Design of Water Brake Dynamometer

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Abstract. The dynamometer is equipment that functions to measure the power and torque generated by the internal combustion engine. The dynamometer has a way of working, namely absorbing mechanical energy generated by the engine at the engine output shaft rotation. The types of dynamometers are the electric dynamometer, eddy-current dynamometer, water brake dynamometer, prony brake, and fan brake. This study aims to obtain a dynamometer design that is simple and has relevant measurement accuracy. This water brake dynamometer is designed to withstand / test engine power up to 13 horsepower. The transfer of power from the engine to the dynamometer is done by adding a shaft and jaw coupling. Torque measurement will use load cell, meanwhile to measure revolutions per minute using proximity sensor. The test will be carried out by measuring the 118cc engine power with the SAE J1349 test method.

1. Introduction

Dynamometer is a indispensable measuring equipment for researching the engine performance of an internal combustion engine. The dynamometer has a way of working, namely absorbing the mechanical energy generated by the engine, while the mechanical energy in question is the rotation of the engine output shaft. The types of dynamometers used today include electric dynamometers, eddy-current dynamometers, water brake dynamometers, prony brakes, and fan brakes. The advantages and disadvantages of these types of dynamometers include, namely. The electric dynometer is more applicable than other dynamometers, but has a relatively expensive price. Eddy-current dynamometer and water brake dynamometer have the ability to operate at high speed at a relatively affordable price. Whereas in the fan brake dynamometer testing is not focused on power and torque, but the focus is on testing engine fatigue, damage and endurance. Prony brake dynamometers have limitations in their application, so prony brake dynamometers are the last choice to use if other dynamometers are not affordable [1]. Water brake dynamometer uses water media that is pumped at high pressure as an absorbing component of engine power. This water pressure will not stop the engine speed being tested, because when the engine speed starts to falter, the water pressure circulating in the dynamometer will increase in temperature until the water cavitates so that the braking load provided by the dynamometer will decrease sharply [2][3]. Water brake dynamometer has the advantage in testing engine acceleration and avoids torsional vibrations, this happens because the water brake dynamometer has little brake fluid inertia. Based on this explanation, the researchers are interested in designing and making an affordable waterbrake type dynamometer with a simple design. This aims to obtain design procedure data and a water brake type dynamometer with a capacity of 13 horsepower and support research on the performance of machines and practical support tools in the Madiun State Polytechnic.
2. Experiment Procedure
The object of this research is the dynamometer design. The design was made using the Solidwork 2016 software. The design of a water brake type dynamometer was carried out with simple design criteria using the main material of HD2 G2 aluminum.

2.1. Dynamometer Design
The impeller in the water brake type dynamometer has 2 sides of the propeller (torus). The maximum power and work efficiency of the impeller are influenced by 2 things, namely the radius (diameter) of the impeller and the profile of the impeller blade [4]. It can be design using the following formula 1. The impeller on water brake dynamometer expressed in stator dan rotor Figure 1.

\[ T = KN^2D^5 \]  

(1)

Fig. 1. Water brake dynamometer

a) Rotor, Stator, and Cover Design.
Torus on the stator is 12 in the shape of an equilateral triangle with an angle of 35 degrees. This selection is based on the trial and error of the author's design. The main material of the stator is aluminum HD2 G2. The stator shown in the figure 2. The torus on the rotor has more numbers than the stator because it serves to maximize the loading power of the dynamometer. The rotor shown in figure 3. The outside diameter of the dynamometer is 216.20 mm while the total width of the dynamometer is 12 cm. The cover rotor and stator shown in figure 4.

Fig. 2. Stator (unit: mm)
b) **Shaft Design.**
To calculate the shaft diameter $d_s$ (mm) can be formulated 2 [5].

$$d_s = \left[ \frac{5.1}{\tau_a} K_t C_b T \right]^{\frac{1}{3}}$$  \hspace{1cm} (2)

c) **Key Design.**
To calculate the diameter of the shaft can be At the moment the plan of a shaft which will be given a pure rotational load or a combination of twists and turns, where the shaft diameter is $d_s$ (mm), then the tangential force on the shaft surface show in formula 3.

$$F = \frac{T}{(d_s/2)}$$  \hspace{1cm} (3)

The shear force acts on the horizontal section by the force, then the shear stress show in formula 4.

$$\tau_k = \frac{F}{bh}$$  \hspace{1cm} (4)

From the allowable shear stress, the required length can be obtained with formulla 5.

$$\tau_{ka} \geq \frac{F}{bh}$$  \hspace{1cm} (5)

d) **Coupling, Bearing, and Seal.**
This part can be obtained in the market based on shaft design.
e) Test Procedure.

The test method used is a 118cc internal combustion engine. Engine performance testing based on SAE J1349 [6]. Preparation in the test, which first installs the engine on the engine mount, connects the engine shaft with the water brake using a jaw coupling, warming up the engine for approximately 5 minutes to achieve optimal engine conditions, flows pressurized water as a loading medium which will be regulated by the inlet water valve to the engine. Achieve the desired rotation (starting from 2500 rpm, 3000 rpm, and 3500 rpm), perform data records of test results (data taken after engine speed is balanced). The data taken is in the form of engine speed (RPM), power on the dynamometer (HP).

3. Result

In this case there is a change in the base material used, which was originally design to use HD2 G2 aluminum base material modified using 6061 aluminum base material. The base material change due to HD2 G2 aluminum is very difficult to find. The results of made the rotor, stator, and cover using a CNC machine shown in figure 5.

![Fig. 5. Part of water brake dynamometer: (a) rotor, (b) stator, and (c) cover](image)

Calculation shaft diameter water brake dynamometer based on ASTM 40 material and power output engine 9,8 kW at 8500 rpm obtained 25 mm. Calculation height and leght of key for shaft and coupling obtained 4,70 mm and 14,10 mm. Specified bearing is 6025 with ball bearing, coupling using fixed coupling, and seal using seal water pump. Final assembling process of water brake dynamometer shown in figure 6.

![Fig. 6. Water brake dynamometer](image)
4. Conclusion

The steps in build of water brake type dynamometer are the design drawing, calculation of the part, and selection of materials to be used. Design drawing and selection of materials starting from; shaft, key, bearing, dynamometer, frame, mechanical seal, boss rotor, locking bolts, nipples, hoses, and lastly measuring instruments.

References

[1] Obert E F 1973 Internal combustion engines and air pollution
[2] Miller B, Allen G, Murphy E and Kirk M Van 2017 Control of a Water Brake Engine Dynamometer System
[3] ARDIANTO A 2013 Analisa Keakurasian Engine Water Brake Dynamometer Jurnal Teknik Mesin 1 294–302
[4] Rao N N N 1968 The basic theory of hydraulic dynamometers and retarders SAE Transactions 650–67
[5] Sularso S K 2004 Dasar Perencanaan dan Pemilihan Elemen Mesin, cetakan Kesebelas, Jakarta, PT Pradnya Paramita
[6] Ignition E P T C-S 2004 Compression Ignition-Net Power Rating SAE International