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Validation of Cost-Effective Data Acquisition System on Motorcycle

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Abstract: A data acquisition system (DAQ) is a combination of software and hardware that makes it possible to measure or control the physical properties of anything in the real world. Unfortunately, the compact DAQ, which is most often used, is too expensive for preliminary study, such as for motorcycle dynamic study. The objective of this study is to study the four degrees of freedom (4-DOF) motion on a motorcycle. To develop cost-effective data acquisition systems using Arduino and to validate the data from the DAQ using actual motorcycle ride motion. In order to detect the vertical motion of sprung and unsprung masses that are taken into consideration, a gyroscope is placed on two separate sections of the vehicle, which are made up of a Yamaha 135 LC chassis and a lower arm. Gyro sensor is being used to gather data on the body's vertical acceleration and vertical motion. The experiment will be carried out at vehicle speeds of 25 km/h for the slalom test. For the bump test, the speed of the motorcycle is 20 and 30 km/h, and for the braking test, the speed of the motorcycle is 20 and 25 km/h. Arduino IDE is used to transmit data from a sensor to a laptop. Generally, as the pattern of slalom tests generated in this study is nearly the same as in the previous study, it can be assumed the experiment is validated, although there is some discrepancy in the peak of roll and yaw rate. The DAQ on motorcycle was validated by comparing with simulation method. In the result, the higher peak of roll and yaw rate is around 40°/s, which may be expected because the rider's speed is less than 5 km/h but the pattern is still the same as in the previous study and the study continued with braking and bump tests.

Keywords: Data Acquisition System, Arduino UNO, Gyro Sensor

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1. Introduction

It is possible to measure or control the physical properties of anything in the real world using a data acquisition system, which is a combination of software and hardware that enables one to do so. When it comes to a comprehensive data acquisition system, sensors and actuators, signal conditioning hardware, and a computer that runs DAQ software are all necessary components to have. Unfortunately, compact DAQ data which is most often used, is too expensive (excluding sensors) for preliminary study, such as for motorcycle dynamic study. Besides, in terms of DAQ development, database systems are complex and cannot be simply integrated with low-cost sensors.

1.1 Data acquisition system

Data acquisition (DAQ or DAS) is a subset of data acquisition. It is the process of sampling signals that measure real-world physical events and transforming them into digital form that can be handled by computers and software. When compared to older means of recording onto tape recorders or paper charts, data acquisition is widely acknowledged to be unique. The signals, in contrast to other approaches, are transformed from the analogue domain to the digital domain and then recorded to a digital medium, such as flash memory or hard disc drives [1]. Analogue signals are transformed into digital form and then processed using an analogue to digital converter (ADC), which is a kind of digital signal processor. Single-channel and multi-channel signals may be acquired by existing digital signal processors. The following are some of the components of data acquisition systems:

I. Sensors that translate physical factors into electrical impulses are also available.

II. Circuitry for signal conditioning, which converts sensor signals into a format that can be translated to digital values.

III. Analog-to-digital converters, which transform sensor signals into digital values after being conditioned. Application software for data capture is managed by software program that are written in a variety of general purpose programming [2].

There are three main types of data acquisition systems. The first is computer-based and uses computers' processing power to perform data transformation, visualization, storage, and/or decision-making activities. PCI and ISA extension cards act as internal data collection devices. Other applications, rather than only data collection, often necessitate computer upgrades. If the computer expansion bus is full, an external data gathering module is employed. External data acquisition systems typically consist of a module connected to a computer. They are connected to the PC using particular connectors. Embedded microcontroller-based systems are the second type. These systems are frequently used in areas like healthcare, automotive, environmental monitoring, and power plants. These systems are developed with a permanent framework and offer mobility and great performance. Embedded microcontroller data collecting systems have various drawbacks. In such cases, a new embedded microcontroller data collecting system is required. In certain applications, such as hazardous or remote locations, dynamically reconfigurable DAQ systems will be crucial, especially in remote architectural reconfiguration. With computer-based data acquisition devices, the FPGA is solely used for timing and triggering, or to create programmable control algorithms. It may also have all the compute, storage, and I/O capabilities required for a data collection system [3].

In research and development, specialized test and measurement instruments are necessary to guarantee that the project operates in accordance with the calculations and to aid in the resolution of issues that arise. A wide variety of models, each with its own set of advantages and disadvantages, may be utilized with data gathering systems to gather information about component properties and characteristics throughout the prototyping and preproduction stages. Table 1.1 show the low-cost versus high-cost data acquisition hardware. Data loggers are also widely used in research and development, for example, to measure acceleration forces in amusement parks, to conduct cell culture experiments in microgravity onboard the International Space Station, to measure acceleration for the avalanche emergency system, and to detect smartphone falls [4].

Table 1: Low-Cost versus High-Cost Data Acquisition Hardware

Device name	Price	Datasheet	Affordable (Preliminary study)	Updatable version	Easy to apply	Prototyping	Stable
 Arduino UNO	RM 25.90	☑	☑	☒	☑	☑	☒
 Model DI-1100	RM 245.30	☑	☒	☑	☑	☒	☑
 Lab Jack T7	RM 2933.80	☑	☒	☑	☑	☒	☑
 Compact Rio	RM 12,500	☑	☒	☒	☑	☒	☑

☑ able

☒ unable

1.2 Arduino UNO

The Arduino UNO is a microcontroller board. It includes a USB connection, a power connector, an In-Circuit Serial Programming header, and a reset button on the front panel. Simply connect it to a computer through a USB wire or power it with an AC-to-DC converter or battery to get started with the microcontroller. The Arduino UNO is compatible with the vast majority of shields created for the Arduino Diecimila microcontroller [5].

A USB connection or an external power source may be used to power the Arduino UNO. This is accomplished by selecting the power source. A non-USB power source may be either an AC-to-DC converter or a battery that provides power external to the computer. Using a centre-positive plug, attach the adapter to the board's power port. A battery's leads may be connected to the POWER connector's GND and Vin pin headers. It is possible for the voltage regulator to overheat and cause damage to the board if it has been use more than 12V [6]. Each of the digital pins may be utilised as an input or an output by using the pin Mode, digital Write, and digital Read capabilities, among other things. Arduino work at a voltage of 5 volts. The Arduino UNO is equipped with a variety of communication interfaces that allow it to communicate with a computer, another Arduino, or other microcontrollers. The Arduino UNO may be programmed using the Arduino software, which is available for download here. The Arduino UNO is pre-burned with a bootloader, which enables users to upload fresh code to it without the need for an additional hardware programmer or other external devices [6].

1.2 Gyro sensor

Gyroscopes are devices that are attached to a frame and that are capable of monitoring angular velocity as the frame is rotated [7]. Gyroscopes are classified into many categories, which are determined by the physical and technological operations the sensor perform. An individual gyroscope may be used alone or in conjunction with more complicated systems such as an Inertial Measurement Unit (IMU), a gyrocompass, an attitude heading reference system, and a GPS navigation system [8]. Figure 1 show the illustration of the basic principle of a gyroscope

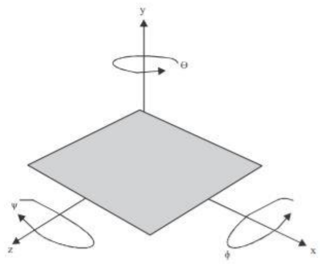


Figure 1: Illustration of the basic principle of a gyroscope [8]

2. Equipment and Methodology

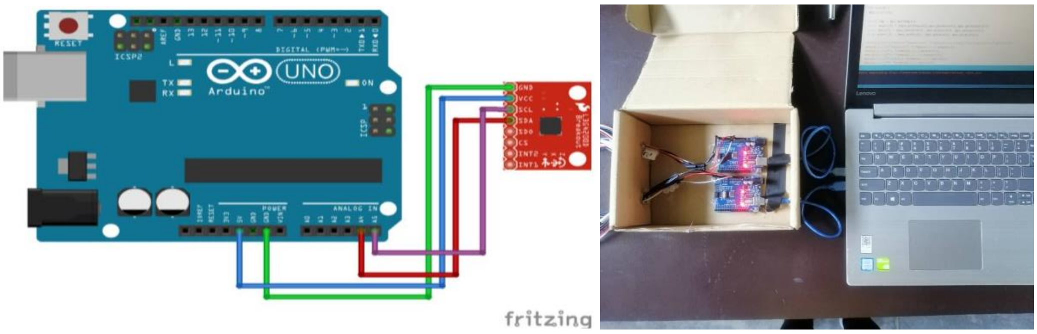
Experimental parameters were set based on the literature reviews, the objective, and the scope. The experiment starts with the slalom test because the data must be validated with previous study and after validation process, another two experiment which is bump test and braking test are performed. The data collected is then tabulated as the result based on the conducted experiment.

2.1 Test Equipment

The roll and yaw rate and vertical motion was measured using a DAQ system that is developed and is installed in sprung and unsprung of motorcycle respectively. Two Arduino UNO microcontrollers were connected to computer. One function is to read the data produced from sprung masses and another one read data produced from unsprung masses.

2.1.1 DAQ System using Arduino UNO and Gyro sensor

The time in seconds (s) following the laptop time was logged by the software. While riding, the rider had all sensors and an Arduino UNO connected to a laptop. Using black tape, all of the connections were secured to the paper box and then placed in a bag for the rider to execute the experiment as shown in Figure 2. The sprung and unsprung connections are denoted by the letters s and un, respectively. In order to avoid confusion during discussion and observation, the rider transfers data from the sensor into Excel once the experiment is over.



(a) (b)

Figure 2: Component setup (a) Circuit diagram (b) Actual hardware

2.1.2 Test vehicle

The Yamaha 135 LC is served as the test vehicle for the experiment. The specifications for the Yamaha 135 LC are as follows: 134cc displacement. Manual transmission is an option for the 135 LC. The 135 LC is a 2-seater moped with dimensions of 1960, 695 and 1255-mm wheelbase. Single-cylinder, four-stroke engines power the test vehicle. The Yamaha 135 LC shown in illustration weighs

105 kg. It has 12 horsepower which is the highest power available on the Yamaha 135 LC motorcycle. Lastly it a 4-speed manual transmission transfers power from the engine to the wheels.

2.2 Experiment Procedures

Using the provided wire connections, the wiring was set up in the gyro sensor to the Arduino UNO and connected to the laptop. Each wire was labelled with the corresponding pin connection and was secured with a cable tie and glued with the hot glue gun. The gyro sensors are installed at the sprung and unsprung parts of the motorcycle; one is installed at the lower arm and one on the motorcycle body, which is located at the motorcycle's center of gravity (COG), which is located below the seat. Figures 2.2 (a) and (b) depict the gyro sensor position on a motorcycle.

(a) (b)

Figure 3: Position of the gyro sensor at (a) sprung (b) unsprung

The Arduino UNO is connected to the laptop and attached to the gyro sensor. Ensure that the Arduino UNO is capable to reading the data released by all of the sensors and can display the output data provided by the sensors in the laptop using the Arduino IDE software by run a simple test. Before beginning the experiment, prepare the track and obstacles that will be utilized. The experiment is carried out at their suggested or recommended speed, which is 25 km/h for the vehicle and 7 m for each cone. Figure 4 depicts the motorcycle's slalom course. Slalom tests are used to collect data and check it against earlier research. Following the acceptance of the data provided in this investigation, which follows the same pattern as the previous study, further two experiments, the bump test and the brake test were conducted. The bump test experiment is 0.17-meter width and 0.06-meter height (width x height), and the speeds are 20 and 30 km/h. For the braking test, the maximum speed before the motorbike shifts to brake is 20 and 25 km/h. Finally, the data from the three experiments was gathered and tabulated. Analyze and plot the graph to assess and compare it to the previous experiment. Conduct a discussion and conclusion of the experiment.

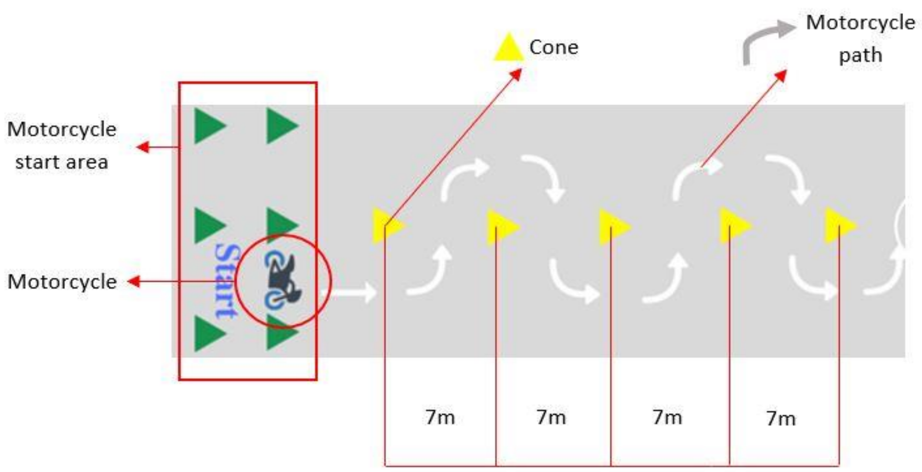


Figure 4: Motorcycle slalom path

3. Validation and Discussion

To validate the data, the slalom test was chosen to work as a validation, and motorcycle testing was conducted. An angle of velocity and a slalom path were recorded. This data was compared in terms of the pattern of the graph with the results of the simulation which was carried out with the help of Advanced Driving Assistance Systems (ADAS) [9]. If the pattern of the graph seems more or less like the graph produced in the past study, the validation can be assumed to be a success and can proceed to the next experiment.

3.1 Slalom Test

Figure 5 depicts a touring motorcycle performing a normal slalom manoeuvre on the road. The cone spacing is 7 m, and the average forward speed is 25 km/h The detail of motorcycle slalom test shown in Figure 5.

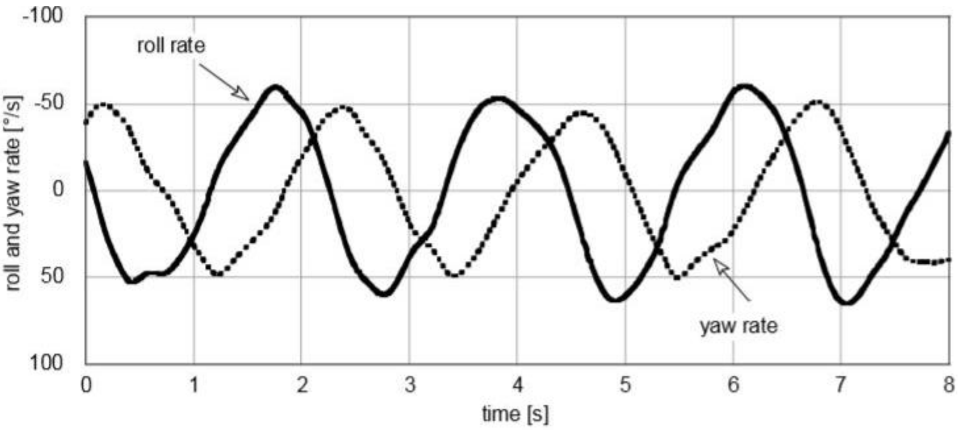


Figure 5: Slalom path, components of angular velocity on simulation [10]

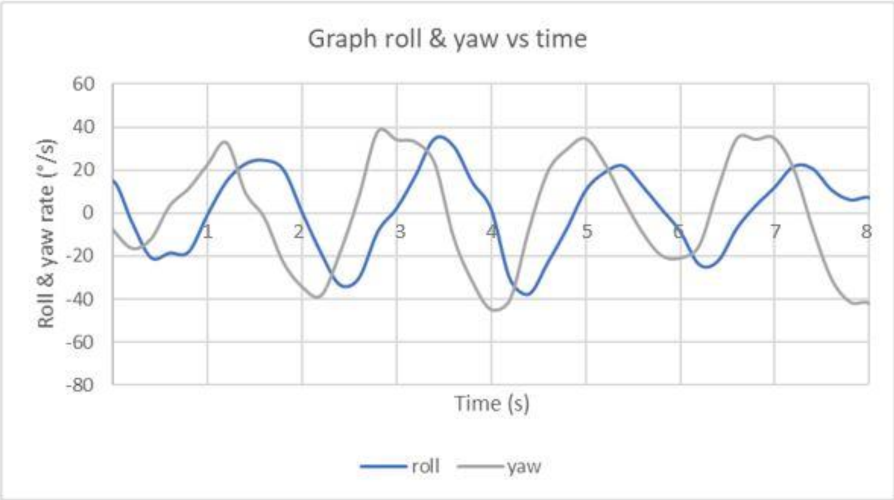


Figure 6: Slalom validation test

Figure 6 depicts the results of the slalom test carried out in this study. According to the observations, the generated result is nearly identical to the outcome of the previous experimenter's simulation. As the pattern generated in this study is nearly the same as in the previous study, it can be said the experiment is validated or verified. The higher peak of roll and yaw rate is around 40°/s, which may be expected because the rider's speed is less than 5 km/h. It will look unstable at the peak of roll and yaw. This is due to the fact that the driving speed of a motorcycle fluctuates for a variety of reasons.

3.2 Bump Test

After the validation process performed and proven the low-cost data acquisition system can get data more or less like high-cost data acquisition system, the study continued with the braking test. Figures 3.3 and 3.4 illustrate the results of the experiment at 20 and 30 km/h. The vehicle test consisted of driving up and over a barrier. The high peak indicates that the vehicle hit and crossed over the bump at that specific time. It is expected that practically all graphs at 30 km/h will have a higher peak than graphs at 20 km/h for sprung masses and unsprung masses. Generally, when the motorcycle goes through a bump, the damper in the suspension system absorbs the energy produced when the unsprung hits the bump, and the suspension system converts the energy to heat energy and transfers the energy to the outside.

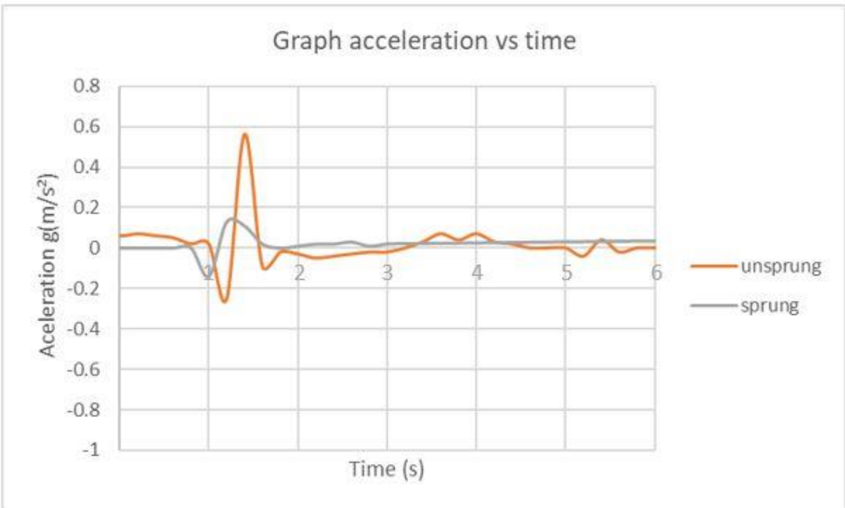


Figure 7: Comparison of pitch experiment (sprung versus unsprung) of 20 km/h

Figure 7 shows that the unsprung maximum acceleration is nearly 0.6 g, while the sprung maximum acceleration is only about 0.2 g. The graph in Figure 7 shows that both the unsprung and sprung acceleration values will decrease before reaching the maximum acceleration. This is because the test vehicle's suspension may be worn, thus when the front suspension meets the barrier at the slowest speed, the shock absorber will bounce back later than the other side.

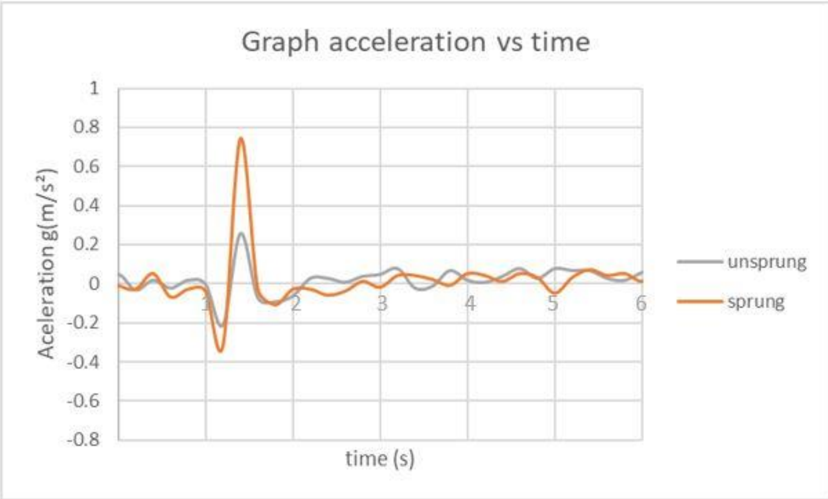


Figure 8: Comparison of pitch experiment (sprung versus unsprung) of 30 km/h

According to Figure 8, the maximum acceleration for unsprung is nearly 0.8 g, while the maximum acceleration for sprung is roughly 0.2 g greater, both of which are greater than at a speed of 20 km/h. It demonstrates that unsprung tends to oscillate more than sprung. The unstable data before and after the bump can be shown in Figure 8, and it have been assumed noises from motorcycle because it only utilized the standard absorber for this experiment, same with data at Figures 7.

3.3 Braking Test

The experiment result for 20 km/h is shown as Figure 9 and for 25 km/h as shown as Figure 10. The vehicle test was utilized to brake inside the allotted riding field. The high peak indicates that at a specific time, when the vehicle was travelling at a greater speed and suddenly braking to check if there was a difference, the vehicle stopping to see if there was a difference. It is expected that the graph at 25 km/h will have a higher peak than the graph at 20 km/h for sprung masses and unsprung masses. The test vehicle's speed is altered in order to investigate the influence of varying speeds on ride performance.

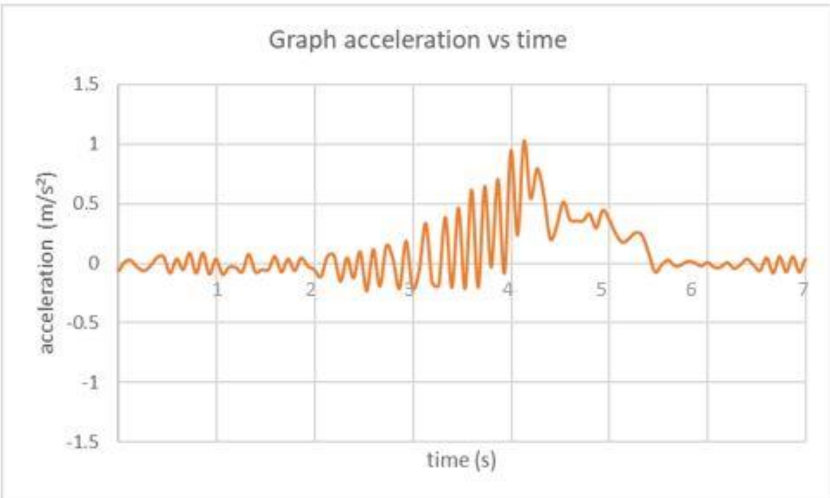


Figure 9: Acceleration-deceleration of vehicle at 20 km/h

According to Figure 9, the vehicle starts to accelerate at time 1 until it reaches a speed of 25 km/h at about 4s. The graph shows the vehicle decelerating after 4s until 7s due to motorcycle braking until fully stopped at 0 km/h. The graph in Figure 8 shows that the sprung acceleration value increases steadily until the point of 1.0 g and then decreases abruptly until the point of 0.0. This is due to the vehicle's shifting speed. When the vehicle is moving, the acceleration increases directly with time, and when the vehicle decelerates, which means braking, the graph decreases.

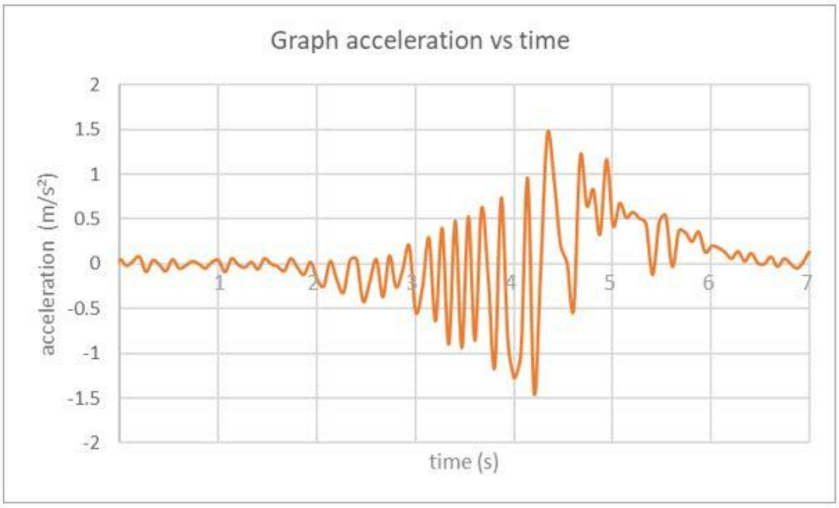


Figure 10: Acceleration-deceleration of vehicle at 25 km/h

According to Figure 10, the vehicle starts to accelerate at time 1s until it reaches a speed of 25 km/h at about 4 s. The graph shows the vehicle decelerating after 4 s until 7s due to motorcycle braking until fully stopped at 0 km/h. The maximum acceleration for springs is 1.5 g, which is greater than at a speed of 20 km/h, and it drops to 0.0 g due to vehicle shift speed, which is stop. It demonstrates that as the speed of the vehicle increases, so does its acceleration. Because it only employed the standard absorber for this investigation, the graph will appear to contain unstable data due to noises from the motorcycle, same with data at Figure 9.

4. Conclusion

In conclusion, the first objective of this dynamic analysis is to study the four degrees of freedom (4-DOF) motion of a motorcycle are completed. The findings of this study allow for a more in-depth examination of the vehicle's speed in relation to the impact of vertical acceleration on the vehicle's sprung and unsprung masses.

Further, the second objective is to develop cost-effective data acquisition systems using Arduino. The data acquisition system in this study which is total cost of this system was RM 97.80 was cheaper than system used in the standard test. As a result, the goal of developing low-cost data gathering systems with Arduino was accomplished.

Lastly, to validation data process from the DAQ using actual motorcycle ride motion can also be reached. The investigation was carried out using three distinct sorts of tests, which were the slalom, braking and bump tests. In the result, the higher peak of roll and yaw rate is around 40°/s, which may be expected because the rider's speed is less than 5 km/h but the pattern is still the same as in the previous study. As a result, the researchers can carry out a thorough development and manufacture of the data acquisition system and wiring system in order to capture more accurate data in their experiment.

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