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Development of Low Cost Radio-Controlled Cars Dynamometer

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Abstract: A dynamometer, often known as a dyno, is a tool used to concurrently measure the rotational speed (rpm) and torque of a moving motor or engine to determine the power output at any given moment. A dynamometer is utilized as part of a testbed for numerous engine development tasks in addition to measuring the power produced by the engine or motor. This study aims to develop a low cost Radio-controlled (RC) cars dynamometer using the concept of small scale chassis dynamometer with size range from 1/20 (12cm-7cm) to 1/10 (35cm-43cm) which can establish the value of RPM, torque and horsepower. In this study, a dynamometer is developed using aluminum profile with size 20mm x 20mm for the chassis with a N35 magnet with size 10mm x 20mm that attached to the gravity roller 50mm x 200mm. The LM393 Hall effect magnetic sensor that connected to Arduino Uno R3 will detect the rotation of the magnet at the roller to calculate RC car RPM, Torque and Horsepower that will be displayed on the Arduino L2C Serial LCD. The result is verified using tachometer to compare the value of the RPM, Torque and Horsepower which provide the percentage error of 0.107%. This dynamometer has potential for STEM activity in the Design and Technology (RBT) subject for student learning in school.

Keywords: Dynamometer, RC cars, Arduino Uno

1. Introduction

A dynamometer, often known as a dyno, is a device used to measure the force, moment of force (torque), or power transmitted by a spinning shaft [1-5]. To measure the power produced by an engine, motor, or other spinning prime mover, for example, torque and rotational speed measurements can be made simultaneously [6-12]. A dynamometer can also be used to determine the torque and power required to operate a driven equipment, such as a pump. Just like any race spec vehicles, radio controlled, or RC, vehicles require the same level of fine tuning and testing to achieve maximum performance. The RC industry has been growing exponentially since the releases of the first RC vehicles in the 60's and the vehicle have been evolving ever since [10]. This steady growth has led to the development of the Remotely Operated Auto Racers (ROAR) foundation which now organizes professional R/C races in both the United States and Canada [11].

In Malaysia, Design and Technology (RBT) is a subject that can exposed the school students about the automotive industry by giving them task to do a project that related to cars. Their project or task given usually involved the RC cars which is small and compact in size that ease the learning process. Introducing this RC dynamometer in Design and Technology (RBT) subject can improve their knowledge and experience especially on the performance of the RC cars. RC car players need dynamometer that can read their car performance but the existing dynamometer which are chassis and engine dynamometer are too big in scale which cannot fit with the RC cars. By utilizing this kind of dynamometer that come with a small scale with size range from 1/20 (12cm-7cm) to 1/10 (35cm-43cm) and compact design with low

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cost budget but meet the purpose. This can help students in school under the STEM program to let them visible to see and now quantify how their adjustments affect the performance of their vehicles [12].

The crankshaft of an engine generates torque, which is a spinning force. An engine's capacity to accomplish work increases with the amount of torque it produces. Though slightly different, the measurement is the same as work. The units' pound-feet and newton-meters are used to measure torque since it is a vector (operating in a certain direction) [13]. Torque is calculated by multiplying the engine's horsepower by 5252 and dividing the result by the engine's revolutions per minute (RPM) [14]. In a car, horsepower refers to the entire power that an engine is capable of generating. In this method, the car has greater power with a higher horsepower, which results in a faster top speed. The formula for calculating horsepower is straightforward: Torque times RPM divided by 5,252 equals to horsepower [15]. Engine speed is determined by engine revs. The number of complete rotations an engine makes in a minute is measured in revolutions per minute, which is a revolving machine. The engine produces more power and full rotations per minute as it operates more quickly [16].

The aim and objective of this study is to develop a low cost RC cars dynamometer using the concept of small scale chassis dynamometer and to establish power curve consisting value for torque and horsepower from dynamometer using Arduino Uno.

2. Materials and Methods

2.1 Raw Materials

For hardware parts, the aluminium profile with size 20mm x 20mm with length about 3 meter used for the chassis development assembled with L corner bracket with size 20mm x 20mm and T head bolt screw with nut with M8 size. N35 magnet with size 10mm x 20mm is placed on the gravity roller with size 50mm x 200mm which contact with both of rear and front wheels. In addition, the anti-slip rubber pad and flexible hook used to provide better testing efficiency. Others are the electronic components such as LM393 Hall effect magnetic sensor, Arduino Uno R3 and Arduino L2C Serial LCD which linked to the Arduino IDE software. Lastly, the rest of the components are the hot glue gun and metal hacksaw 12 inches used for fabrication as shown in Table 2.1.

Table 1 - List of material and equipment

No.	Part	Quantity
1.	Aluminium profile 2020	3 meter
2.	L corner bracket 2020	40 pieces
3.	Gravity roller 50mm x 200mm	2 pieces
4.	T head bolt screw with nut	80 pieces
5.	N35 magnet 10mm x 20mm	1 piece
6.	LM393 Hall effect magnetic sensor	1 piece
7.	Arduino Uno R3	1 piece
8.	Anti-slip rubber pad	20 pieces
9.	Flexible hook	1 piece
10.	Arduino Uno casing	1 set
11.	Hot glue gun	1 set
12.	M12 nut	8 pieces
13.	Metal hacksaw 12 inches	1 piece
14.	Arduino L2C Serial LCD	1 piece

2.2 Schematic Design

A schematic is characterized as a simple, symbol-based illustration of a concept. A schematic diagram is a visual representation of a process, device, or other object's parts using standardized, frequently abstract symbols and lines. This dynamometer schematic diagram shows the magnetic sensor detect signal from the rotation of the magnet attached to the dynamometer roller driven by RC car wheels to display the output on the LCD that controlled by Arduino Uno as shown in Figure 1.

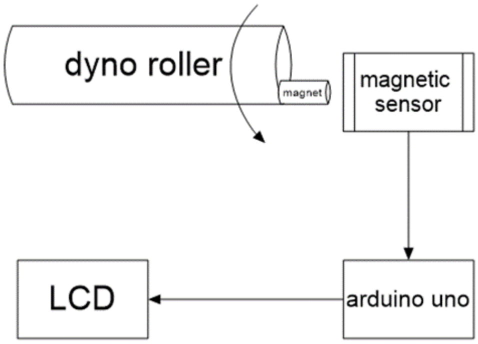

Fig. 1 - Dynamometer schematic diagram

2.3 Equation

The magnetic sensor will detect the RPM of the RC car from the roller with a magnet on its side then send the signal to the Arduino Uno that connected to the Laptop or PC. The data for the torque and horsepower will be calculated by the formula inserted in the Arduino IDE consisting four equations as shown below. The equation to find the value of the Torque and Horsepower is labeled as equation [1] and [2] respectively.

$$T = l \; x \; \alpha \qquad [1]$$

$$N = RPM$$

$$l = mr^2$$

$$\alpha = \frac{\omega}{t} = \frac{\Pi N}{30t}$$

$$HP = \frac{TxN}{9550} \qquad [2]$$

T	=	torque
l	=	moment of inertia
α	=	angular acceleration
N	=	rotation per minute
m	=	mass
r	=	radius
t	=	time
ω	=	omega
Π	=	pi
HP	=	horsepower

3. Results and Discussion

3.1 Solid Modelling

The dynamometer design was built using SolidWorks 3D CAD modelling to construct a scale drawing of the imagined dynamometer as shown in Figure 2. As a starting point, a basic rectangular frame layout was used. On a uniform two rollers would be utilized with adjustable slotted frame under both of the front and rear cars' tyres. Within a series of high-speed bearings that are press-fit into a system of bearing carriers, the rollers would be free to rotate. A magnet is attached to the side of the rear roller. The vehicle would then be held in place by straps that can hold the vehicle in position with a stopper at the front.

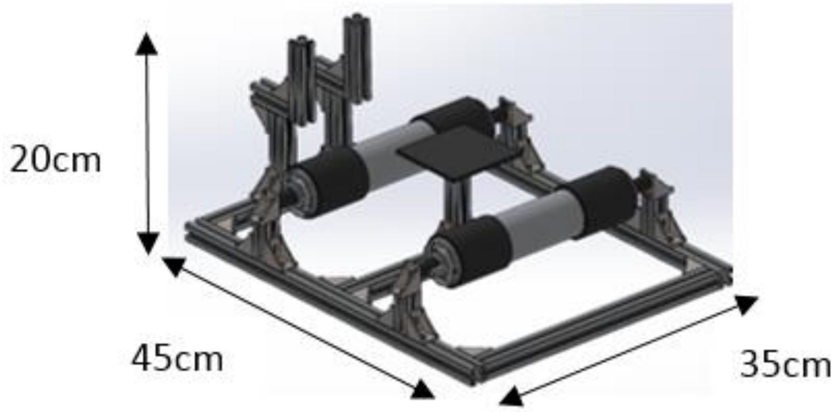

Fig. 2 - Dynamometer design

3.2 Fabrication Process

The first process to begin the construction phase is following the appropriate cut list. Each section of the frame is to be cut precisely using metal hacksaw with smooth and flat end surface using aluminium profile to make sure each joining is rigid as shown in Figure 3.

Fig. 3 - Frame joint

The aluminium profile is design to pair with the T head bolts with nuts and the L corner bracket. Each joining with a precise cut will provide 90 degree joining. The square base chassis fix together using socket wrench with an appropriate dimension that suitable for the RC car size range as shown is Figure 4.

Fig. 4 - Square base chassis

The two rollers used for both rear and front wheels is attached on the top side of the chassis. A magnet placed at the side of the roller to contact with the magnetic sensor. Each end of the rollers is welded together with the M12 bolts to assembled with four L corner brackets that welded to aluminium profile as the rollers carrier as shown in Figure 5. These rollers can be adjusted to move along the side of the chassis depending on the size of the RC cars. To minimize slip between the tyres and the rollers during the testing, anti-slip rubber pad is placed on the rollers. This helps to provide accurate results.

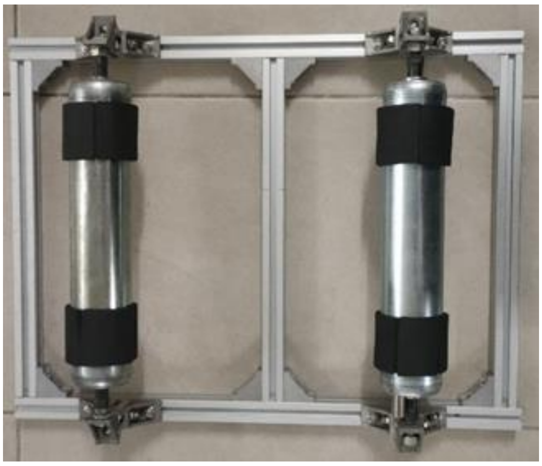

Fig. 5 - Chassis with rollers

Fig. 6 - Complete chassis dynamometer

3.3 Coding

The magnetic sensor will detect the RPM of the RC car from the roller with a magnet on its side then send the signal to the Arduino Uno that connected to the Laptop or PC. The data for the torque and horsepower will be calculated by the formula inserted in the Arduino IDE. The results will be displayed on the LCD.

```
time=millis()-oldtime;        //finds the time
rpm=(rev/time) *60000;        //calculates rpm
oldtime=millis();             //saves the current time
rev=0;
Serial.print("rpm=");
Serial.println(rpm);
angular_speed= (3.142*rpm)/(30*timeelapse);
inertia=mass_roller*(radius_roller*radius_roller);
torque=inertia*angular_speed;
horsepower=(torque*rpm)/9550;
```

3.4 Functionality Testing

RC car body shell is removed to make it easier to hook the chassis to the dynamometer. This will avoid the car from moving during the testing. All the apparatus is setup where the Arduino is connected with the magnetic sensor and the LCD as shown in Figure 7.

Fig. 7 - Dynamometer setup

RC car accelerated using the controller as the dynamometer is ready to run to collect the data. The value for the RPM, torque and horsepower are 2698, 1.77 Nm and 0.5 HP respectively displayed on the LCD as shown in Figure 8.

Fig. 8 - LCD display the RPM, torque and horsepower

At the same time, the value for the RPM which is 2700.9 recorded using the tachometer to compare the value of the RPM from the magnetic sensor as shown Figure 9.

Fig. 9 - RPM value from the tachometer

3.5 Torque and Horsepower Calculation

Table 2 - Comparison between display and calculated result

	Display	Calculated
RPM	2698	2700.9
Torque	1.77	1.767
Horsepower	0.50	0.449

Table 2 shows the comparison between the display and calculated data. All of the display data is collected from the dynamometer while the calculated data is collected based on the RPM reading from the tachometer. There is a small different for the value of the RPM displayed from the dynamometer and tachometer which are 2698 and 2700.9 respectively. This value will also cause the different value for the Torque and Horsepower where the value of Torque from the dynamometer is 1.77 while the value of Torque calculated is 1.767Nm, the value of Horsepower from the dynamometer is 0.5 while the value of Horsepower calculated is 0.449 Nm.

$$Error \ = \frac{measured\ RPM - real\ RPM}{real\ RPM} x100\% \qquad [3]$$

The error calculated in percentage of the comparison data from the value of the RPM which is 0.107% using equation 3. The main reason for a slight different in the value for the RPM is cause by the efficiency of the magnetic sensor and the type of magnet used. These errors can be reduced by using high accuracy sensor and proper type of magnet which refer to the strength of the magnet.

4. Conclusion

This RC car chassis dynamometer was successfully developed with low cost budget using the concept of small scale chassis dynamometer in given time. The prototype is fully function as well as it can read the RPM and provide the value for torque and horsepower of the RC car through the Arduino Uno with the Hall effect magnetic sensor as shown in the previous chapter. RC car with scale 1/10 was used to run and gathered the data. As the wheels rotate, the magnetic sensor will detect the rotation of the magnet attached to the roller. Arduino IDE will collect the data of RPM and calculate the value for the torque and HP that will be displayed on the LCD as a result. Finally, we can conclude that this dynamometer was successfully being developed where the working method and its efficiency was successfully being recorded.

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