Investigating the Performance of a Laboratory Dynamometer for a Three-wheeler Engine Test Rig

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Abstract- The dynamometer is to mimics driving condition in an indoor controlled condition measuring engine output parameters like speed, torque, power, combustion conditions and exhaust compositions. However, the complexity and dynamics involved in the making of this instrument makes it unaffordable for student research except it is funded. This work reports an innovative method adopted to measure a three-wheeler engine output parameters. An automobile vehicle dynamo was adopted which requires low speed and outputs high torque. Driving conditions were incorporated as brakes for the dynamo which mimics the driving terrains experienced by the engine. A data acquisition unit capable of converting the electrical signals into readable values on a screen and a user interface on a PC completed the dynamometer development. The dynamometer was then calibrated against known output values of speed and torque. A three-wheeler engine was mounted on a test rig and the dynamometer was used to measure output speed, torque and energy dissipated. A Bajaj engine was mounted and the engine output tested for two types of transmission of manual and continuously variable transmission. The measured output from the engine showed that the developed dynamometer performed effectively and therefore be adopted for use for student research in this area.

Keywords- dynamometer, load, speed, terrain, torque.

1 INTRODUCTION

The dynamometer is the most important measuring device in measuring engine output parameters because it combines various functions like speed measurement, torque measurement, power measurement, exhaust temperature measurement among others. Direct methods usually make use of brakes for measuring speed and torque simultaneously, while the indirect method uses approximate means (Chybowski, 2008).

Over the years, dynamometer have been applied for several applications as follows; A fractional horsepower dynamometer is used in Mechatronics, non-linear and adaptive control laboratory experiments (fractional horsepower), a rope brake dynamometer coupled with brake and motor to measure the minimum torque and various factors involved while the design is done (Gopinath 2014), Kin-Con dynamometer and an external recording system for Force, angle and velocity from the Kin-Con dynamometer against known weights, angles and user velocities (performance kin-con), bulb dynamometer to synthesise children with their weight, height, body composition and handedness (de Souza et al. 2014), and in another application, a chassis dynamometer was used to describe and refine the European Driving Cycle (EDC) (Casadei & Maggioni 2016).

More recent reports on dynamometer includes; dynamometer use based on direct torque control for motorized spindles (Tongtong *et al.*, 2019), determination of the performance of interventions in trunk flexors (Rodriguez-Perea *et al.*, 2019), aircraft landing gear wheel force and moment determination (Jaroslaw *et al.*, 2020), laboratory testing for a fuel cell vehicle (Loshe-Busch *et al.*, 2020), comparison of data obtained from dynamometer with pin-on-disc (Federici *et al.*, 2019), influence of load, fuel, driving conditions and resistance conditions on heavy diesel vehicles (Chen *et al.*, 2018) and brake wear emission measurement (Mathissen *et al.*, 2019). The experience of drivers and users of three-wheelers is an important which can be described through the driving patterns based on users need (Bagul *et al.*, 2021). Studies are continuously ongoing on driver behaviour (Adisa and Eludiora, 2021) and driving patterns (Bagul *et al.*, 2021) for small engines but the equipment to effectively carry this out are very expensive, hence the need to locally develop methods of solving this issue. This study was carried out to develop a dynamometer using available resources locally for student research in engine performance testing.

2 METHODOLOGY

This session explains the materials, method and testing of the dynamometer.

2.1 MATERIALS

2.1.1 Microcontroller

Various factors are considered in the choice of microcontroller to be used for a particular purpose. These include: the number of digital inputs, analogue inputs and size of program memory storage required, the magnitude of clock frequency, the number of interrupts and timer circuits required and an internal ADC stage.

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2.1.2 Data Acquisition Unit

The components used in building the Data Acquisition Unit of the dynamometer are resistors, capacitors, diode, bridge rectifier, transistor (Bipolar junction transistor), transformer (step-down), LCD, crystal oscillator and current sensor.

2.1.3 The Power Supply Configurations

A +5V direct current (DC) supply was used across the components except the relays which was at 12V. The power supply has a linear power supply consisting of step-down transformer, filter capacitor, and voltage regulators to give the various voltage levels. The power supply circuit diagram is shown in figure 1. A rectifier was developed with four diodes to form a full wave bridge network. Also, from figure 1, C_1 is the filter capacitor which is inversely proportional to the ripple gradient of the power supply, when arranged with a 240V transformer on a 50Hz supply. The transformer secondary gave *r.m.s* voltage output of 12V.

Fig. 1: Power supply circuit

Fig. 2: Voltage Divider

2.1.4 Voltage Divider And Current Monitoring Stage

The Arduino can only accept voltage up to 5v on an analogue input. However, voltage across a circuit can range as high as 20vdc in certain situations especially in an open circuit pv voltage. At such instances, a voltage divider that would provide 5V at 20V battery voltage and less at according to requirement of various components was designed for this work. In other to achieve the voltage level across the components, a voltage divider calculator shown in figure 2 was used. The parameters were set that 20V. The next step is to track the current being consumed by a load, or produced by a source. ACS715 Hall Effect sensor was used to track the current being passed.

2.2 CONSTRUCTION

After carrying out all design and analysis, the project was constructed and tested to ensure its working ability. The construction was done in three different stages.

1. The implementation of the whole project on a solder-less experiment board (bread board).
2. The soldering of the circuits on Vero-boards.
3. The coupling of the entire project to the casing.

2.3 BRAKING – TERRAIN MIMIC

The braking system is a set of resistors arranged in parallel with switch for each one so that they work independently. They are made of automobile head lamp bulbs with two types of capacities; 120W and 800W combined to form; 120W, 800W, 920W and 1600W representing L_0 , L_1 , L_2 , L_3 and L_4 respectively.

The other parts that make up the dynamometer are; Switches (2 types: single pole, single throw and double pole, single throw), USB Jack capable: for data transfer, A DC motor (Bosch for Benz cars), A 12V 60mAh DC Battery, capacitor, Arduino software and Laptop.

Fig. 3: Data Acquisition Unit

Fig. 4: (a) 120W and (b) 800W load board

3 RESULTS AND DISCUSSION

The data recorded for speed and torque for CVT and manual transmission are presented in figures 5 and 6 respectively.

A Bajaj three-wheeler engine was mounted on its test rig while the dynamometer was also connected to the engine and test rig to record the speed and torque output of the engine. The engine was run first when there was no load or braking on the dynamometer and data was recorded for both manual transmission (MT) and continuously variable transmission (CVT) respectively. The engine was run throughout its entire transmission ratio for both transmission type and the data recorded are presented in Tables 1 & 2. Subsequently, the data were analysed at 95.5% confidence level as presented in Tables 3 & 4 showing the mean, variance and confidence level.

Fig. 5: Result of CVT Transmission using the dynamometer from No load to L4

Fig. 6: Result of Manual Transmission using the dynamometer from No load to L4

Table 3. ANOVA for Speed (MT vs CVT)

SPEED	Mean		Variance		F	F _{critical}
	MT	CVT	MT	CVT		
Lo	54.96	177.15	530.77	7423	40.383	4.183
L1	53.74	169.22	537.93	5259.14	47.186	4.183
L2	53.09	164.97	524.17	6253.99	38.953	4.183
L3	51.09	162.75	543.63	5526.63	42.376	4.183
L4	40.74	167.22	268.93	3959.14	81.021	4.196

Table 4: ANOVA for Torque (MT vs CVT)

TORQUE	Mean		Variance		F	F _{critical}
	MT	CVT	MT	CVT		
Lo	5.61	3.51	3.19	1.08	9.77	4.183
L1	5.51	3.21	3.13	0.31	12.75	4.183
L2	5.79	3.37	3.21	1.36	12.64	4.183
L3	5.78	3.07	2.01	0.74	25.73	4.183
L4	7.37	1.86	1.98	0.66	95.87	4.196

From the analysis, it can be seen that there was significant difference in the data for each loading condition for each of the transmissions type. In line with the relationship between speed and torque, the result correlates with the inverse relationship between speed and torque. Also, the values recorded for speed and torque were higher for the CVT than in MT, depicting a better performance of the CVT over the MT.

4 CONCLUSIONS AND RECOMMENDATIONS

The test carried out using the developed dynamometer was repeated three times and the same result was recorded for each. The indication of this is that the dynamometer performance is acceptable for the intended use for student research work. The variations recorded in the readings for various conditions and transmissions for speed and torque accurately compare with known relationships for these parameters. Also, the components used for braking or otherwise driving terrain mimic were adequate and it is sufficient to describe the three-wheeler drive cycle. The variations are significant at 95.5% confidence level and the design and experiment can be replicated.

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