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DEVELOPMENT OF AN AFTER-MARKET UNIVERSAL FUEL GAUGE FOR MOTORCYCLE

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ABSTRACT

ASEAN countries have shown continuous increment in demand and usage of motorcycles. In addition as an alternative mode of transportation, motorcycle has become a cultural lifestyle and even status symbol for the citizens – especially for high-performance motorcycles. However, factory-installed fuel gauges are not available for most of these classes of motorcycles. They are only equipped with a warning light which triggers upon low fuel capacity. This study is aimed at designing and testing a universal after-market fuel gauge for motorcycles. The coupling of an ultrasonic sensor with an Arduino circuit board was utilized in developing the device. Both simulation and experimental assessments were carried out at flat and inclined surfaces to validate the accuracy of the device. It was observed that percentage errors between the experimental and simulation results were below 20%. The newly designed device with an accuracy of more than 80% would provide reasonable fuel measurement accuracy at low cost with user-friendly interface. Conclusively, the developed innovation is capable in providing a better motorcycling experience with respect to fuel measurement method and display.

Keywords: Universal after-market fuel Gauge, motorcycle, ultrasonic sensor, measuring method, fuel gauge design.

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1. INTRODUCTION

ASEAN countries have shown continuous increment in demand and usage of motorcycles. Indonesia topped the list in 2014 and closely followed by Thailand, Philippines, Malaysia and Singapore [1]. In Malaysia, motorcycle is a favourite option as an alternative mode of transportation due to its relative affordability (e.g. low procurement price, road-tax and fuel consuption) and general convenience (e.g. small in size and better maneuverability through congested cities) in comparison to other kinds of transportation. In a developing country, a cheaper means of transportation takes the highest shares before followed by passenger cars. According to Jabatan Pegangkutan Jalan (JPJ) statistic report on the registered motorcycle on Malaysia road, there were 422,225 units of motorcycles registered in 2005 and the trend increased to 600,000 units in 2012 [2]. Overall, the motorcycle market in Malaysia shows a positive annual increment in demand and registration. It was also projected that such trend would continue for years to come due to the ever increasing cost of living in the particular country. Nevertheless, it is also interesting to note that motorcycle has become more than just mere mode of transportation in these countries [3].

Motorcycling has become a cultural lifestyle and even a status symbol to the citizens – especially upon involving high-performance motorcycles such as the Ducati Desmosedici RR, Harley Davidson's Road King, BMW S1000RR and the likes. However, as strange as it may sounds, a number of these high performance and mass market motorcycles are not factory-installed with fuel gauge. These motorcycles are only equipped with low sensitivity sensor which triggers upon low fuel capacity. This has lead for motorcyclists to seek the use of after-market fuel gauge to overcome this inconveniency. Therfore, the objective of this study was to design and test a universal motorcycle after-market fuel gauge. The purpose of the device is to provide reasonable fuel measurement accuracy at low cost with user-friendly interface.

2. LITERATURE REVIEW

Kwezner et al. [4] stated that consumers are excited to see new technology and development into the market over the years. There are many types of measurement techniques available that range from manual or mechanical to electromechanical, electronic contacting and electronic non-contacting. Ultrasonic measurement technique is a non-destructive and non-invasive measurement technique that is based on the reflection of sound from interfaces. The reflection can help detect the properties of the liquid sample as reported by Michelle M. Schirru [5]. The ultrasonic sensor usually works by emitting frequency signals which are inaudible to human ears. The time taken for the signal to travel back to the transducer could be utilized in measuring the level (volume) of liquid (fuel) in the motorcycle's fuel tank. In addition to its ease of measurement, its compact size and non-reactive nature makes it a suitable sensor that can be easily and safely installed in the motorcycle fuel tank.

Moreover, ultrasonic sensor range is short and cost effective. The standard of ultrasonic gadgets depends on the measurement of time it takes to send and receive the reflected ultrasonic sound wave from the medium. The wave can be compressional or transverse. Whereas, in liquid, the wave is longitudinal. Therefore, the particle propagation is parallel to the direction of wave propagation. The speed of ultrasonic waves can be more effectively affected than the speed of light especially with respect to the factor of temperature and vaporous medium that affects it tremendously [6]. Studies have shown that the higher the temperature, sound waves travel at a much higher velocity. While the temperature at the level gadget can be remunerated by a temperature sensor in the ultrasonic gadget, the level estimation might be precise if the whole space between the sensor and fluid is at ambient temperature. The sort of vaporous media additionally impacts the speed of the sound waves. For instance, sound voyages very nearly three times speedier in helium than it airs. Most ultrasonic gadgets can be modified for the kind of vaporous media the sound waves would go through as noted by Terzic et al. [7].

Dhande et a. [8] mentioned that the ultrasound sensor can be used to measure at millimetre precision due to its robust nature under almost all working condition which contradicts with another report where temperature is dependent. The abilities of ultrasonic sensor to emit and receive wave at certain frequency which capable of measuring the depth of liquid makes it ideal for a motorcycle's tank. In addition, the accuracy is independent of liquid density and no calibration with medium is required [9]. Gong et al. [10] discussed on how the fluid level is measured using ultrasonic test using mathematical modellings. Kumar et al. [11] included a temperature sensor for compensation as the entire space between the sensor and liquid must be at similar temperature. The Digital fuel pointer configuration would in all likelihood be more precise, more dependable, less expensive than other simple meters, and shows the highlights for the advantage of both clients [12].

Upon usage, the installed ultrasonic sensor can only be placed at the top location inside the fuel tank. Gawade et al. [13] demonstrated how the system is placed under the fuel lid as shown in Figure 1. The power for the ultrasonic sensor is supplied from the motorcycle battery block to operate the system. Another reference for the positioning of the ultrasonic sensor is in referring to Rosemount (2013).

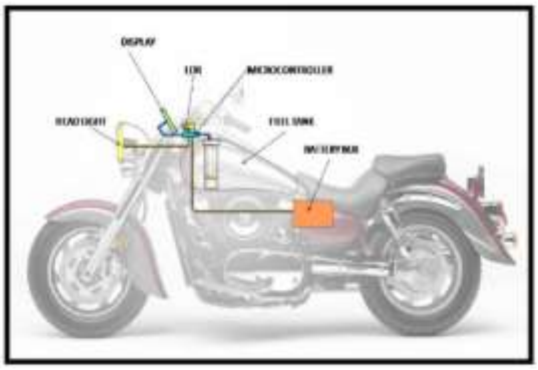

Figure 1 A model showing the underneath association for fuel observing framework [10].

From the literature, there are various studies that had highlighted the other advantages of ultrasonic sensor as a measuring tool involving liquid. The ultrasonic estimation innovation makes up for better directional, precise measurement and overall robust characteristics. Therefore, further cemeted its selection as the sensor of choice for the device.

3. METHOD & MATERIALS

The measurement provided by the device was measured via experimental techniques. Figure 2 shows the schematic diagram of the setup. The ultrasonic sensor which was connected to an Arduino microcontroller was placed under the 3D-printed motorcycle fuel cap. The Octane 95 fuel was poured into the experimental flask. The test was performed on the following inclination surface: (i) 0 degree inclined surface, and (ii) 20 degrees inclined surface. The durations of the experiments were 480 and 600 seconds prior to data collection. Boundary condition for volume of the tank has the radius of 9 cm and height of 32 cm. The ultrasensor was placed at a height of 35 cm. The setup was in referece to Husni et al. [14]. The respective study has completed an extensive experiment on flat and inclined surface for ultrasonic senor. The primary goal for the test was to examine the segment precision under ordinary conditions.

3.1. Computer Aided Design (CAD)

Computer Aided Design was used to design the device. The Autodesk Inventor was the software of choice for this method. With the aid of CAD, a motorcycle fuel cap was designed to include an ultrasonic sensor and the microprocessor in between the outside cap. The design for the motorcycle fuel lid was based on the Yamaha YZF-250RR fuel lid. The design was later exported to STL file format for 3D printing. The design was scaled to 12:1 for precision. The model of the fuel cap was then printed in-house in using a 3D printer available at the FABLAB of INTI International University, Nilai, Malaysia.

3.2. Programming

The program load on the Arduino board was coded using Arduino C++ program in enabling parameter control. The code was written with the goal of the reading the level (depth) of fuel in the motorcycle fuel tank.

3.3. Simulation

Simulation was achieved using Arduino software run on a data acquisition system for data collection purposes.

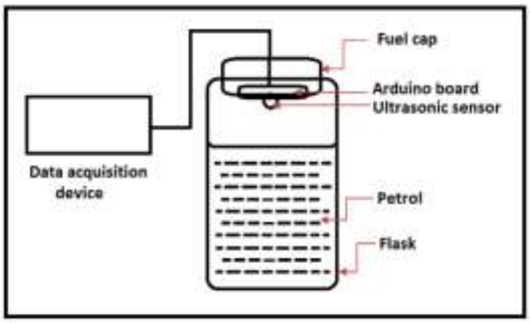

Figure 2 Experimental setup

4. RESULTS AND DISCUSSION

The level of fuel in the tank was measured for both flat and inclined surfaces. Validation between the experimental and simulation results was conducted and discussed.

4.1. Experimental and simulation results on flat surface

Table 1 shows percentage errors between simulation and theoretical results for the flat surface. It was observed there was maximum error when the petrol level was at 5 liters. At maximum petrol level, the percentage error was found to be average. In general, the percentage errors are so small that theoretical results agree with that of simulation results.

Table 1 Simulation and theoretical result on flat surface

No.	Simulation / cm^3	Theoretical /cm^3	Percentage Error / %
1.	0	1017	1.00
2.	1000	1272	21.40
3.	2000	2290	12.30
4.	3000	3562	15.60
5.	4000	5089	21.4
6.	5000	5216	4.10
7.	6000	6107	1.75
8.	8000	8906	10.20

Figure 3 shows volume of fuel over time when the surface was flat. The trends for the experimental and simulation results are similar, indicating the accuracy of the device developed. The experiment was done under ambient temperature. Some studies concluded that ultrasonic wave is affected by the surrounding temperature. By adding a temperature sensor which can sense the surrounding temperature and send the data to the microcontroller the reading of the fuel in the tank can be enhanced and improved.

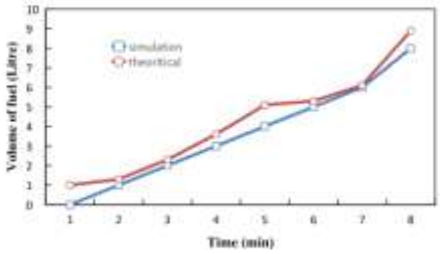

Figure 3 Volume of fuel vs Time for the flat surface

4.2. Experimental and simulation results for incline surface at 20 degrees

The second testing situation investigated segment precision under incline surface of 20 degree conditions. This scenario was performed for 600 seconds. Table 2 shows simulation and theoretical results when the surface was inclined at 20 degrees. It was found that the difference between the simulation and theoretical results is higher on incline surface. However, majority of two-wheelers operate when the vehicle is perpendicular position. The inclined road condition in some places might slightly affect the accuracy of the readings.

Table 2 Simulation and theoretical results on inclined surface

No.	Simulation / cm^3	Theoretical / cm^3	Percentage Error / %
1.	0	757.94	1.00
2.	1000	1152.38	13.22
3.	2000	2862.00	30.11
4.	3000	4228.25	29.04
5.	4000	6098.50	34.41
6.	5000	6566.51	23.85
7.	6000	6943.08	91.35
8.	8000	8099.64	1.23
9.	9000	8279.76	8.70
10.	10000	8360.33	19.61

Figure 4 shows volume of fuel over time when the surface was inclined 20 degrees. The trend for both results is almost similar showing the accuracy of the device for the inclined surface. At lower volume, the software notifies the rider that the fuel level is very zero. However, theoretical result shows that there is approximately a volume of petrol which can produce a range of 20 km based on the data assumption taken from Yamaha YZR-R25 for a single person load at normal driving condition.

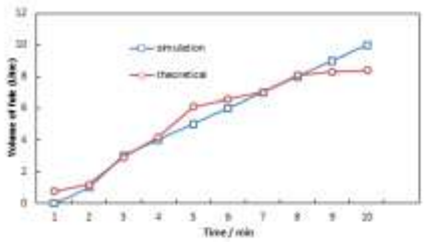

Figure 4 Volume of fuel vs Time when the surface is inclined 20 degree

5. CONCLUSION

The utilization of ultrasonic sensor in motorcycle for the purpose of measuring the level of fuel in the tank is feasible and flexible in term of measurement acurracy, cost and installation. This study might as well be the push start for manufacturer to adapt to the change. The first prototype of the device provides information on fuel level and consumption based on speed and acceleration. Both simulation and experimental assessments were carried out at flat and inclined surfaces to validate the accuracy of the device. It was observed that percentage errors between the experimental and simulation results were below 20%. Conclusively, the developed innovation is capable in providing a better motorcycling experience with respect to fuel measurement method and display. For future work, user experience is an important factor in successful products. Therefore, the fuel gauge could might as well provide additional information such as fuel economic usage range and the likes.

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