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Design, Fabrication and Testing of Electric Pottery Wheel

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Abstract

The focus of this work is to discuss the design and building of an electric pottery wheel in order to solve the challenges of manual pottery wheels and increase the efficiency, accessibility, and quality of pottery manufacture. The objective is to develop an electric pottery wheel that is reliable, easy to use, and safe, with constant rotational speed and torque. By managing the spinning process, the electric pottery wheel will make pottery making more accessible to a larger number of people, including those with limitations in their bodies. It will also enable potters to create complicated patterns and fine details with perfect precision. To create an efficient and flexible wheel, select high-quality components, conduct thorough evaluations, and use relevant safety measures, collaboration among ceramic artists, engineers, and designers is required. This report emphasizes the importance of inclusivity, productivity, and artistic potential in the pottery community, as well as a budget breakdown and timeline for the fabrication process. The fabrication of an electric pottery wheel has the potential to revolutionize the pottery-making process and empower a diverse group of individuals to get involved in this ancient craft.

Keywords

electric, fabrication, potential, pottery manufacture, pottery wheel, budget, empower

1. Introduction

Pottery is an age-old craft that has developed throughout the years. Traditional pottery wheels were worked by foot or hand, requiring the potter to exert considerable physical effort. However, as technology has improved, electric pottery wheels have gained appeal in both beginner and professional pottery studios.

Nepali culture has a rich history with pottery. The earliest artifacts discovered at Lumbini are at least 2600 years old [1]. Almost every Nepalese village has a huge pottery water pot that is used for gathering, storing, and moving water. These vessels are used to cool water as well. Additionally, a lot of Buddhist and Hindu religious ceremonies require clay objects. Candles and ghee light are lit in little ceramic cups during pujas. A unique ceramic setup designed specifically for distilling rice or millet alcohol is used to make the traditional Newari rice wine known as aila [1]. This setup consists of a huge ceramic vessel with holes cut in the bottom, along with other clay containers of varying sizes. It would not be feasible to create formidable aila without this special holed vessel [1].

Nepali potters' skills have been passed from generation to generation. There are many families who trace their history through the occupation of ceramics. In Nepal, there are two major pottery production centres: Bhaktapur and Thimi. Thimi is a beautiful tiny town located between Kathmandu and Bhaktapur [1]. Ceramics manufactured in Bhaktapur are considered better to those made elsewhere, because to the unique usage of black clay known as "Dyo Cha". Only Bhaktapur Prajapatis are permitted to dig for it, and only once a year. Digging clay is a difficult and dangerous job. People dig in groups for more than 10-12 feet [1].

1.1 Problem Statement

Individuals with physical limitations or those without sufficient strength are unable to operate manual pottery wheels since they demand great physical work and skills. Furthermore, manual work can be challenging and time-consuming, decreasing result in a pottery production. We want to solve these concerns by introducing an electric pottery wheel, which will improve the efficiency, accessibility, and precision of pottery production.

1.2 Working Principle

Potters use electric pottery wheels to create ceramic objects such as bowls, vases, and plates. The operation of an electric pottery wheel is straightforward. The wheel is made up of a rotating platform that is propelled by an electric motor. The potter sits in front of the wheel and shapes the clay with their hands as it spins. The potter starts by pressing the clay down onto the rotating platform to center it on the wheel. Once the clay is centered, the potter shapes it with their hands into the desired shape. The speed of the wheel can be adjusted to meet the needs of the potter. The potter can start and stop the wheel as necessary because the electric motor that powers it is managed by a foot pedal. An electric pottery wheel's general operation is based on the rotation of a platform propelled by an electric motor, which enables the potter to use their hands to shape clay into different shapes.

1.3 Objectives

1.3.1 Main Objective

- To design, fabricate and test electric pottery wheel.

1.3.2 Specific Objectives

- To design the pottery wheel's components such as wheel head, belt and pulley mechanism, bearing, shaft and frame.
- To fabricate the pottery wheel on the basis of specified design.
- To test the pottery wheel's power consumption, rotational speed.
- To perform the economic analysis of the project.

1.3.3 Significance of Study

- It could address the accessibility challenges faced by individuals with physical disabilities or limited strength.
- It could help potters to work for longer periods without experiencing excessive fatigue.
- It could create employment opportunities by manufacturing pottery equipment.

1.3.4 Assumptions

- The size of wheel is limited to 300mm diameter.
- The speed of the motor is in between 45 to 60 RPM.
- The speed of the wheel head is in between 100 to 130 RPM.
- The material used for the wheel head is Aluminum.
- The maximum clay load is about 4 kg.

2. Literature Review

The author used a 2-horsepower motor to develop and construct an electric potter's wheel for molding ceramic goods. The wheel shaft, pulley and belt systems, stresses on the bolts and bearing, moments of inertia and the radius of gyration of the wheel head, as well as the speed control system were taken into consideration while designing machine components. The greatest force the wheel head can support during the ceramic shaping process is 16.18 kg of clay, according to design calculations and observations made when the machine was being tested [2].

A review was made to determine how well the manual wheel has been used for maximum production in the nation's face epileptic power supply. It examines the art of throwing, advantages and disadvantages of each types of wheels and how convenient their uses are is also examined. The main problem was Nigeria's rate of power supply and the need to promote less focus on electric wheels, which would not be ideal for a struggling economy [3].

An illustration was provided for a step-by-step process for developing and making a cheap potter's kick wheel utilizing a motor axle. This method has been put to the test by producing some ceramic goods, and it proved to be quite successful. It served as an invitation to ambitious potters in countries that were developing to try creating the equipment required for ceramic workshops, pottery houses, and individual potters [4].

An illustrative step-by-step approach was made in the design and fabrication of a simple potters kick wheel using the motor flywheel and other materials at a reduced cost. The fabrication was completed and the equipment was subjected to a vigorous tests using it to produce some ceramic wares, and it was found to be effective [5].

An effort was made to create a pottery wheel machine that uses an electrical motor and sewing machine pedal for operation. Its function was to effectively transfer human foot action to the potter's wheel by using a pedal mechanism and a bevel gear arrangements. When the pedal presses down, the flywheel transfers mechanical energy to the horizontal shaft through a belt drive system before converting it to vertical rotation for the pottery wheel's circular motion. Because it includes an electric motor, this device requires less human effort to make an earthen pot in a shorter time [6].

A conceptual model was introduced to run a potter's wheel on variable speed with a DC power source in order to address issues in the pottery industry i.e. non-supply of continuous electricity in rural area. The machine's ergonomic design was developed with the help of artisans, and artisans tested it by creating various clay pots on it. It rotates using a DC motor along with regulator to regulate the potter's wheel's speed as needed for the throwing procedure used to create earthenware's of various shapes and sizes [7].

An effort was made to build up the potter wheel machine which is operated by pedal on sewing machine as well as initial operated by motor. The project work started with survey and was identified that a pottery making machine which has the capacity to produce the huge pots was requirement. By making less efforts to produce large items, the project's primary goal was to put an emphasis on the people living in rural regions. As a result the rate of pottery manufacture was accelerated by employing this device [8].

3. Methodology and Materials

3.1 Methods

The following methodologies were used throughout the project:

3.1.1 Design

The first step was to design the electric pottery wheel, taking into account the necessary materials and components. This was accomplished through the use of Solid Works. In the design of the various machine elements, the following items were considered.

i. The Wheel and Motor Shaft
ii. The Belt and Pulley Mechanism
iii. Bearing
iv. The wheel head

3.1.2 Fabrication

Once the design was finalized, the components were made using the techniques such as Welding, Cutting, Grinding, Lathe operation etc. according to the design.

3.1.3 Assembly

The components were assembled together to make the finished electric pottery wheel. The components were joined by welding, bolting, or screwing.

3.1.4 Wiring

Following the manufacturer's instructions and safety guidelines, the electrical components were wired together.

3.1.5 Testing

The final step was to put the electric pottery wheel through its paces to ensure that it is in good working order. This was entail running the motor at various speeds and testing the wheel head's stability using tachometer. Also, the rotational speed of the wheel was measured using tachometer. In order to calculate power consumption, the rated power of motor along with the losses that arises in belt and pulley mechanism was considered and calculated.

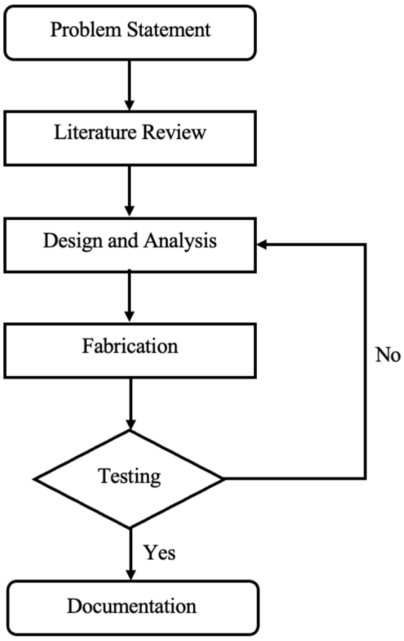

Figure 1: Work flow Diagram

3.2 Materials

3.2.1 Motor

A high-torque motor capable of consistently rotating the wheel head is required. The motor having power of 72 watt rotating at 60 rpm is used. The motor is of 2 steps with lowest RPM of 45 and highest of 60 RPM.

3.2.2 Wheel head

The wheel head is made up of a strong material that can withstand the forces of clay throwing. Aluminum sheet of thickness 5 mm is used with diameter of 300mm.

3.2.3 Frame

The frame must be strong and stable in order to support the weight of the motor, clay and wheel head. Square tube (20×20×2) mm, angle iron (25×25×4) mm and flat plates (20×4) mm are used.

3.2.4 Belt and Pulley

Belts and pulleys are used to transfer power from the engine to the wheel head. The size of driver pulley is 6" and that of driven pulley is 2". The belt used is a A36 V-belt.

3.2.5 Wiring and Electrical Components

To connect the motor with power supply, electrical wire and switch are required.

3.3 Working Mechanism

3.3.1 Rotational Motion

The electric motor is the center of the pottery wheel. When the motor receives electricity, it transforms electrical energy into mechanical energy, which drives the wheel head by a belt and pulley drive system. How quickly the wheel head revolves and how much resistance it can withstand from the clay being worked on are both determined by the motor's speed and torque.

3.3.2 Electric Motor

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3.3.3 Wheel head and Centering

The clay is positioned on a circular platform known as the wheel head. The clay rotates in a circle while the pulley turns the wheel head. While the wheel is spinning, the potter shapes and positions the clay with their hands. The primary method of centering involves the potter making sure that the bulk of the clay is spread uniformly around the point of rotation, which eliminates wobbling and uneven shape.

3.3.4 Clay Manipulation

The potter centers the clay and then shapes it into the desired shape with their hands and a variety of tools. As the potter works on the clay, the rotating wheel head generates the required centrifugal force to support stability and symmetry. Trimming and Detailing: The potter can use trimming tools to get rid of extra clay and perfect the shape as the clay object dries and becomes firmer. The item may be built on a smooth, even base thanks to the rotating wheel head. While the wheel is turning, you may use detailing techniques like carving, texturing, and adding handles.

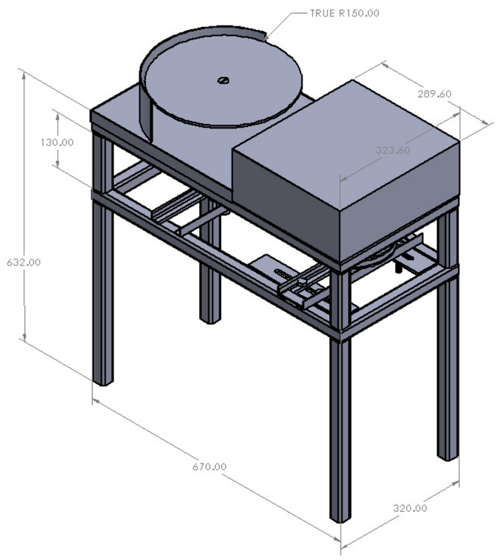

Figure 2: 3D Model of Electric Pottery Wheel

3.4 Analytical Design of Various machine Elements

In the design of the various machine elements, the following items were considered,

i. The wheel and motor shaft,
ii. Bearing,
iii. Moments of inertia of the wheel head,
iv. Radius of Gyration of the wheel head,
v. Belt and pulley mechanism.

3.5 Design of the Shaft

The wheel shaft and motor shaft are made of mild steel with the following dimensions and properties:

Length of wheel shaft (Lw) = 30 cm
Length of motor shaft (Lm) = 20 cm

Due to the easily availability of materials, we consider diameter of wheel shaft and motor to be 25mm and 20mm respectively.

Diameter of wheel shaft (Dw) = 2.5 cm
Diameter of motor shaft (Dm) = 2.0 cm
Modulus of Elasticity of Steel (E) = 200 kN/mm^2
Modulus of Rigidity of Steel (G) = 80 kN/mm^2

So,

$$\text{Cross-sectional area of the shaft (A)} = \pi \times \frac{D^2}{4} \quad [9] \tag{1}$$

Cross-sectional area of the wheel shaft (Aw) = 490.87 mm^2
Cross-sectional area of the motor shaft (Am) = 314.5 mm^2

And,

$$\text{Volume of the shaft } (V) = \pi \times \frac{D^2}{4} \times L \quad [9] \tag{2}$$

$$\text{Volume of the wheel shaft } (Vw) = 147262.15\ \text{mm}^2$$

$$\text{Volume of the motor shaft } (Vw) = 62831.85\ \text{mm}^2$$

3.6 Compressive Stress on the Shaft

The compressive stress on the shaft on no load (without clay) condition can be calculated using the weight of the wheel head and the cross-sectional area of the shaft as follows:

$$\text{Compressive Stress on the wheel Shaft}(\sigma_w) = \frac{\text{Weight of the wheel head}(W_{wh})}{\text{Cross-sectional area of the wheel shaft } (A_w)} \quad [10] \tag{3}$$

So, assuming the suitable data as:
Density of aluminum (ρ) = 2710 kg/m^3
Width of the wheel head (W_h) = 5 mm
Diameter of wheel head (D_h) = 30 cm = 300 mm

Then,

$$\text{Volume of the wheel head } (V_{wh}) = \pi \times \frac{{D_h}^2}{4} \times W_w \tag{4}$$
$$= 353429.17\ \text{mm}^3$$

Mass of the wheel head (m_{wh}) = $\rho \times V_{wh} = 0.956$ kg
Weight of wheel head (W_{wh}) = $m_h \times g = 9.38$ N

Substituting the values for W_{Wh} and A_w into equation (3), we have

$$\sigma_w = \frac{\text{Weight of the wheel head } (W_{\text{wh}})}{\text{Cross-sectional area of the wheel shaft}(A_w)} \tag{5}$$
$$= 0.019\ \text{N/mm}^3$$

And,
Mass of the pulley (m_p) = 1.414 kg
Weight of pulley (Wp) = $m_p \times g = 13.87N$

$$\text{Compressive Stress on the motor Shaft}(\sigma_m)$$
$$= \frac{\text{Weight of the pulley } (W_p)}{\text{Cross-sectional area of the motor shaft } (A_m)}$$
$$= 0.0441\ \text{N/mm}^2$$

3.7 Strain Energy Stored in the Shaft

$$\text{Strain Energy Stored in the Wheel Shaft } (U_w)$$
$$= \sigma_w^2 \times \frac{V_w}{2E} \quad [11] \tag{6}$$
$$= 1.32 \times 10^{-4}\ \text{N.mm}$$

$$\text{Strain Energy Stored in the motor Shaft } (U_m)$$
$$= \sigma_m^2 \times \frac{V_m}{2E} \tag{7}$$
$$= 3.05 \times 10^{-4}\ \text{N.mm}$$

3.8 Twisting Moment or Torque of the Shaft

Since the shaft is subjected to torsion, the torsion equation holds. So,

$$\frac{\tau}{R} = \frac{T}{J} = \frac{G.\theta}{L} \quad [10] \tag{8}$$

Since the wheel shaft is solid,

$$J_w = \pi \times \frac{D_w^4}{32} = 38349.52\,\mathrm{mm}^4$$
$$R_w = \frac{D_w}{2} = 12.5\,\mathrm{mm}$$
$$\theta_w = \frac{J_w \times L_w}{R_w \times G} = 11.54^{\mathrm{a}\circ} = 0.2\,\mathrm{radians}$$

So, Torque on the wheel shaft is given by:

$$T_w = \frac{G.\theta_w}{L_w} \times J_w = 2045.30\,\mathrm{N.m} \tag{9}$$

Since the motor shaft is solid,

$$J_m = \pi \times \frac{D_m^4}{32} = 15707.96\,\mathrm{mm}^4$$
$$R_m = \frac{D_m}{2} = 10\,\mathrm{mm}$$
$$\theta_m = \frac{J_m \times L_m}{R_m \times G} = 3.93^{a\circ} = 0.06\,\mathrm{radians}$$

So, Torque on the shaft is given by:

$$T_m = \frac{G.\theta_m}{L_m} \times J_m = 376.991\,\mathrm{N.m} \tag{10}$$

3.9 Torsional Shear Stress on the Shaft

$$\tau_w = \frac{R_w \times T_w}{J_w} = 667\,\mathrm{N.mm}^2 \tag{11}$$
$$\tau_m = \frac{R_m \times T_m}{J_m} = 240\,\mathrm{N.mm}^2 \tag{12}$$

$$\text{Combined torsional stress on the shaft} = \sqrt{\tau_m^2 + \tau_w^2}$$
$$= 708.86\,\mathrm{N.mm}^2$$

Thus, the torsional shear stress on the wheel shaft and motor shaft is 668 $\mathrm{N.mm}^2$ and 35 $\mathrm{N.mm}^2$ respectively.

3.10 Power Transmitted by the Wheel Shaft

The power transmitted by the wheel shaft can be calculated using the shaft torque and the speed of the driven or follower pulley as follows:

$$P = \frac{2 \times \pi \times N_2 \times T_w}{60} \qquad [9] \tag{13}$$

Where,
N_2 = Speed of the driver pulley (RPM)
T_w = Torque of the wheel shaft

From the pulley system calculation in section 3.15, $N_2 = 180$

Recall that T_w = 2049398 N.mm = 2049.4 N.m

Substituting the values of T_s and N_2 into equation, we get:

$$P = \frac{2 \times \pi \times N_2 \times T_w}{60} = 38552.99W \tag{14}$$

3.11 Maximum Bearing Load

Let λ = required length of bearing carrying a load of L Newton.

Then,

$$L' = \lambda \times P \times d_w \qquad [10] \tag{15}$$

Where,
λ = bearing length (mm)
P = allowable mean bearing pressure (varies from 172.4 to 17235 kPa for normal service)
λ = 33.83 mm

So, $L' = 152.24$N i.e., $L = 15.5$ kg

For safety purposes, if we consider a safety factor of 4 then, Maximum clay load = 3.8 kg Clay of weight greater than 3.5 kg should not be thrown on the wheel head.

3.12 Moment of Inertia of Wheel Head

If we take the wheel head to be a uniform disc, we can calculate the moment of inertia and radius of gyration as follows:

The moment of inertia at the center G is given by:

$$I_G = \frac{m_h \times D_h^2}{8} \qquad [9] \tag{16}$$
$$= 10800\,\mathrm{kg.mm}^2$$

Also,
Moment of inertia at any part of the circumference

$$I_o = I_G + m_h \left(\frac{D_h}{2}\right)^2 \qquad [9] \tag{17}$$
$$= 32400\,\mathrm{kg.mm}^2$$

3.13 Radius of Gyration of the Wheel Head

$$I = m.K^2 \tag{18}$$

On arranging equation (14) we have,

$$K = \left(\frac{I}{m_h}\right)^{1/2} \tag{19}$$

For the wheel head, radius of gyration at center is :

$$K_G = \left(\frac{D_h^2}{8}\right)^{1/2} \qquad [10] \tag{20}$$
$$= 106.07mm$$

The radius of gyration at circumference of the wheel head

$$K_0 = \left(\frac{3 \times D_h^2}{8}\right)^{1/2} \qquad [11] \tag{21}$$
$$= 183.71\,\mathrm{mm}$$

3.14 Belt and Pulley System

The pulleys used have the following dimensions:
Driver pulley diameter (d_1) = 6" = 152.4 mm
Driven pulley diameter (d_2) = 2" = 50.8 mm

The speed of the driver pulley (N_1) = 60 RPM

The speed (N_2), of the driven pulley is given by:

$$N_2 = \frac{d_1 \times N_1}{d_2} \quad [12] \quad (22)$$

$$= 180\,\text{RPM} \quad (23)$$

The speed of the belt can be calculated by using the formula:

$$\text{Belt speed (m.min}^{-1}\text{)} = \frac{\pi \times \text{pulley diameter (mm)} \times \text{pulleyspeed (RPM)}}{1000} \quad [12] \quad (24)$$

For the driver pulley:

$$\text{Belt Speed} = \frac{\pi \times 152.4 \times 60}{1000} = 0.48\,\text{m/sec}$$

For the Driven pulley:

$$\text{Belt Speed} = \frac{\pi \times 50.8 \times 180}{1000} = 0.48\,\text{m/sec}$$

Also, the tension in the belt as the pulleys rotate can be calculated as follows:

Using the driven pulley, we have:

$$\text{Torque} = \text{Difference in Tension} \times \text{radius of pully}$$

$$\text{Radius of driven pulley } (r_2) = \frac{50.8}{2}\,\text{mm} = 25.4\,\text{mm}$$

Since the shaft is connected to the driven pulley, we use the torque of the shaft in our calculation. Hence,

$$\text{Torque on shaft} = \frac{(T_1 - T_2)}{r_2} \quad [12] \quad (25)$$

$$\frac{T_1}{T_2} = exp(\mu.\theta) \quad [12] \quad (26)$$

For an open belt,

$$\sin\alpha = \frac{(r_2 - r_1)}{x} \quad [12] \quad (27)$$

and,

$$\theta = (180° - 2\alpha) \times \frac{\pi}{180}\,\text{radian} \quad [12] \quad (28)$$

Where,
x = center to center shaft distance,
r_1 = radius of the driver pulley,
r_2 = radius of the driven pulley,
θ = angle of contact or lap in radians,
μ = coefficient of friction between rubber belt and dry cast iron pulley,
T_1 = tension in the belt on the tight side,
T_2 = tension in the belt on the slack side From tables, $\mu = 0.30$

Also, that $r_1 = 76.2$ mm, $r_2 = 25.4$ mm, $x = 310$ mm

So,

$$\sin\alpha = \frac{(r_2 - r_1)}{x} = \frac{76.2 - 25.4}{310}$$

Now,

$$\alpha = 9.44°$$

$$\theta = (180° - 2 \times 9.44) \times \frac{\pi}{180}\,\text{radian} = 2.8\,\text{radians}$$

But,

$$\frac{T_1}{T_2} = \exp(\mu \cdot \theta)$$

$$\text{or, } \frac{T_1}{T_2} = \exp(0.3 \times 2.8)$$

$$\text{or, } \frac{T_1}{T_2} = e^{0.84}$$

$$\text{i.e, } \frac{T_1}{T_2} = 2.3 \quad (29)$$

On arranging equation (21) we have,

$$T_s = (T_1 - T_2) \times r_2$$

$$\text{or, } (T_1 - T_2) = \frac{T_s}{r_2}$$

$$\text{or, } (T_1 - T_2) = \frac{214757}{25.4}$$

$$\text{or, } (T_1 - T_2) = 8455$$

$$\text{So, } T_1 = 8455 + T_2 \quad (30)$$

From equation (25) and (26) we have,

$$2.32 \times T_2 = 8455 + T_2$$

$$\text{or, } T_2 = \frac{8455}{1.32}$$

$$\text{or, } T_2 = 6405\,\text{N.mm}$$

Then,

$$T_1 = 8455 + 6405 = 14860\,\text{N.mm} \quad (31)$$

So, T_1 is approximately twice as large as T_2.

3.15 Required Torque for Pottery Wheel and Motor

In this section required torque to handle the throwing of the clay of 3.5 kg and the required power of the motor to be used is calculated. Along with this whether the chose motor is able to produce required power or not is compared.

3.15.1 Required Torque for Wheel Head

$$\text{Required torque } (T_r) = \text{Force} \times \text{Radius} \quad [10] \quad (32)$$

$$= 0.4375\,\text{N.m}$$

3.15.2 Torque Produced by the Motor

Motor Speed (N) = 60RPM
Motor Power (P) = 72 watts

$$T_P = \frac{60 \times P_p}{2 \times \pi \times 60} \quad [10] \quad (33)$$

$$= 11.45$$

Since, the produced torque is greater than the required torque, 72 watts motor can be used with 60 RPM.

3.16 Modeling, Fabrication, and Assembly

3.16.1 Modeling Procedure

The modeling of the parts such as frame, shaft, wheel head, motor casing, etc., was done in Solid works 2022. The individual parts were modeled individually and then assembled, whereas the models of motor and bearings were imported.

3.16.2 Fabrication

After the completion of modeling of the components in SW software, required parts were procured from the vendors. These include pulley, bearings, belt, motor and material for wheel head. In addition to this the remaining components such as shaft and frame were fabricated in the workshop and assembled. Welding, cutting and grinding operations were used for fabricating the frame. First, square tube of mild-steel was cut as per the designed length and the edges were grinded to make a perfect joint and then welded together to make the frame. After the welding was completed, the welding was grinded in order to remove the excess weldment. In addition to this, lath machine was used for machining of the shaft. First of all, desired length of mild-steel bars was cut. Facing and turning operations were performed on them to obtain the required geometry. The casing for motor was made using GI sheet. The motor was held in a fixed position with the help of nut and bolt arrangement. The bearings were fixed into the place using nut and bolt arrangement and the pulley and belt assembly was done with the motor. After this wiring of the motor was done with electrical components such as wire, switch and the adaptor.

3.17 Testing of the Machine

After the complete fabrication of the Electric Pottery Wheel machine, testing was performed to determine the rotational speed of the wheelhead and the power consumption.

For determining the speed of wheel head for various load, a reflector was sticked to the wheel head and the machine was run with no load condition on the whee head. Then a tachometer was used to measure the speed of wheelhead. We pressed the laser button on the tachometer and made sure the light falls directly on the wheel. Then the tachometer was held steady as the tachometer takes measurements. Once the measurement stabilized, we use the buttons on the tachometer to display the measured speed and other parameters such as minimum and maximum speed. Then the same process was repeated for various load conditions and the reading was taken.

For determining the power consumption of the motor, first the voltage and current drawn by motor was noted for no load condition using the multi-meter and using the data obtained and the governing equation $P = I \times V$ power consumed by the motor was determined. Then the process was repeated for various load conditions, reading was taken and power consumption for various load conditions was determined.

4. Result and Discussion

4.1 Process Involved

Different processes were followed step by step to obtain the results for analytical design, geometrical design and the simulation of the electric pottery wheel so that the designed taken into consideration can withstand the load and work properly. The steps followed are:

4.1.1 Research

In research step, identification of the problem was studied, evaluation of the literature and hypothesis creation was done along with this design research and beneficial population was analyzed.

4.1.2 Materials Selection

In the process of material selection, the environment was taken into consideration by estimating the mechanical properties of the materials. As the machine is exposed mostly with water, we chose square iron tube and angle iron for the frame, galvanized sheet for the casing and aluminum for the wheelhead and synthetic rubber for the belt because they are based on best economical and field of use.

4.1.3 Market Research for Cost and Availability of Components

We went to different vendors and workshops in order to find whether the components required for our project along with the price, they are available or not. As a result, the materials mentioned were chose based on the best economical budget.

4.1.4 Collection of Components for Fabrication

The different components required for the fabrication process such as square iron tubes, pulley of diameter 2”, angle iron, galvanized sheet, rod for the shaft, belt and electrical components such as switch, wire, motor and plugs are collected.

4.1.5 Design and Calculation

All the steps involved in design process were taken into consideration for making of an electric pottery wheel. All the design follows a third-angle orthographic projection. They were derived from the models prepared in SolidWorks and used as a reference during the fabrication procedure.

The steps involved in our process are

Analytical: In this step all the calculations required such as compressive stress of the shaft, strain energy stored in the shaft, twisting moment on the shaft, shear stress on the shaft, power transmitted by the shaft, maximum bearing load, moment of inertia and radius of gyration of wheelhead, belt and pully system, torque produced by motor and torque required for wheelhead are done.

Geometrical: In this step we designed a 3D model with the help of Solid-Works software. Various components such as wheelhead, frame, pulley, casing, belt, shaft, bearing, nut and bolts were designed.

4.2 Assembly and Fabrication

Figure 3 shows rendered image of assembled machine model. Figure 4 illustrate the different view of the fully assembled machine. Figure 5 presents a rendered model prepared before fabrication and Figure 6 shows a fully fabricated machine.

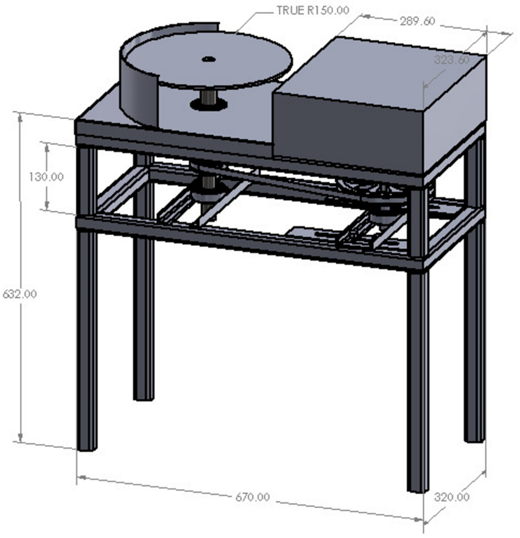

Figure 3: Rendered Image of Assembled Model

4.3 Observation

The observations for different sample weight are listed in Table 1. The tests were performed as mentioned in section 3.17.

Table 1: Test for Rotational Speed

S.N	Load (Kg)	RPM	S.N	Load (Kg)	RPM
1	No Load	125	5	2.0	113
2	0.5	118	6	2.5	111
3	1.0	116	7	3.0	110
4	1.5	115	8	3.5	108

Table 2: Test for Power Consumption

S.N	Load Condition (Kg)	Current (A)	Voltage (V)	Power Consumption (W)
1	No Load	4.56	11.55	52.668
2	0.5	4.5	11.55	51.978
3	1.0	4.4	11.6	51.04
4	1.5	4.3	11.62	49.966
5	2.0	4.29	11.5	49.335
6	2.5	4.2	11.56	48.552
7	3.0	4.11	11.6	47.676
8	3.5	4.04	11.56	46.7024

Table 3: Testing and analysis of Potter wheel [7]

S.N	Motor RPM	Calculated Wheel Head RPM	Observed RPM of Wheel Head	Slip %	Current (A)
1	3000	184.43	164	11.1	0.35
2	2864	176.07	54	69.3	5.06
3	2700	165.98	55	66.9	1.07
4	2600	159.84	98	38.7	4.39
5	2400	147.54	97	34.3	2.01
6	2300	141.39	77	45.5	2.9
7	2200	135.25	60	55.6	2.9
8	2000	122.95	120	2.4	3.28
9	1900	116.80	112	4.1	3.78
10	1500	92.21	56	39.3	5.06

Table 4: Calculation of Slippage from Fabricated Machine

S.N	Load	Studied Speed of Motor	Studied Speed of Wheel Head	Calculated Speed of Wheel Head	Slip %
1	0	53	125	159	21.4
2	0.5	52	118	156	24.4
3	1	52	116	156	25.6
4	1.5	51.5	115	154.5	25.6
5	2	51	113	153	26.1
6	2.51	53	111	153	27.5
7	3	50	110	150	26.7
8	3.5	50	108	150	28

Table 4 shows that the slippage values demonstrated by the designed machine under varying loading conditions from 0 kg to 3.5 kg is lower compared to the reference machine that usages constant load for 5 kilograms from the test shown in Table 3. The relation between the current and speed of the wheel head is comparatively more linear on the designed machine compared to the reference machine. The change in current concerning the change in speed of the wheel head in the case of the reference machine is highly fluctuating and it is

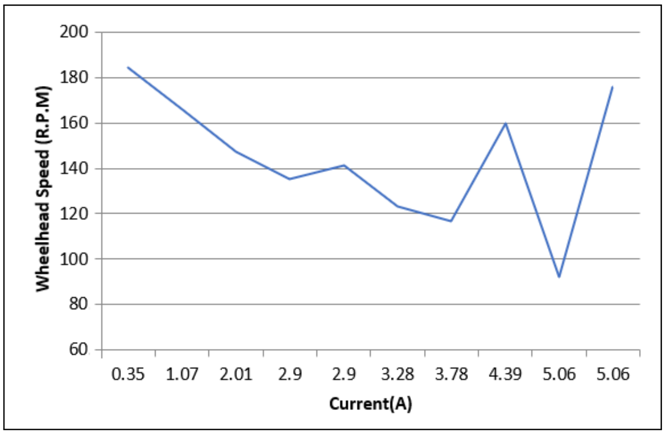

Figure 4: Current vs RPM for Reference EPW

difficult to show the relation between these changes. In contrast, in case of the designed machine, the speed of the wheel head decreases with an increase in load. As a result the current also decreases due to the decrease of speed in the motor while adding loads.

The sharp up and down on the reference graph shown in Figure 4 is due to the low slippage of the belt system at that point which results in a higher value of Wheel head RPM. Although, the motor speed is low as a result it draws less current.

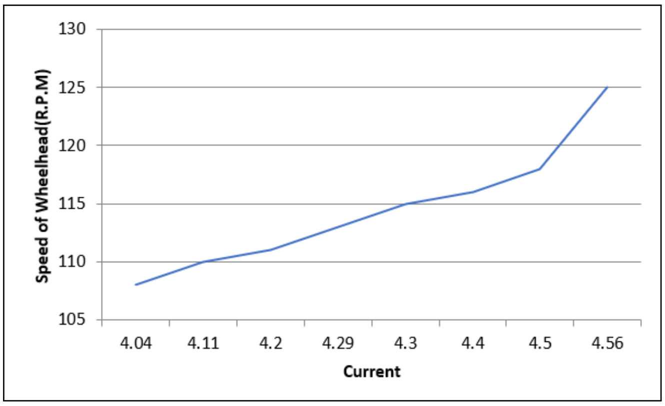

Figure 5: Current vs RPM for Designed EPW

4.4 Cost Analysis

The cost required for different materials, equipment and process used in the project are as shown in Table 5.

Table 5: Cost analysis

S. N	Components	Material	Rate (NRs)	Quantity	Cost (NRs)
1	Frame	Square tube (MS)	120/kg	10 kg	1,200
2	Pulley (2")	Cast iron	300/unit	1	300
3	Pulley (6")	Cast Iron	900/unit	1	900
4	Axial load bearing (20 mm)	UCFL 204	200/unit	1	200
5	Axial load bearing (25 mm)	UCFL 205	400/unit	2	800
6	Belt	EPDM	6/inch	36"	215
7	Wiper Motor 12V, 6A, 60 RPM	-	-	1	3,000
8	Electric wire	-	25/m	1m	25
9	Switch and plug	-	-	1	100
10	Wheel head	Aluminum sheet (30x30x5)	-	960gm	400
11	Fitting (nut, bolt, etc.)	Mild Steel	-	-	550
12	Shaft	Mild Steel	310/ft	4nft	1,200
13	Battery (12 V, 5A)	-	-	-	2,000
14	Miscellaneous	-	-	-	4,000
	Total	-	-	-	14,890

The manufacturing cost of EPW is about Rs. 15,000 but the cost of electric pottery wheel available in which has to be imported from the foreign country which is about Rs. 27,000 to over 30,000 excluding the custom duties.

4.5 Financial Analysis

Financial analysis is carried out to have an idea on the financial feasibility of a design. Here, a financial analysis is done to find out net present value and payback period of pottery wheel along with the benefit cost ratio of the fabricated pottery wheel. The total cost of project was about Rs 15000 excluding the labour cost for manufacturing.

Assumptions:

Assumed product = Diyo
Working Hours in a Day = 6 hours
Working Days in a Month = 25 days
Working Months in year = 10 months
Production of Diyos per hour = 30
Salvage value = Rs 2000
Service life = 3 years
MARR = 12%
Damaged pieces per 10000 pieces = 500

Net Present Value

Product of the pottery wheel (Diyo).
Cost for Manufacturing Diyos:
Labor cost in Month = Rs17300
Labor cost in Year = Rs173000
Power consumption per day = 49.8 w×6hr
= 0.3 Kwh

According to Nepal Electricity Authority (NEA), Cost of 1 kwh electricity =Rs 4(≤20 units)
Total cost of power per year = 0.3×25×10×6
= Rs. 300

Weight per Diyo = 40gm
Raw material required per day = 7.2 kg
Cost of raw material per day = 504
Cost of raw materials per year = Rs 126000
Production of Diyos per year = 30×6×25×10
= 45000 uits

Production of Diyos per year after subtracting damaged pieces = 42750 units
Cost of Baking, Drying, and glazing per year = Rs 20000
Repair and maintenance cost per year = Rs 3000
Total cost for production per year = Rs 322300
Total earnings in a year = Rs 42750×10
= RS 427500

Net Present Value (NPV)

$$= -15000 + 105200 \times (P/A, 12\%, 3) + 2000 \times (P/F, 12\%, 3)$$

$$= \text{Rs. } 239114$$

Payback Period

Table 6: Calculation for Payback Period

Period	Cash flow (NRs.)	Cost of Funds in NRs (MARR = 12%)	Cumulative cash flow
0	-15000	0	-15000
1	105200	-1800	88400

Payback period is given by:

$$\begin{aligned}\text{PBP} &= \text{number of years} \\ &\quad + \frac{\text{Amount to be recovered}}{\text{Cumulative cash flow of preciding year}} \\ &= 0 + \frac{15000}{88400} \\ &= 62\text{ days}\end{aligned}$$

B/C ratio:

$$\begin{aligned}&\text{B/C ratio} \\ &= \frac{427500 \times (\text{P/A}, 12\%, 3)}{-2000 \times (\text{P/F}, 12\%, 3) + 15000 + 322300 \times (\text{P/A}, 12\%, 3)} \\ &= 1.3\end{aligned}$$

B/C ratio is greater than 1. Therefore, this project is economically feasible.

The financial and economical analysis was done to determine the feasibility of the project. These studies show that this project is financially and economically feasible.

5. Conclusion, Limitations, and Recommendations

5.1 Conclusion

- Pottery wheel's components such as wheel head, belt and pulley mechanism, bearing shaft and frame were designed through analytical and geometrical approach.
- The components of pottery wheel were fabricated based on specified design.
- Power consumption and Rotational speeds were tested by using multi meter and tachometer respectively.
- Financial and Economical analysis was done for the project.

The electrical pottery wheel's purpose is to reduce the amount of physical effort needed to create the ceramic products. For the production of ceramic items like flowerpots, water pots, and cooking pots, less effort is needed, and the production process takes less time. When compared to other pottery production instruments and equipment, it is a more cost-effective and simple mechanism to use. It is energy-efficient, environmentally friendly, and does not pollute the environment or the community. Potters may make simple as well as complex clay things with less time and human effort by utilizing this simple machine. The rate of pottery manufacturing will rise with the use of this equipment.

Based on the fabricated EPW machine and its performance we can conclude that the general objective of fabricating a pottery machine with locally available resources is fulfilled. Similarly, the specific objective of testing the rotational speed and power consumption is achieved alongside the economic analysis is done between market cost with manufacturing cost which has a price difference of around Rs. 10,000.

5.2 Limitations

Despite our best efforts to fabricate the best and efficient electric pottery wheels machine, the EPW machine is still bound to have some limitations. Some of the limitations are listed below as:

- The motor used has a low rotational speed i.e. 60 RPM
- The machine has only 2 variable speeds based on motor i.e. 60 RPM and 45 RPM
- As seen from the test, the machine is not capable of modeling a heavy amount of clay at a time.

5.3 Recommendations

The list of recommendations for future improvement of the machine are:

- Suitable motor with speed regulator could be used for variable rotating speed of the wheel head.
- Solar panel can be connected that helps to recharge the battery increasing its portability.

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