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Redesign and modification of torque measurement instrument for centrifugal pump

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Abstract. The main function of a pump is moving fluid through a pipe from one place to another. The dominant characteristic of a centrifugal pump is its output torque and power. Torque is obtained from the measurement of force using a dynamometer, then the result is multiplied by the moment measuring arm (L). Dynamometers are used to measure weight, which is influenced by gravity, which is mass (m) multiplied by the acceleration of gravity (g). The design concept of this equipment consists of a free moving motor body, dynamometer layout, safety pump, and fluid flow pipe. The pump is designed to be equipped with laboratory scale test kits and sketches of images made using ZWcad. The product design test is carried out using a comparison of the torque value to the centrifugal pump both in filled and unfilled condition. The difference in the value of the output torque is not too far from the theoretical calculation, so this torque measuring instrument is worth using.

1. Introduction

The addition of a torque measuring device is necessary. The sliding seat engineering research on the observation pump for laboratory effectiveness requires [1]. The use of several forms of standard mechanisms for the application of torque to various implant components is inevitable, especially in vital tools both in industrial activities and household needs [2]. Today, there is no torque measurement system used by industry that is capable of fulfilling the expectations [3]. The design of proper torque measurement systems is needed to solve problems in the industries. The analysis focuses at pump characteristics involving torque and rpm rotation that has been produced. To measure torque and rotation, the addition of a measuring device mounted on the pump is necessary [4]. The pump is driven by an induction motor to produce torque. The obtained torque formulation is as follow:

$$T = \frac{5250 \cdot P}{n} \quad (1)$$

Where,

T = torque (Nm)

N = rotation perminute (rpm)

P = power (watt)

The pump as a tool transfer fluid, converts the mechanical energy of the shaft that moves the pump blades into kinetic energy and fluid pressure [5]. Pump specifications are categorized by the amount of fluid that can be flowed per unit time (capacity) and lift energy (head) of the pump [6, 7]. Torque is obtained by measuring the force using a dynamometer, then the result is multiplied by the moment measuring arm (L). The unit of torque is Nm [8]. The addition of a torque measuring device is applied

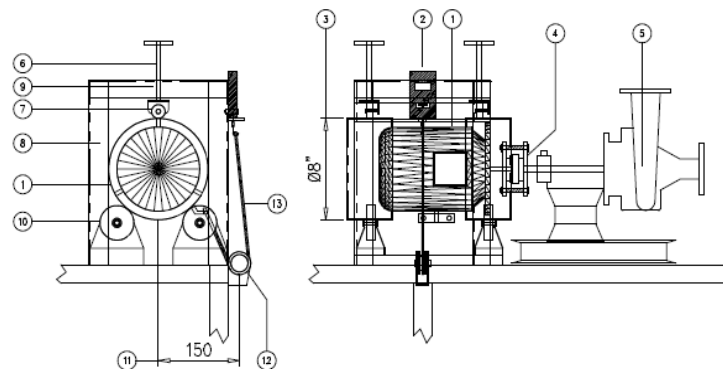


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by making a measurement mechanism that utilizes the torque force that is forwarded and read the force gauge balance apparatus. This addition is needed considering the need for pump torque measurements for data collection purposes. Pump torque data is needed in calculating pump performance [9, 10].

2. Method

The pump is designed with the modification of an electric motor torque successor system. With the addition of this tool, the drive motor can move freely according to the torque. The mechanism of pump movement is obtained from the addition of bearings on each side of the pump, made as a rail / path / for motor movement / rotation. With the addition of bearings on both sides of the electric motor and ring covering the motor, it allows the motor to rotate along the ring path. The motor rotation is held by a torque measuring balance. The magnitude of the rotating force / motor torque reads torque meter as the torque produced by the electric motor, as shown in Figure 1.



Caption

- | | |
|--|---|
| 1. 3 phase induction motor | 7. Bearing 6201 for smoothing motor movement /rotation |
| 2. Digital dynamometer | 8. Vertical elbow as Pump holder frame |
| 3. 8 inch pipe for path | 9. Horizontal Elbow 50 x 50 SA.36 as the frame of the pump holder |
| 4. Clamp plate | 10. Bearing 6306 as a support for the bottom so the motor can rotate smoothly |
| 5. Centrifugal pump | 11. Catrol |
| 6. Thread for stabilizator pump movement | 12. Cable for dynamometer device |

Figure 1. Design of pumps and torque gauges

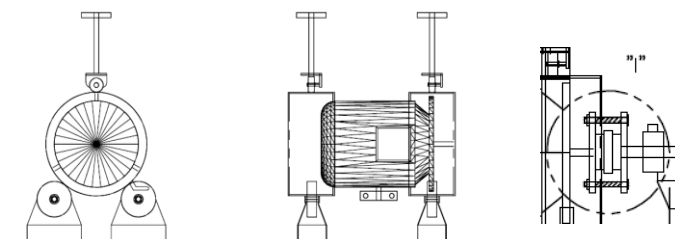


Figure 2. Design of motor movement mechanism

Figure 2 shows the mechanism of a free moving motor, which plays the role of providing additional tools that support the motor which allows it to rotate in all directions.

Product concept design :

1. Mechanism design

The mechanism of motor movement is made by adding bearings, plates for the path mechanism of the movement of the bearing and torque to resist motor movement / rotation. The equipment is made of a metal plate that is bent to form a cylinder encircling the motor. On the outside of the motor are installed two bearings that connect the motor body and the plate surface. Thus the motor can rotate with the outer plate rotating plane. To hold the electric motor rotation, one side is connected with a torsimeter. Thus the energy of the pump rotation is transferred to the torque meter into a tensile force. This tensile force is read as the magnitude of the tensile force of the motor according to the reading result of meter torque.

2. Design of dynamometer

The dynamometer is mounted on one side of the holder and connected to the motor body with a cable. Dynamometer facing forward to facilitate reading the scale. The connecting cable of the dynamometer functions as a connector so that the dynamometer can be read when the motor rotates clockwise or counterclockwise. Dynamometer holder uses steel elbows, because of the tough character.

3. Pump safety

Figure 3 shows the design of pump safety when it is running with the addition of spesific device. The tool in the form of clamp coupling that functions as a binder between the motor and the pump, so that when the motor is operated, it will not be separated from the holder. Coupling clamps are made of two metal plates and four sets of binding bolts.

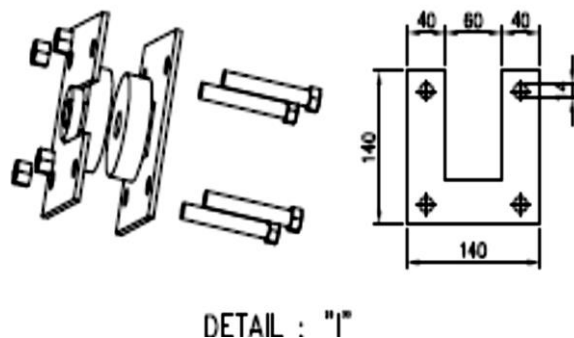
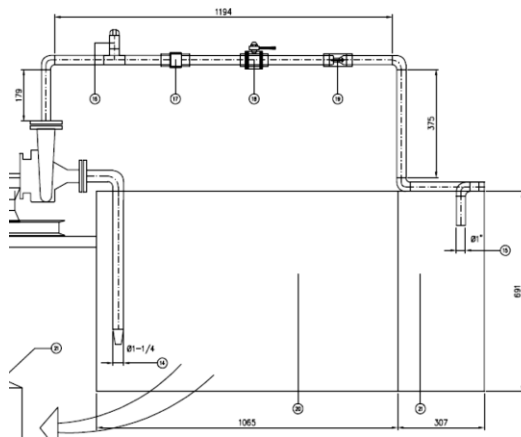


Figure 3. Design of pump safety

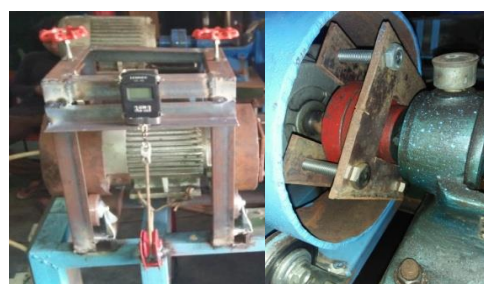
4. Pipe instalation

Pipe installations are arranged using PVC pipes, with input pipes : 1-1 / 4 "and the output is : 1". The output pipe uses a smaller diameter to increase the output pressure (Figure 4). Figure 5 shows a tool for motor movement that can rotate in any direction with a bearing 6306 at the bottom of the cylinder with a bolt as a connecting pipe to the motor body.

**Figure 4.** Pipe installation design**Figure 5.** Pump and movement mechanism design

3. Result and discussions

Figure 6 shows the design of the dynamometer support using steel elbows and the installation of coupling clamps using 2 plates that tie the coupling between the motor and the pump with 4 sets of bolts. The principle and method of work of designing centrifugal pump torque measuring devices as follows: When the electric motor is turned on, the motor body rotates clockwise spontaneously. It happens because the motor rotates following its torque and direction. The movement of the motor body automatically rotates the rope as a connection to the dynamometer that is pulled down through the pulley. The body of the motor becomes the support of the rope so that the dynamometer installed at the top of the motor will issue an output value in units of kg when the motor is moving and pulling the rope dynamometer. Then the rotating motor body is held by the rope and the rotation is forwarded to the motor to be forwarded to the pump shaft with the opposite rotation to the motor stator. The motor stator is connected with a coupling with a plate as security so that the motor is inseparable from the pump while rotating. When the pump shaft rotates automatically, the fluid will be sucked and enter the pump house in the flange section and pushed out into the flange out section.

**Figure 6.** Design of torquemeter and coupling clamp

- The Test Analysis of Centrifugal pumps torque

$$\tau = \frac{5250 \times P}{n} \quad (2)$$

Where P is 2 HP, n is 2900 rpm. So

$$\tau = \frac{10500}{2900} = 3.62 \text{ lb. ft} = 4.91 \text{ Nm}$$

- Fluid velocity obtained

$$v = \frac{Q}{A} \quad (3)$$

$$v = \frac{3,06 \times 10^{-3}}{5,064 \times 10^{-4}} = 6.04 \text{ m/s}$$

$$P : 1,5 \text{ kW} = 1500 \text{ W}$$

$$F = \frac{P}{v} \quad (4)$$

$$F = \frac{1500}{6,04} = 248.34 \text{ N}$$

- Torque

$$\tau = F \cdot L \quad (5)$$

$$\tau = 284.34 \times 0.150 = 42.65 \text{ Nm}$$

Pump torque without load is obtained from calculating torque pump equipped by stator that is designed (Table 1).

Table 1. Pump performance without load

Pump performance		
Experiment	Mass m (kg)	Gravity Acceleration g (m/s ²)
1	2.430	9.806
2	2.495	9.806
Rate	2.463	9.806

- Forces (F)

$$F = m \cdot g \quad (6)$$

$$F = 2.463 \times 9.806 = 24.15 \text{ N}$$

- Torque (τ)

$$\tau = F \cdot L \quad (7)$$

$$\tau = 24.15 \times 0.150 = 3.62 \text{ Nm}$$

Torque pump with load is obtained by experiment conducted to measure mass and pressure (Table 2).

Table 2. Pump performance with load

Pump performance		
Experiment	Mass m (kg)	Pressure of fluid (mBar)
1	7.815	1200
2	6.400	1200
Rate	7.108	1200

Water debit from the pump is calculated using the V-notch calculation equation :

$$Q = \frac{8}{15} \sqrt{2 \cdot g} \tan \frac{\theta}{2} H^{\frac{5}{2}} \quad (8)$$

$$Q = (0,53) \sqrt{2 \cdot 9,81} \left(\tan \frac{60}{2} \right) (0.06^{\frac{5}{2}})$$

$$Q = 1.2 \times 10^{-3} \text{ m}^3/\text{s}$$

Velocity of water debit is calculated using formula:

$$v = \frac{Q}{A} \quad (9)$$

$$V = \frac{1.2 \times 10^{-3}}{5.064 \times 10^{-4}} = 2.37 \text{ m}^2$$

Force of pump derivated from velocity of fluid flow with the equation of:

$$F = m \cdot \frac{v^2}{l} \quad (10)$$

$$F = 7.10 \cdot \frac{2.37^2}{0.150} = 266.19 \text{ N}$$

Torque of pump obtained from pump shaft measurement to the arm of torque meter. We obtained from Equation (5):

$$\tau = 266.19 \times 0.150 = 39.93 \text{ Nm}$$

Table 3 and Figure 7 show that torque without load between theoretical result and the experiment conducted has a difference of $4.91 \text{ Nm} - 3.62 \text{ Nm} = 1.29 \text{ Nm}$.

$$\frac{\text{The difference}}{\text{Theoretical}} \times 100\% = \frac{1.29}{4.91} \times 100\% = 26.27\% \quad (11)$$

Figure 8 shows that torque with load between theoretical result and the experiment conducted has a difference of $42.65 \text{ Nm} - 39.92 \text{ Nm} = 3.03 \text{ Nm}$.

$$\frac{\text{The difference}}{\text{Theoretical}} \times 100\% = \frac{3.03}{42.65} \times 100\% = 7.1\%$$

Table 3. Torque comparison

The torque without load (Nm)		The torque with load (Nm)	
Theoretical	Real	Theoretical	Real
4.91	3.62	42.65	39.92

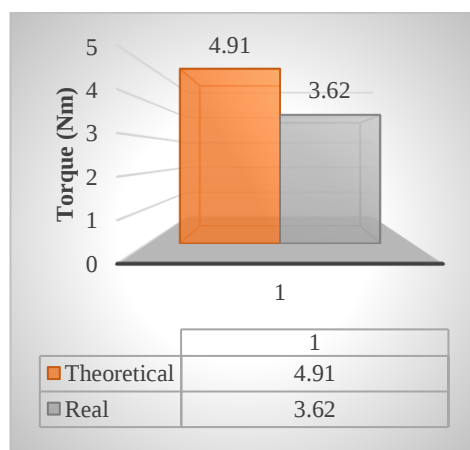


Figure 7. Torque without load

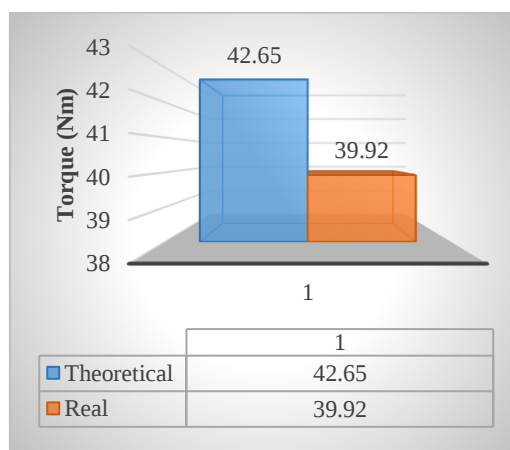


Figure 8. Torque with load

The value of torque with a ratio between 0 to 5 Nm. It can be concluded that the design of a torque meter on a centrifugal pump can work well and it can be concluded that the design of a torque meter on a centrifugal pump can work well, thus helping the performance of the centrifugal pump torque measurement tool be better.

Some suggestions can be given after conducting this research so that in the future there will be better research. The rope should use a rope with a low stress so that it can reduce the force lost, and Dynamometers should be connected to a computer so that the resulting graph is more accurate.

4. Conclusion

The addition of support frame to hold the pump provides a strong force to maintain pump stability and reduce vibration. The addition of holder aims to increase the measurement accuracy of the torque meter. The torque meter does not get disturbed by engine vibration, so the scale reading can work well. The addition of plate clamps provides an operator safety factor and acts as vibration damper. This torque measurement can work well if it is ensured that its tools does not get interference from external factors. The design of this gauge is able to eliminate the vibration factor and provide more easy readings to the operator. Finally the result of pump torque measurement is match to the pump specifications.

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