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Applications of DC Electric Motor as a Driver for A Grain Throwing Machine Tool

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Abstract
The application of a DC electric motor as a drive for the grain thresher machine uses electrical energy from solar panels, which is then stored in a 24 Volt 50 Ah accumulator. This research aims to understand the characteristics and performance of a DC motor as a driver for the grain thresher machine. The research was carried out in August 2021 at the Electrical Engineering Laboratory of the Samarinda State Polytechnic.The results of testing and calculations when the engine is run without load with a 24Volt 50Ah battery, the output power is 176.24 Watt, the current is 9.15 Ampere, the motor rotational speed is 3070 RPM, and the threshing cylinder pulley speed is 745RPM. In testing the machine using a grain load of three repetitions, an average output power of 223.55 Watt was obtained, a current of 11.73 Amperes, a motor rotational speed of 2900 RPM, and a threshing cylinder pulley speed of 703 RPM; the grain friction force influences this value. Paddy against the threshing cylinder. The estimated capacity of the battery to run the grain thresher machine with the average current generated by the DC motor during the load test with the grain is 3.41 hours without solar panels.
Keywords:*DC Electric Motor, Driving Motor, Motor Power, Rotational Speed*

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I. Introduction

Until now, many Indonesian people still manually carry out the post-harvest process, especially in threshing grain with a simple tool, namely "*gebyok*"a board made of wood, but some have also used rice threshers. The grain threshing machines are powered by fossil fuel engines, which results in high levels of air pollution.

A machine using fossil fuels hurts the environment, and one way to save fossil energy is to use alternative or renewable energy that is environmentally friendly. Solar panels are a source of electricity that uses sunlight as a source. The enormous amount of energy generated from sunlight makes solar cells an up-and-coming alternative energy source for the future(Irawan and Jamaluddin, 2018).

Of course, a grain threshing machine requires several supporting components, one of which is an electric motor. In this case, the electric motor is the main component, which functions as the driving force for the grain threshing machine. There are several types of electric motors, so the advantages offered in driven threshing machines also vary. Therefore the selection of an electric motor must be adjusted to the needs required of the rice threshing machine itself.

From the various types of electric motors with the observations that have been made, a DC-type electric motor is used as the driving force for the rice thresher. The use of DC motors as drives with solar power because the output of solar panels is DC voltage and does not require an inverter so that it can reduce operational costs, with an accumulator as a storage of electrical energy from solar panels while getting sunlight, the accumulator will be filled thereby saving time.

This research aims to understand the characteristics and performance of a DC motor as a driver for the grain thresher machine.

II. Literature Review

A. Driving Machine

According to NyomanBagia and Parsa (2018), a driving machine is a machine that is very vital in machining processes related to mechanical forces. The force that aims to give the effect of movement to a stationary component with a propulsion engine works properly.

AccordingtoNyomanBagia and Parsa (2018), propulsion machines generally use electric motors, which convert electrical energy into mechanical energy. Electric motors can be found in fans, washing machines, water pumps and vacuum cleaners.

B. DC Electric Motor (Direct Current)

According to Kuswardana (2016), a DC motor will produce an output in the form of rotation with input in the form of energy. As the name implies, direct current (DC) motors use a direct current voltage supply to operate a DC motor. In a DC motor, there are two coils, namely the field coil, which produces a magnetic field, called the stator, and the anchor coil, which functions as a place for the formation of electric motion force, which is called the rotor. If the current in the armature coil interacts with the magnetic field, a torque (T) will rotate the motor.DC motors have several parts, as shown in Figure 1, so the engine can work. These parts are:

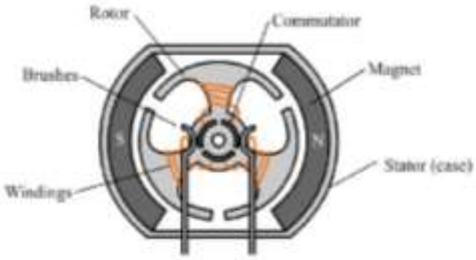

Figure 1 Parts of a DC motor(Admin)

1. As part of a magnetic circuit, the stator has a set of field poles attached to the stator. A DC motor has two field poles, and magnetic lines of increasing energy pass between the bars.
2. The rotor converts electrical energy into mechanical energy through rotary motion. The rotor comprises a steel shaft with a stack of cylindrical core pieces sandwiched. In the core, there are grooves in which the rotor windings are laid.
3. The commutator consists of hardened/insulated copper bars with mica. The function of the commutator is to collect the induced current from the armature conductors and convert it into direct current through the brushes.
4. Brush (Brush) is made of a mixture of carbon materials equipped with a pressure spring and contact brush. Brushes are usually installed superimposed on the side of the commutator, whose purpose is to supply electricity to the motor.

C. Torque

According to Kuswardana (2016), torque or twisting moment is a quantity caused by force on a rotating axis that can affect changes in an object's rotational motion, which can cause an object to rotate. The formulation of torque is as follows:

$$T=F.r \ldots (1)$$

Description: T = turning moment (Nm); F = repulsive force (Newtons), and r = distance between the sides of the coil on the rotating axis (meters)

D. Motor Power and Efficiency

According to NyomanBagia and Parsa (2018), the power in a motorized vehicle engine is the power generated by the engine. This power is generated by torque and angular speed depending on the load given to the motor. Emphasis on a DC motor can be divided into two, namely input power and output power; the input power can be calculated using the formula below:

$$Pin = V \times I \ldots..(2)$$

Description: V = voltage (Volts); I = current (Amperes)

When the motor rotates at the same time, losses occur; these losses reduce the value of the torque and power produced by the motor. The power that the losses have reduced is called the motor's output power. To find out the value of the motor output power, the following formula can be used:

$$P\text{-}out = V \times I \times \eta \ldots\ldots. (3)$$

Description: V = voltage (Volts); I = current (Ampere); and η = motor efficiency (%)

Or you can also use this equation :

$$P\text{-}out = t \times \omega \ \ldots\ldots..(4)$$

Description: T = Torque (Nm); and ω = angular velocity (Rad/s)

If it is known that it is not the angular velocity, but the rotational speed (RPM), then the formula becomes:

$$P = \tau\omega 2\pi / 60000 \ \ldots\ldots.(5)$$

Note: P = power in kilowatts (kW); t = torque in newton meters (Nm); and
ω = angular speed (RPM).

The power obtained in the formula above is still in kWt units. To convert to horsepower, units use the following formula:

$$P = \tau\omega 2\pi/33000 \ldots\ldots\ldots (6)$$

Description: P = power in HP; t = torque in newton pound-feet (lbf.ft); and
ω = angular speed (RPM)

Linear speed is obtained through the angular velocity on the sprocket with the following formula:

$$V = \omega.r \ldots\ldots\ldots (7)$$

Description: V = linear speed (m/s); ω = angular speed (rad/s); r = wheel radius (m)

Because the formula above still uses angular velocity (rad/s), then to convert rotational speed (RPM) to angular speed (rad/s), the following formula is used:

$$\Omega = (2.\pi.n) / 60 \ldots\ldots.. (8)$$

Description: π = determination 3.14; and n = engine speed (RPM).

After knowing the magnitude of the input and output power of the motor, we can determine the amount of motor efficiency, and efficiency is a measure used to determine how effectively the machine has been made. To determine the efficiency, it can be done by comparing the motor's output power with the input power provided. The value of wasted energy during the process can be seen at this moment. To calculate the efficiency of the motor, you can use the formula:

$$\eta = Pout / Pin \times 100\% .... (9)$$

Description: η = efficiency (%); Pout = output power (Watts); Pin = input power (Watts)

E. Transmission

Transmission is a tool system designed to become a unit composed of a device that moves a tool so that the agency can work. The main types of transmission elements are belts and pulleys.

Siburian (2019) states that a pulley system with a belt consists of two or more pulleys connected using a belt. This system allows it to transfer power, torque, and speed and move heavy loads with various diameters. Most industries use a belt transmission, namely the V-belt (V-belt); this can be considered in several ways because it is easy to handle and the price is low.

F. Battery (Accu)

Rosyid (2021) states that a battery or accu is a device that can store electrical energy in the form of chemical energy so that it can be used when solar panels do not get an energy source from the sun.Accu is a secondary cell because the battery can be recharged with an electric current in addition to producing an electric current. This is because chemical reactions in cells can be reversed. So when the cell is charged, electrical energy is converted to chemical energy, and chemical energy is converted to electrical power when the cell is working. To calculate the length of time and energy resistance on the battery can be calculated by the formula:

$$T = Is/Ib \ldots.. (10)$$

Description: t = time (hours); Is = current accumulator capacity (Ampere Hour), and Ib = load current (Ampere).

III. Research Methods

A. Time and Place

The research was carried out in August 2021 at the Electrical Engineering Laboratory of the Samarinda State Polytechnic.

B. Materials and Tools

The materials used are a 24V 350W DC motor, solar panel, battery, solar charge controller, 1x4 mm NYAF cable, hollow steel, angle iron, seat bearing, drive pulley, driven pulley, V-belt, and oil paint.The tools used are a cutting grinder, electric drill, meter, tools, nail gun, and welding machine.

C. Design Procedures

The steps in implementing the design are as shown in the flowchart presented in Figure 1 below:

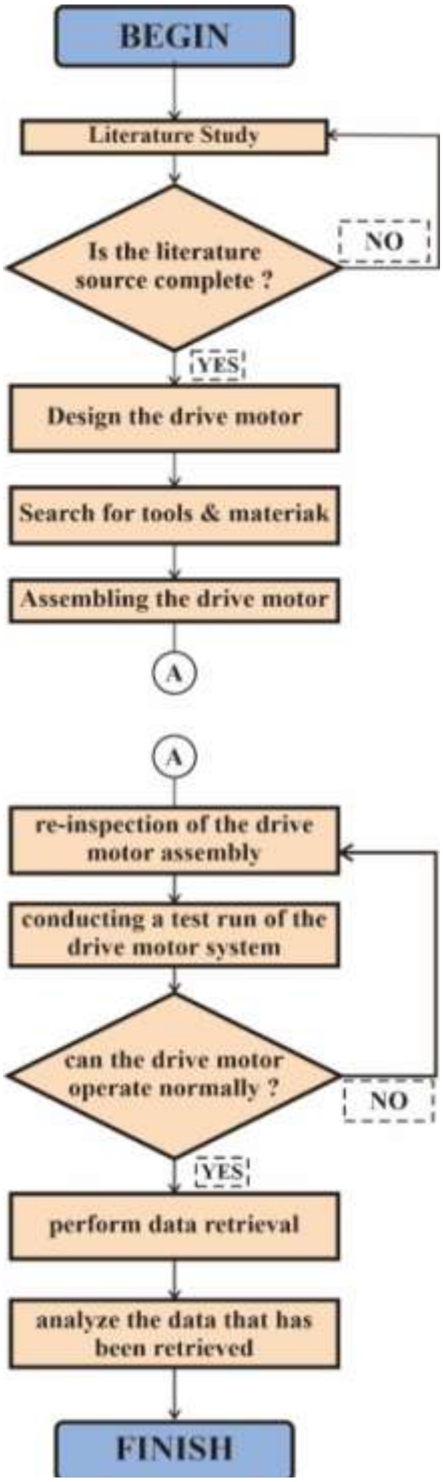

Figure 1. Flowchart of Design Procedures

D.Research Activities

Research activities include DC motor testing, motor speed testing, which is loaded by threshing grain and the resulting current, data collection and data analysis.

E. Tool Design

The design of the drive motor for grain threshing consists of several sub-sections, as follows: the specifications of the DC motor driving the grain threshing machine are presented in Table 1, Figures 2, 3, and 4 below:

Table 1. DC Motor Specifications for Grain Thresher Machines

Unite Motor	
Type	MY1016
Voltage	24 V DC
No-load speedNo-load speed	3350 RPM
Output power	350 W
Current Rating	18.7 A
Motor Dimensions	Diameter 10 cm x Thick 8 cm
Torque	1,2 Nm

Figure 2. DC motors

Figure 3. Drive Pulley

Figure 4. Thresher Cylinder Pulley

F. Data Collection

In this research, the first thing to do is test a DC motor's ability as a pulley drive. This aims to determine how much the motor's speed decreases when the threshing cylinder pulley is installed by measuring the DC motor's rotational speed. This measurement is carried out by providing a 24 Volt DC source. Then, measuring the current and speed of the driving motor and the driven pulley, also measuring the voltage and current of the DC motor, as follows:

1.Digital Tachometer

To measure the speed produced by a DC motor and also measure the speed of the cylindrical pulley driven by the motor when loaded and without load, the author uses a Hioki Digital Tachometer type FT-3405 to count the number of DC motor revolutions per minute.

2. Voltage

The voltage required by the DC motor to get the speed according to the specifications is 24 Volts; the parameter that the author uses is the VDC voltage by measuring the voltage from the battery or accumulator.

3. Flow

The motor generates the output current until it is installed with the cylinder pulley, and the windis generated when testing the grain load to be threshed.

IV. Results And Discussion

A. Calculation of Motor Input Power and Torque Based on Specifications

Based on the specifications of the selected DC motor, the input power of the motor can be calculated as follows:

Output Power = 350 Watts
Current = 18.7 Amperes
Voltage = 24 volts
No-load speed = 3350 RPM

The calculation of the motor input power value can be determined using the following formula:

$P_{in} = V \times I$…... 2)

Description: Pin = input power (Watts), V = voltage (Volts), and I = current (Amperes),
The calculation of the input power value is as follows:

$P = V \times I$
$P = 24 \times 18.7$
$P = 448.8$ Watts

So the value of the input power to the DC motor used is based on a calculation of 448.8 Watts.
Calculation of the efficiency value of a DC motor can use the following formula:

$\eta = P_{out}/P_{in} \times 100\%$..... (9)

Description: η = efficiency(%),Pout = output power, and Pin = input power (Watts)
Then the calculation of the DC motor efficiency value is:

$\eta = P_{out}/P_{in} \times 100\%$
$\eta = 350/448.8 \times 100\%$
$\eta = 77.98\ \%$

So the efficiency value of the DC motor is based on a calculation of 77.98%.
Calculating the amount of torque generated by a DC motor can be calculated using the formula:

$T = P_{out}/\omega$ ……. (4)

Information: T = torque (Nm), Pout = motor output power (Watt), ω = angular speed (rad/s)
To find the angular velocity can be calculated using the formula:

$\omega = 2\pi N/60$ ….. (8)

Description: ω = angular velocity (rad/s), N = rotational speed per minute (RPM)
Then the angular speed is:

$\omega = 2\pi N/60$
$\omega = (2\times 3.14\times 3350)/60$
$\omega = 350.633$ rad/s

Then the calculation of the large torque is:

$T = P_{out}/\omega$
$T = 350/350{,}633$
$T = 0.998$ Nm

So based on the calculation results of the DC motor specifications, the torque generated by the motor is 0.998 Nm.

H. DC Motor Test Results

The test carried out in this research is by testing the DC motor as the driving force for the grain thresher machine, and it has been made according to the desired design and knowing the power generated by the motor. To collect DC motor data, a research method was used by placing the tachometer towards the motor pulley and then towards the driven pulley to find out the ratio; the voltmeter was installed in parallel with the dc motor, and the ampere meter pliers were installed on one of the motor cables.The results of testing the DC motor as a driver for the grain thresher machine are presented in several Tables 2, 3, 4, 5, 6, 7, and 8 below:

Table 2. No-Load DC Motor Test Data

Volt (V)	Current (A)	Motor rotation (RPM)
24,7	1,23	3260

Table 3. DC Motor Test Data Installed with Grain Thresher Pulley

Volt (V)	**Current (A)**	Drive pulley Rotation (RPM)	Threshing Pulley Rotation (RPM)
24,7	9,15	3070	745

Table 4 DC Motor Test Data With Rice Grain Loads

Repetition	Voltage (V)	Drive pulley Rotation (RPM)	**Current (A)**
1	24,5	2940	11,20
2	24,4	2880	12,15
3	24,4	2880	11,85
Average	24,4	2900	11,73

Table 5. Dc Motor Test Data With Rice Grain Load in Seconds

Second	Voltage (V)	Current (Ampere)	Drive pulley Rotation (RPM)
1	24,6	9,19	3070
2	24,5	10.03	3040
3	24,4	11,85	2880
4	24,4	10,07	3000
5	24,6	9,29	3050
6	24,6	9.02	3080

C. DC Motor Test Calculation Data

Table 6. No-Load Dc Motor Calculation Data

Motor Spin (RPM)	Input Power (Watt)	Output Power (watt)	∞ (Rad/s)	Motor Torque (Nm)
3260	30,3	23,6	341,21	0,069

Table 7. DC Motor Calculation Data Installed With Grain Thresher Pulley

Drive pulley Rotation (RPM)	Input Power (Watt)	Output Power (watt)	Motor Torque (Nm)	Threshing Pulley Rotation (RPM)	∞ (Rad/s)
3070	226	176,24	0,548	745	321,32

Table 8. DC Motor Calculation Data with Rice Grain

Drive pulley Rotation (RPM)	Input Power (Watt)	Output Power (watt)	Motor Torque (Nm)	Threshing Pulley Rotation (RPM)	∞ (Rad/s)
2940	274,4	213,99	0,695	713	307,72
2880	296,48	231,19	0,766	699	301,44
2880	289,14	225,48	0,748	699	301,44
2900	286,60	223,35	0,736	703	303,30

Table 9. DC Motor Calculation Data With Rice Grains in Seconds

Time (Second)	Drive pulley Rotation (RPM)	Input Power (Watt)	Output Power (watt)	Motor Torque (Nm)	∞ (Rad/s)	Threshing Pulley Rotation (RPM)
1	3070	226,07	176,30	0,548	321,32	745
2	3040	245,73	191,60	0,602	318,18	737
3	2880	289,14	225,48	0,748	301,44	699
4	3000	245,71	191,80	0,610	314,00	728
5	3050	228,53	178,22	0,558	319,23	740
6	3080	221,89	173,04	0,536	322,37	747

D. Characteristics of Testing DC Motors as Driven for Grain Thresher Machines

After making observations and calculations on testing the DC motor as a driver for the grain thresher machine, an analysis of the performance of the DC motor can be carried out as follows:

1. The first test to be carried out is to determine the performance of the DC motor without load until the DC motor is installed with the grain thresher cylinder pulley, as shown in Figure 6.

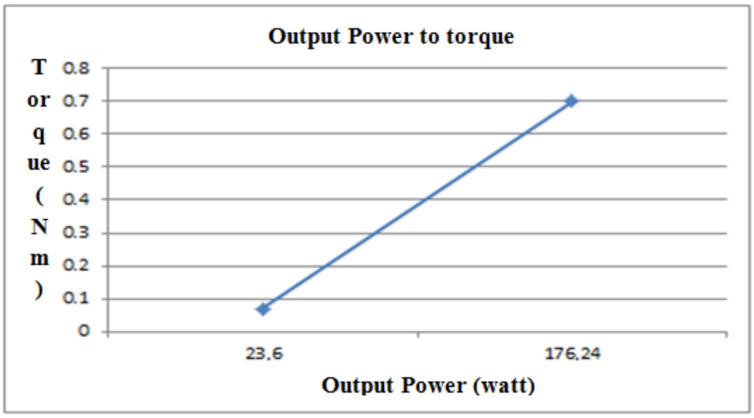

Figure 6. Graph of DC Motor Output Power to Torque

Based on the graph presented in Figure 6, it can be understood that the output power of a DC motor is directly proportional to the torque generated by the DC motor.

2. The change in the rotational speed of the DC motor to the motor current from no load until the DC motor is attached to the grain thresher cylinder pulley is presented in Figure 7.

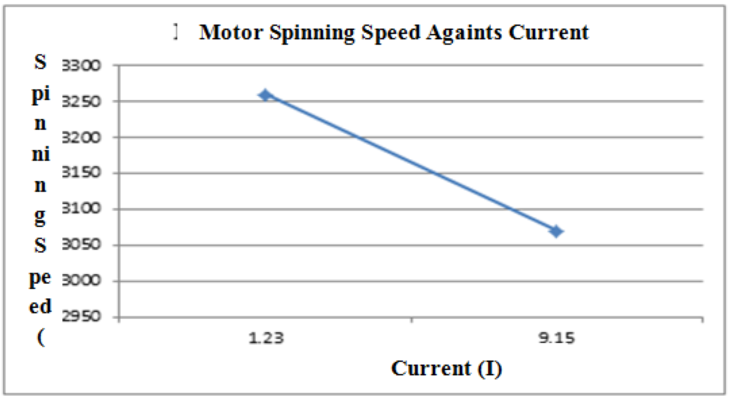

Figure 7 Graph of DC Motor Spinning Speed Against Current

Based on the graph presented in Figure 7 shows the effect of changing the rotational speed of the DC motor from no load to being attached to the grain thresher cylinder pulley; it can be understood that the rotational speed of the motor is inversely proportional because when the no-load current is generated it is low and vice versa the rotational speed of the DC motor is fast. But when it is installed with a threshing cylinder pulley, the DC motor's current increases while the DC motor's rotational speed decreases.

3. Changes from the output power of a DC motor as a thresher pulley driver to torque, the data used to describe the characteristics of the output power to the torque of a DC motor is presented in Figure 8.

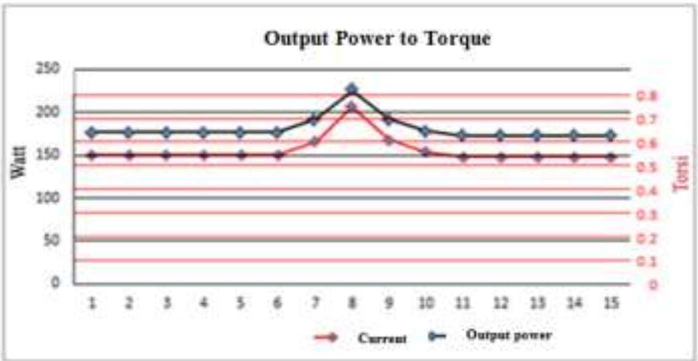

Figure 8 Graph of Output Power to Torque in Seconds

Based on the graph presented in Figure 8 shows the effect of the DC motor output power on torque; based on the test above, the difference between the test without load and with grain load obtained, at 1 to 5 seconds, is a no-load condition and starting from 6 seconds it begins to change when given grain load, then over time the grain starts to fall off resulting in a reduction in the bag causing the DC motor power and torque to return to no-load conditions.

4. Changes from the DC motor current as the thresher pulley driver to the motor rotational speed, the data used to describe the characteristics of the current to the DC motor rotational speed is presented in Figure 9.

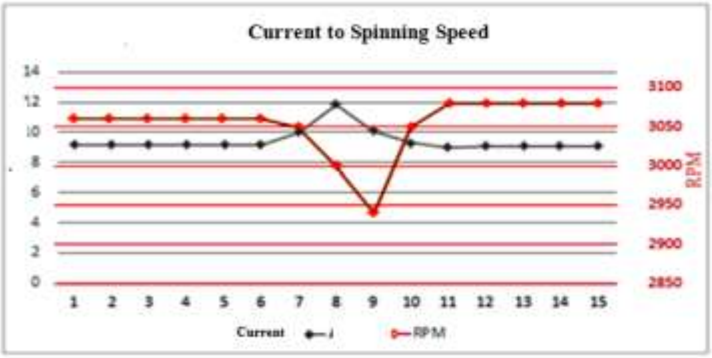

Figure 9 Graph of Current to Spinning Speed in Seconds

Based on the graph presented in Figure 9 shows that the effect of the current generated by the DC motor on the change in the rotational speed of the DC motor at 1 to 5 seconds is a no-load condition, and starting at 6 seconds, it experiences an increase in current caused by the grain load. Increasing current also causes the DC motor's rotational speed to decrease; over time, the grain load starts to fall off, the current decreases and the motor's rotational speed returns to a no-load condition.

5. Changes in current to torque in DC motors, the data used to describe the characteristics of torque to current in DC motors are presented in Figure 10.

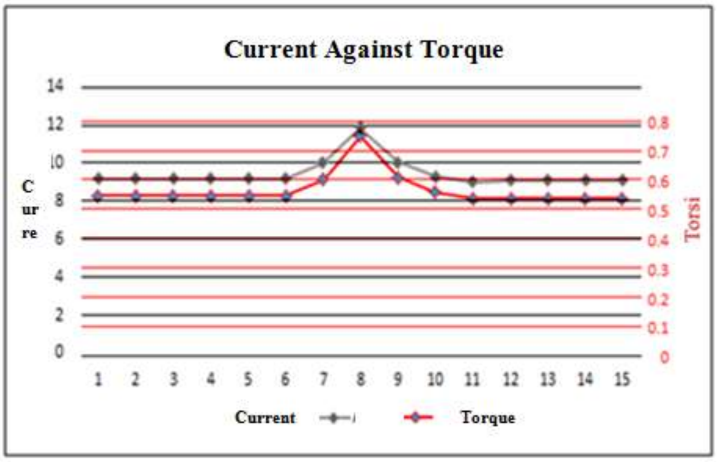

Figure 10 Graph of Current against Torque in Seconds

Based on the graph presented in Figure 10 shows that the effect of the current generated by the DC motor on the change in motor torque at 1 to 5 seconds is a no-load condition, and starting at 6 seconds, the current increases due to the grain load. With increasing current also causing motor torque to grow, it can be understood that current is directly proportional to motor torque.

E. Determine the Resistance of the Battery (Accu) on the Motor

This study uses a power supply from a battery (battery) with a voltage of 12 volts and a current capacity of 50 Ah. The store needed to drive a DC motor is 24 volts, so what is used is two batteries arranged in series to meet the required power supplyneeded.

To determine battery resistance, it is necessary to know the average current generated by the motor when it is working; in testing a DC motor with a grain load, the average of three repetitions is 11.73 Amperes.
Then the usage time is:
t =Is/Ib (2.11)
t=50Ah/(11.73 A)
t = 4.26 Hours (battery efficiency of 20%)
t = 3.41 Hours of usage time
Based on the calculations, battery life when running a grain thresher without solar panels is 3.41 hours.

F. Results of the Grain Thresher Machine

Based on the test results and discussion above, it can be stated that the tool can work as planned, but there are several weaknesses, namely:

1. Cannot be installed with a fan as cleaner grain dirt because, if installed, it will aggravate the performance of the motor and the resulting current exceeds the nominal current.
2. The tool frame is too heavy, making it difficult to move; this can be overcome by replacing the frame material with a lighter weight.
3. The hole where the grain is fed is too big; a cover needs to be added so that the grain that is knocked out is not thrown out

V. Conclusions And Recommendations

A. Conclusion

Based on the results of the calculations and tests, it can be concluded as follows:

1. On a grain thresher driven by a DC motor, the results of testing and calculations when the machine is run without load with a 24Volt 50Ah battery, the output power is 176.24 Watt, the current is 9.15 Amperes, the motor rotational speed is 3070 RPM, and the cylinder pulley speed thresher 745RPM.
2. In testing the machine using a grain load of three repetitions, the average output power is 223.55 Watt, the current is 11.73 Ampere, the motor rotational speed is 2900 RPM, and the threshing cylinder pulley speed is 703 RPM, the force rice grain friction against the threshing cylinder influences this value.
3. The DC motor, as the driver of the grain thresher machine, has good performance, so if the output power is large, the torque and current will also increase, inversely proportional to the motor's rotational speed.
4. With a threshing cylinder rotational speed of 745 RPM, the grain is threshed very quickly, thereby increasing production capacity.
5. The estimated capacity of a 24 Volt 50Ah battery to run a grain thresher machine with an average current generated by a DC motor during a load test with the grain is 3.41 hours without a solar panel.

B. Suggestion

Based on the results of the research, several suggestions can be put forward, namely as follows:

1. It is necessary to research the temperature of the motor generated during the operation of the grain thresher machine.
2. There is a need for scale maintenance of the DC motor as the driver of the grain thresher machine, namely care of the bearings so that they do not cause heavy frictional forces which result in high currents being generated.
3. It is hoped that support in research like this will involve competent parties in their fields to maximize research results.

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