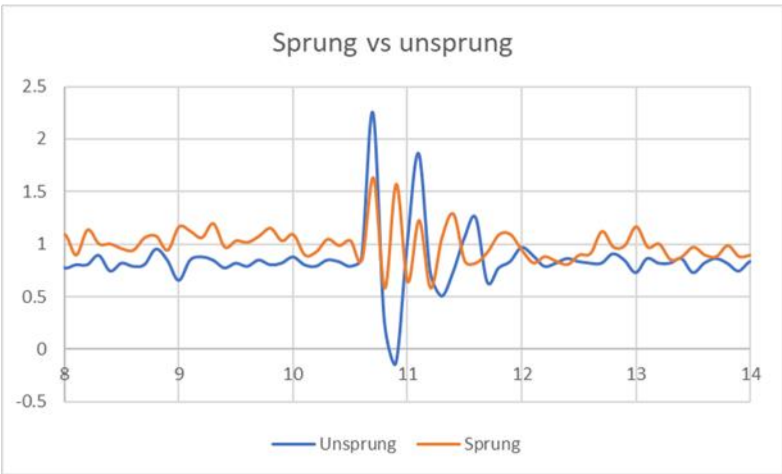
The result presented vertical acceleration recorded by using accelerometer proved the force from performance spring bigger than standard spring. Graph constructed for clarity the peak point when vehicle before hit the bump, during hit the bump, and after hit the bump. From analysis for driving comfort, vehicle suggested to use standard spring for low vibration and comfortable while driving.

3.1 Experimental validation

When validating data from experiments that involve accelerometers at both the sprung and unsprung locations of a vehicle need to ensure that the accelerometers used in the experiment are properly calibrated. By following the manufacturer's guidelines for calibration or consult a qualified technician. Calibration helps establish the accuracy and reliability of the sensors. Data in experiment must be equivalent as simulation, which is G force in unsprung mass higher than sprung mass. Figure 4 (a) and (b) show comparison of sprung and unsprung mass in simulation and comparison sprung and unsprung mass in experiment.



(a)



(b)

Figure 4: (a) simulation result (b) experiment result

3.2 Sprung Acceleration

Experiment of sprung mass acceleration by ride on speed bump which is 2.44meter x 0.40meter x 0.07meter (length x width x height). The result obtained with two parameter which is standard spring damper and performance spring damper. This parameter will be compared in g force unit which is 1g equal to 9.81 m/s^2. the test conduct in 10, 15, and 20 km/h.

Figure 5 shows the result of comparison between performance spring and standard spring when vehicle hit the bump. From the graph show there have 3 critical point which is show the first point is the vehicle before hit on the bump where for the standard spring shows -2.089 g and performance spring shows -2.134, seconds point show the vehicle during hit the bump where for standard spring shows 0.089 g and 0.373 g for performance spring, and the last point after vehicle hit the bump where the standard spring shows -1.970 g and -2.268 g for performance spring. The experiment show on the graph, the vertical acceleration of performance spring higher than standard spring which is the different point between performance spring and standard spring before hit the bump is 0.104 g at 6 seconds, during hit the bump is 0.283 g at 6.2 seconds, and after hit the bump is 0.299 g at 6.4 seconds.

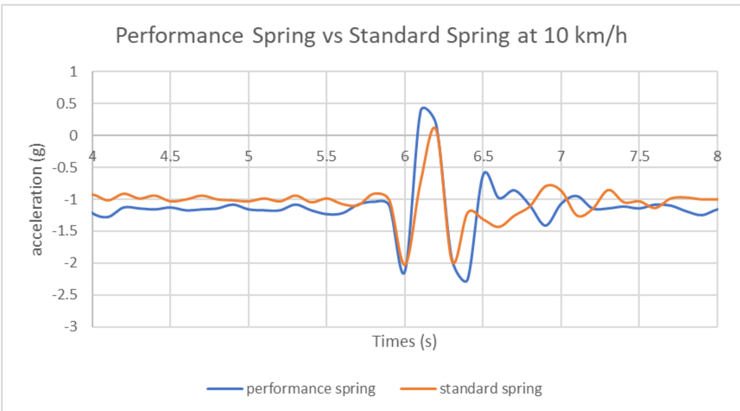


Figure 5: Result sprung at 10km/h

Observation from result sprung mass in 15 km/h in Figure 6 shows the critical point at performance spring higher than standard spring. The pin point before vehicle hit the bump at 11 seconds for standard spring is -2.029 g while for performance spring is -2.686 g. the different from both spring is 0.360 g. Next, during vehicle hit the bump the point for standard spring is 0.089 g at 11.2 seconds while for performance spring is 0.194 g at 11.3 second and the different from both spring is 0.105 g. The final point after vehicle hit the bump is -1.970 g 11.3 seconds for standard spring while -2.343 g at 11.6 seconds for performance spring. The different is 0.373 g.

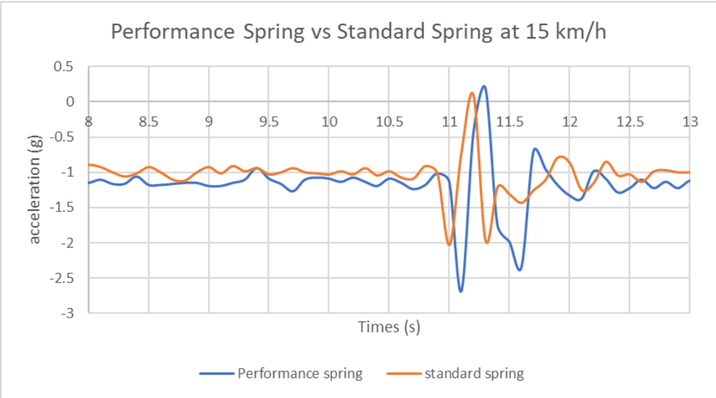


Figure 6: Result sprung at 15km/h

Observation from result sprung mass in 20kmh in figure 7 shows the critical point at performance spring higher than standard spring. The pin point before vehicle hit the bump for standard spring is -1.149 g at 11.4 seconds while for performance spring is -1.210 g at 11.4 seconds. the different from both spring is 0.060 g. Next, during vehicle hit the bump the point for standard spring is 0.230 g at 10.5 seconds while for performance spring is 0.520 g at 10.6 seconds and the different from both spring is 0.290 g. The final point after vehicle hit the bump is -1.360 g at 11 seconds for standard spring while -2.100 g at 11 seconds for performance spring. The different is 0.740 g.

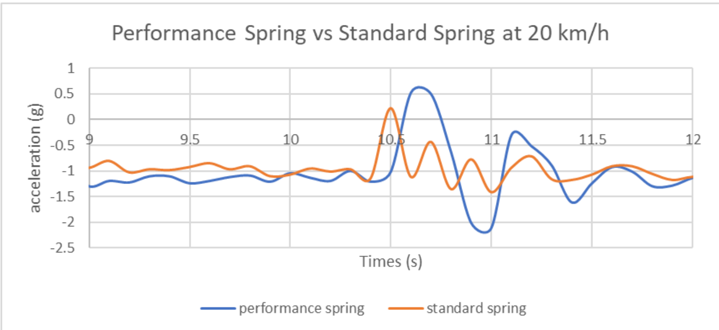


Figure 7: Result Sprung at 20km/h

3.3 Unsprung mass result

The experiment involved measuring the acceleration of the unsprung mass when riding over a speed bump with dimensions of 2.44 meters in length, 0.40 meters in width, and 0.07 meters in height (length x width x height). The measurements were taken on a component that is not supported by an absorber.

Two parameters were considered in the experiment: the standard spring damper and the performance spring damper.

The comparison between the performance spring and the standard spring when the vehicle hits the bump is illustrated in Figure 8. The data obtained from the unsprung mass provides a clearer understanding of the peak points between the two types of springs. The graph reveals three critical points, representing different stages: the vehicle's position before hitting the bump, during the impact, and after clearing the bump.

According to the experimental results displayed on the graph, the vertical acceleration of the performance spring surpasses that of the standard spring. Specifically, before hitting the bump, there is a difference of 1.550 g between the performance spring and the standard spring, observed between 17 and 17.5 seconds. During the impact of the bump, the performance spring registers a vertical acceleration of 0.280 g at 17.4 seconds. After the vehicle has cleared the bump, the performance spring shows a vertical acceleration of 1.030 g at 17.7 seconds.

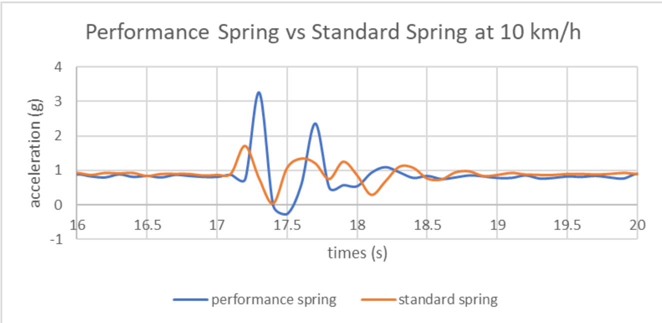


Figure 8: Result Unsprung at 10km/h

The results of the observation on unsprung mass at a speed of 20 km/h, as depicted in Figure 4.7, indicate a noteworthy finding. The critical point occurs in the opposite direction for the performance spring compared to the standard spring. Prior to the vehicle encountering the bump, the standard spring recorded a measurement of 1.850 g at 12.4 seconds, whereas the performance spring showed a higher reading of 2.550 g. The difference between the two springs is 0.700 g. Subsequently, when the vehicle hits the bump, the standard spring registered a measurement of 0.240 g at 12.6 seconds, while the performance spring exhibited a reading of -0.390 g at 12.5 seconds. The difference between the two springs in this scenario is 0.630 g. Finally, after the vehicle has cleared the bump, the standard spring recorded a measurement of 1.040 g at 12.8 seconds, while the performance spring showed a slightly higher reading of 1.280 g at 12.7 seconds. The difference between the two springs at this point is 0.240 g.

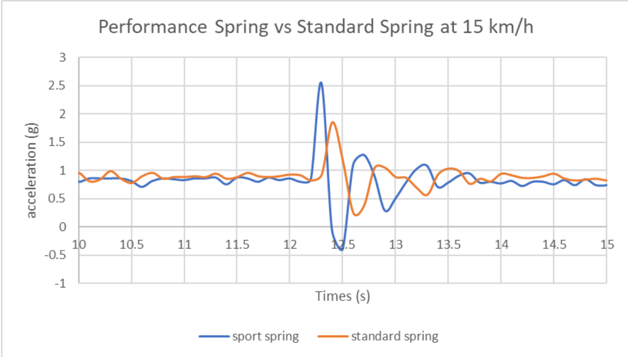


Figure 9: Result Unsprung at 15 km/h

The observations of the unsprung mass at a speed of 15 km/h, depicted in Figure 11, reveal significant findings. Interestingly, the critical point for the performance spring occurs in the opposite direction compared to the standard spring. Before the vehicle encounters the bump, the standard spring measures 1.895 g at 13.6 seconds, while the performance spring shows a higher reading of 2.253 g. This results in a difference of 0.350 g between the two springs. Upon hitting the bump, the standard spring records a measurement of 1.189 g at 13.7 seconds, whereas the performance spring displays a reading of -0.134 g at the same time. The difference between the two springs in this scenario is 1.320 g. After the vehicle has cleared the bump, the standard spring records a measurement of 1.478 g at 13.8 seconds, while the performance spring shows a slightly higher reading of 1.860 g at the same time. The difference between the two springs at this point is 0.380 g.

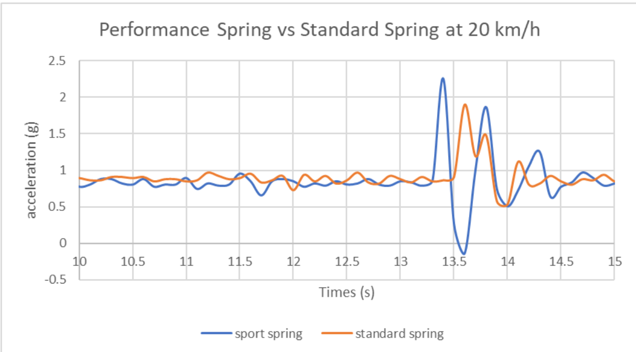


Figure 11: Result Unsprung at 20km/h

3.4 Root Mean Square of Vehicle Ride Test

Table 2: Root Mean Square (RMS)

Types	Performance spring			Standard spring		
Speed	10 km/h	15 km/h	20 km/h	10 km/h	15 km/h	20 km/h
Sprung	1.3639	1.3458	1.3002	1.0498	1.0411	0.9985
Unsprung	0.7866	0.7609	0.7608	0.8278	0.8175	0.8221

Table 3: Improvement of Vehicle With Standard Spring

Improvement of vehicle with standard spring (%)	Speed	10 km/h	15 km/h	20 km/h
	Sprung	-29.92	-29.26	-30.28
	Unsprung	4.97	6.92	7.46
	Average	-12.48	-11.17	-11.41

Based on the data presented in Table 2, the table provides the root mean square (RMS) values for the vehicle ride motion when encountering a bump obstacle. In general, the average improvement of the vehicle equipped with a standard spring is greater when compared to the performance spring. The table also shows a notable decrease in acceleration when traversing the bump obstacle. When comparing the performance spring and the standard spring, Table 3 shows the evident that the vertical acceleration of the vehicle with the performance spring is higher at the sprung mass, which has the potential to negatively impact the vehicle's ride comfort.

4. Conclusion

The experiment conducted aimed to evaluate the vertical acceleration resulting from the interaction between the sprung mass and unsprung mass of a vehicle. Two types of springs were used which is performance springs and standard springs. The purpose was to compare the forces exerted by each type of spring on both the sprung and unsprung masses. Based on the data observation, it was found that the performance springs generated larger forces on both the sprung mass and unsprung mass compared to the standard springs which is 1.3002 g for performance spring and 0.9985 g for standard spring. This suggests that the performance springs have a greater impact on the overall vertical acceleration of the vehicle. The experiment further examined the effect of speed on vibration. Three different speeds were tested which is 10 km/h, 15 km/h, and 20 km/h. The results indicated that as the speed increased, the level of vibration decreased. This phenomenon can be attributed to the support provided by the longitudinal axis of the vehicle, which helps to reduce vibrations as the speed rises. Additionally, the experiment demonstrated that the standard spring damper system offered better ride comfort compared to the performance springs. This implies that the standard springs provided a smoother and more comfortable ride experience for the vehicle occupants. In summary, the experiment showed that performance springs exerted greater forces on both the sprung and unsprung masses, resulting in increased vertical acceleration. However, the standard spring damper system offered improved ride comfort compared to the performance springs.

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