

DESIGN AND FABRICATION OF A MANUALLY OPERATED POTTER WHEEL BY USING SEWING MACHINE PEDAL MECHANISM

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ABSTRACT: This design proffered an efficient method of doing forming of an earthen pot. The design was originally conceived to meet the needs of those working on the pottery business in rural areas, due to poor access to electricity. Most potters' works in these rural areas possess at least a cell phone but lack the means to charge them. This study focused on the design and fabrication of a manually operated potter wheel by using sewing machine pedal mechanism, for the intents of reduce the back pain and neck pain while yet to making of an earthen pot. The potter's wheel machine was designed to be simple, cheap, durable and easily maintained. It was fabricated using locally sourced materials and is intended to encourage local ingenuity and empower aspiring entrepreneurs especially in developing countries. Its purpose is to efficiently transfer human foot motion less than 60 rpm via a sewing machine pedal mechanism and sprocket-chain step-up to rotate the potter's wheel. A sewing machine pedal mechanism operating drive converts vertical rotation into horizontal rotation by using bevel gear. In this machine sprocket and freewheel is used to maintain the speed of potter wheel at the time of making of an earthen pot.

Keywords: potter's wheel, sewing machine pedal, bevel gear, flywheel, freewheel, and chain.

I. INTRODUCTION

The idea of human powered mechanisms has been implemented in many different purposes. Some applications include Human Powered sewing machine, generating power, flower mill, Nursery Fertilizer Mixer, Wood Cutting machine, and other machines etc... Some third world development projects currently transform used bicycles into pedal powered tools for sustainable development.

The sewing machine pedal mechanism operated rotate potter's wheel utilizes human energy to manufacture an earthen pot on the wheel efficiently. The goal is to provide technological solution to problem in the rural area by using detailed opportunity recognition, evaluation, and development of prototype. The prototypes are then turned over to the developing world for manufacturing, distribution and use. Less commonly, sewing machine pedal mechanism is used to rotate potter's wheel for forming an earthen pot or clay pot.

The potter's wheel rotates from sewing machine pedal mechanism is perfect for remote areas, hilly regions, strategic location, Islands etc., where electricity generation is scanty if not nil. The potter wheel gives opportunity to human to make beautifully shaped pots for personal and commercial use. To make an earthen or ceramics pot, you need a potter wheel which rotates manually. The sewing machine pedal operated potter wheel is to overcome problem with the current manual potter wheel used in rural area. There were number of uncertain factors such as to maintain the speed of potter wheel as per requirement. The flywheel and freewheel is useful to keep the potters the wheel rotating even if the pedaling is stopped. While using this wheel, the potters form a clay pot as well as pedals by seating in the same position. This process helps to avoid the health problem of potter like knee pain, back pain, etc..., and person to maintain physical fitness through exercise of muscles of legs.

II. LITERATURE REVIEW

• Short History on Pedal Powered Machines

Throughout Human history, human arms, hands and back is generally used to apply energy for various means. After the invention of seat rowing shell, particularly of bicycle, another normal means of developing power from human muscles are considered to be as legs. Treadle has been the most common means of producing power through legs from many centuries. Treadles are still commonly used in low power range, especially for sewing machines. In the past, the maximum output where two treadles were used to perform some tasks would have been quite small.

The combination of Pedals and cranks was not used to generate power until recently, which is a common way to generate power today. Almost 50 years after the invention of steerable foot-powered bicycle by Karl Von Kraiss in 1817, The Pedals and Cranks were added to the bicycle by Pierre Michaud that started the enthusiasm for riding a bicycle that has lasted to the present.

Human powered machines are considered as outdated technology ever since the discovery of electricity and fossil fuels. Thus, it's easy to forget the huge improvement in its design and increase in its productivity. Pedalling was the most efficient mechanism to harvest human energy that was discovered in 19th century.

Otto Von Guericke was the one who created the world's first electrical machine in 1660. The electromagnetic energy that is used today succeeds the previously used form of electricity. The electricity usage today which has been used from 1831 to 1846 was possible due to theoretical and practical experiments performed by Faraday, Weber and Gauss in relation of current, magnetic fields and force. The design of modern motors and generators was possible due to these theories. The electrical machines went under rapid development from 1880 to 1900. Thus the review of the works done on human power generation has been provided.[1,2,3]

- **Early Development**

In the southern Levant, The wheel coiling technique does not become prevalent until the second half of second millennium BCE, even though it appeared by the second half of fifth millennium. Thus, this technique that had high learning cost but was techno-economic took 3000 years to be adopted widely all over the world. This technique disappeared twice between fifth and second millennium BCE; once after the collapse of chalcolithic societies and second after the collapse of urban societies at the end of second millennium BCE. The explanation of the disappearance of the wheel coiling technique was explained in terms of context of production and transmission of the craft (Roux 2000, 2008): The technique was in the hands of only few craftsmen attached to politico-religious elite, and was restricted with an exception for the manufacture of ceremonial vessels. The mediation of the craft stopped after the disappearance of politico-religious elite and its demands.

The potter's wheel was back in the first half of the third millennium BCE and was used extensively, which gave rise to the urbanization of the promoting techniques to step up the craft production. However, by early bronze IV period, just by the end of chalcolithic period, the coiling technique disappeared again. The extent of the wheel coiling technique being in the hands of the specific potters with status as that of the chalcolithic potters was unknown. The analysis of EB III ceramic assemblage of Tell Yarmouth, a fortified urban centre located in south-western Canaan, in central shephelah among the major EB III sites of southern Levant was undertaken in accordance with these issues. Two tournettes have been discovered on this site, proving the use of rotary instruments to produce ceramics.[4,5]

- **Recent Development**

The potter's wheel is a machine used to create pots or ceramics. Occasionally it also came to known as Potter's lathe. However, it is actually a different machine similar to the machine used for shaping wood and metal. The excess clay from dried wares was removed by using potter's wheel. It was also used for application of incised decoration or rings of colour. The potter's wheel was simply extended to the techniques of jiggering and jollying. In jiggering, the semidried clay body which is placed atop a rotating plaster mould is shaped with the help of jiggering tool. The jiggering too shapes the top face of the clay-ware as it moulds the underneath one. The term is specific to the flatware shaping. The technique similar to jiggering is jollying specifically refers to the production of hollowware such as cups and bowls where the wares have symmetrical, hollow centre.

A simple coiling technique was used to craft many early hand-built ceramics. The clay body was rolled into long coils that were then punched checked and beaten together to form a body of a vessel. The coils were wound along the top of the piece by turning the vessel around, which increased its height by completing every single turn. All the energy required in order to construct a ceramic was supplied by hands of the potter in coiling method. However, all of it changed after the introduction of potter's wheel. Once the heavy potter's wheel was kicked or turned with a stick, it would continue rotating based on its momentum. In wheel turning, the energy supplied was not directly from the potter's hand but from the turning of the wheel.

The speed, efficiency and the symmetrical shape of the clay ware was optimized after the introduction of potter's wheel. The work that took days to complete was reduced to one which could even be completed in minutes. In early ages where coiling technique was used, the ceramics were placed on mats or leaves to make it able to turn conveniently. The arrangement of mat and the ceramic allowed the potter to turn the mat rather than walking around the ware to add coils to the clay body. It has been theorized that the early forms of potter's wheel were an extension to this procedure. The early forms of potter's wheel were thus coiled while turning the wheel by hand or foot. However the later developments led to the turning of potter's wheel by the energy supplied which kept the momentum in place to speed up the throwing process. The potter's wheel came into use by the dates 6000 BC to about 2400 BC suggested Bryant (2013). The stone potter's wheel found at the Mesopotamia city of Ur, in modern Iraq has been said to from about 3000 BC. However, an even earlier dated thrown wheel fragments were discovered in the same place. The use of potter's wheel had become common by the time of early civilizations of Bronze Age.[4,6]

In Iron Age, The potter's wheel had a turning platform about a meter above ground floor which was had a long axle connected to the heavy wheel at the ground level. This made the potter easier to turn the turning wheel by kicking by foot which made the potter able to manipulate the clay on the wheel by both hands. This method of pottery was popular throughout the old world but was unknown in the pre-Columbian new era where methods like coiling and beating were used. The motor-driven wheel has become popular in the modern times. It was particularly used by the potters and educational institutions for educational purposes. Regardless, human powered wheels are still widely used by many potters. Since the early period when man was trying to create domestic tools, the idea and method of pottery was brought into light. That was known as the origin period of pottery. Since then many methods of improving production has been found. After the clay has been finished moulding, the ware was baked in fire and blackened from outside to make the product tougher. During the period when the method of throwing didn't exist, the pottery was a very essential component of life and most of the potters were female.

The ceramic vesicle making was made a lot easier after the foundation of the throwing machine which made the throwing process easy. This process boosts the economic production rate significantly that made the life of the potter's much easier in the affluent society. The whole make of the machine was depended upon the science behind wheel and axle. In the mechanism, the wheel was mounted on the axle or drum of smaller diameter both on the same axis. Examples of the above explanation are wheel and steering wheel of the automobile, the doorknob and the windlass. The potter's wheel that is to be constructed here will make both able and disable people whose hands are functional to use it for making pots and earthen ware. The machine to be used here needs a crank handle to propel the axle, which will make the above attached wheel to turn. These designs make the process of throwing much more effortless and efficient, which will boost up the production rate considerably.[6]

Since 2001 to 2012, an analysis was undertaken to evaluate the design, product development and practice in ceramics in Uganda. The analysis studied the common designs, process and products of Uganda. It was held largely in Kampala and the suburbs and western Uganda. Both local hand and machine assisted product processes were studied to widely pasteurize the production of what was undertaken by the pottery strata. The potter's had a different level of understanding of the materials they used, which was associated with the pattern of the potters and their product. The community they worked in and the general clientele were also the components associated with the potters. Given the trends of new designs in ceramics and the influence of prevalent village, the pottery practices continue to face challenges in local marketing of products. The derived conclusion is that the potters in Uganda need to go beyond the original practices which have been carried out for generations. In terms of design processes and market survey, the types of design processes used by most of the potters is unpredictable with minimum input

making it lacking in the trending designs. The most of the potters had been simply copying what is being mostly sold in the market without even thinking about the product's sustainability and viability.

Most of the formally educated potters sought the use of potter's wheel after the equipment. There was a wide range of locally created potter's wheels mostly using the manual technologies such as treadle or kick wheel. These technologies were cheap and easy to repair if broken. Some established institutions used some expensive imported potter's wheels, whose designs were imitated in most of the potter's wheels. There seemed no equipment similar to the forming equipment made locally in Uganda.[7]

The potter's wheel and the physical ability to operate a manual or electric wheel are essentially needed to create pottery and ceramics. Pottery is the activity which satisfies the own interest of the potter as well as the need to make and use. The term and process of making is in fact a fundamental part of being human. Maximum productivity is expected in every aspect of human struggle fulfilling the demands of the consumer whether a manual or automatic machine is used. The field of ceramics can't work without this one aspect. A potter must meet the requirements of the consumer especially with the difficulties in the environment a potter has found himself or herself into. Maximum productivity is required whether a manual or an automatic potter's wheel is used. The electric wheel is a great innovation. However, it has both his positive as well as negative parts. The electric wheel could have a negative effect in growing societies or the remote villages where electricity is rarely or scarcely available.[8]

III. MATERIALS AND METHODS

• Mechanism of Operation

The sewing machine Pedal Operated potter's wheel is a type of potter's wheel in which the source of mechanical power is provided by the human effort while rotating a shaft, with its corresponding angular speed (ω human) and torque (T human). Usually, a sort of mechanical transmission system is needed to adapt these variables into the potter's wheel required ones (ω gen and T gen). Then, this mechanical power is converted with the aim of being stored without damaging the storage system. Almost any device can contain the principle of using pedal motion to create the same motion as a motor.

• Power Analysis

Heslin and Annete provided 2440 kcal which is about 119W of power in, 10.299MJ or 2861Wh of energy as the average daily consumption of an average male every single day, which is approximately the same amount of energy that is stored in a typical car battery (2400Wh). Food is the primary fuel that is used in the production of human power. To fuel the metabolic process, the human body utilizes the energy stored in the chemical bonds. These chemical bonds are carbohydrates, proteins, fats and fibre to fuel metabolic processes. Basal metabolic functions that sustain life, and advanced metabolic function used during physical activities are the processes that are fuelled by the energy. Kilocalories (Kcal) and food calories (C) are the units used to measure food energy. 1 Kcal is equal to 1C. The foot energy is measured in joules (J) in the metric system, where 1C is equal to 4184J.[1,2]

• Human power

It is generally accepted that a reasonably fit, well fed human being between 20 and 40 years old can produce a steady power output of around 75 watts for long periods (Fraenkel, 1986). This may not be the case in many developing countries, so a more realistic output may be around 30 to 40 watts. This power is transferred to the pedal when the potter pushes them up and down in a reciprocal motion. This is a very natural movement for the human body; it can be sustained for several hours, if the parameters of stroke length and the cadence are matched with the ability of the potter. A steady output of 75watts is the equivalent of walking up stairs at home in 20 seconds. This may not seem such a difficult task but try doing it continuously for 4–6 hours each day. Assuming a 75 watt output, it is possible to calculate what can be done with this human power.[4]

• DESIGN ANALYSIS

General Design Considerations

Generally, the design of this potter's wheel depends on the height of potter's wheel, the potter's wheel mounted on the shaft, comfortable for the potter to seat. The rotating speeds maintain the potter's wheel, as per the requirements of the throwing process. In the above constraints, the following design consideration and assumption has been made for this project design;

I. Sizing and Economic Considerations: This potter wheel machine is design to compact in consideration of the potter to comfort as well as reduction in the cost of fabrication.

II. Safety Consideration: This potter's wheel is design in such a way that anybody can use it for the throwing process on the wheel at minimum effort.

III. Ergonomics: The ergonomics aspect has to do with optimizing the human powered, and also considered as following points.

- The reduced the strain of the arm and shoulder
- The reduced the lower back pain
- The reduced the knee pain

IV. Technological consideration: The design of this system is well considered in such a manner that it can be produced within the technology of our immediate environment.

Frame Design

Choosing Frame Material

The design process of objects under manually foot pedalling changing loading is the knowledge of service load history. It is especially important in the case of the pedal exerciser in which components are under threat of fatigue damage formation because of the diversified influence of many factors of deterministic and random nature. Manually foot operated any machine frames encounter a complex set of stresses which in most cases cannot be calculated by hand. Therefore, in designing a frame, engineers usually makes use of an older design which has proven reliable as a starting point. The frame of the sewing machine pedal

mechanism was designed to potter's wheel with little modifications on the materials used in order to minimize cost and also considering availability of materials. The materials used for manually operated potter's wheel frames have a wide range of mechanical properties. For most machine builders, mild steel is the material of choice; mild steel machine frame impart a certain level of confidence in the ability of the machine mechanisms. The ideal combination of performance and purchase cost is provided if using mild steel machine frame. Mild steel machine frame can be easily repaired cheap; it reveals frame stress injuries before they become failures as well. For the manually operated potter's wheel, a mild steel frame is used for the support of mechanism. It's mechanism stores and releases energy at different positions of the pedal. The table below shows all the component parts of the mechanism and the materials used.

Table 3.1: components and materials used

Component	Material	Source
Main Frame	Mild steel	Locally Sourced
Sewing machine pedal Mechanism	Cast Iron	Purchased
Bevel Gear Pair	Steel	Purchased
Shafts	Mild Steel	Locally Sourced
Sprocket	Steel	Purchased
Freewheel	Cast Iron	Purchased
Chain	Steel	Purchased
Potter's Wheel Head	Mild Steel	Locally Sourced

Frame Dimensions

Construction of the Frame is made up of mild steel of angle size 50 x 50 x 5 mm, its height is 600 mm of four corners. Length of the frame as per dimension of sewing machine pedal mechanism to fit in the frame is 600 mm and also width of the frame to maintain as per the sewing machine pedal mechanism is 500 mm. The dimensions of potter's wheel table, along with the amount of lateral and vertical clearance needed, in the planning and design of potter's wheel table facilities are taken into account to ensure the safety of the user and promote efficient pedaling. The dimensions of the potter's wheel table are: height of 0.60m, width of 0.60m, length of 0.50m.



Figure 3.1: Frame of Potter Wheel

Force Input

This system is designed assuming the average mass of 60 kg and pedalling time as 60 minutes. From reviewed literatures, the pedal input force can be computed as below:

Input force

$$F = \frac{mv}{t} \quad (3.1)$$

Gear Ratio

Khurmi and Gupta stated the gear ratio, also known as its speed ratio, is the ratio of the angular velocity of the input gear to the angular velocity of the output gear. The gear ratio can be calculated directly from the number of teeth on the gears in the system. This system is made up of 2 stage gear systems. The teeth on gears are designed so that the gears can roll on the chain link smoothly without slipping. The number of teeth on gear is proportional to the radius of its pitch circle, which means that the ratios of the gears' angular velocities, radii and number of teeth are equal. Mathematically,

$$\frac{\omega_A}{\omega_B} = \frac{R_B}{R_A} = \frac{T_B}{T_A} = \frac{D_B}{D_A} \quad (3.2)$$

Where ω_A, ω_B = angular speed of Bevel Gear A and B respectively

R_A, R_B = Radius of Bevel Gear A and B respectively

T_A, T_B = Number of teeth on Bevel Gear A and B respectively

D_A, D_B = Diameter of Bevel Gear A and B respectively

First stage gear system: The first stage gear system is comprised of the input pedal system and the output Bevel Gear which is shown in the figure below:



Figure 3.2: Input Pedal Mechanism and Bevel Gear

The gear system is made up of a driver toothed bevel gear (A) which has 25 teeth and the driven bevel gear (B) with 20 teeth. Jansen and Slob (2003) stated that a human can pedal an average of 60rpm comfortably. In the light of the above, the rpm of the Bevel Gear can be determined by rearranging equation (1) to obtain:

$$\frac{\omega_A}{\omega_B} = \frac{T_B}{T_A} \text{ OR}$$

$$\omega_B = \frac{T_A}{T_B} \omega_A \quad (3.3)$$

The pitch P of a gear which is the distance between equivalent points on neighbouring teeth along the pitch circle can be expressed as:

The pitch of the driver bevel gear A can be computed from the number of teeth T_A and the radius R_A of its pitch circle as:

$$P_A = \frac{2\pi R_A}{T_A} \quad (3.4)$$

While the pitch of the driven bevel gear B can be computed as:

$$P_B = \frac{2\pi R_B}{T_B} \quad (3.5)$$

The speed ratio can be obtained as:

$$S_R = \frac{T_B}{T_A} \quad (3.6)$$

Second stage gear system (Sprocket and Freewheel)

The second stage gear system is composed of sprocket teeth 52; freewheel teeth 18 which can be seen in the figure below:



Figure 3.3: Sprocket and Freewheel arrangement

To get the speed (rpm) of the freewheel, since the bevel gear mounted on shaft in the first stage and the sprocket form amounted on the same shaft, they rotate at same speed, that is $\omega_B = \omega_C$

Required maximum speed for the potter's wheel, the freewheel speed (rpm) can be calculated as:

$$\frac{\omega_C}{\omega_D} = \frac{T_D}{T_C} \quad (3.7)$$

From equation (3.9), the speed of freewheel can be calculated as:

$$\omega_D = \frac{T_C}{T_D} \omega_C \quad (3.8)$$

Where ω_C & ω_D = Angular speed of Sprocket and freewheel respectively

T_C & T_D = Number of teeth on Sprocket and freewheel respectively

Hence the overall gear ratio of the system can be expressed as:

For the first stage gear system:

$$G_{R1} = \frac{T_A}{T_B} \quad (3.9)$$

For the second stage gear system;

$$G_{R2} = \frac{T_C}{T_D} \quad (3.10)$$

Then the overall gear ration (GR)

$$GR = G_{R1} \times G_{R2} \quad (3.11)$$

Chain Drive Selection

In order to select a chain drive, the following essential information must be known:

- The power to be transmitted;
 - The speed of the driving and driven sprockets;
- To calculate the:

Pitch of the chain

$$P = \frac{2\pi(R+r)}{T_C + T_D} \quad (3.12)$$

Centre distance

$$X = \frac{D_C + D_D}{2} + 30 \quad (3.13)$$

Length of chain

$$L = \frac{P}{2}(T_C + T_D) + 2X + \frac{(\frac{P}{2}\text{cosec}\frac{180}{T_C} - \frac{P}{2}\text{cosec}\frac{180}{T_D})}{X} \quad (3.14)$$

This can be simplified as:

$$L = Y + 2X + Z$$

Where:

T_C = Number of teeth on the driver sprocket

T_D = Number of teeth on the driven Freewheel

P = Pitch of the chain

X = Center distance

$$Y = \frac{P}{2}(T_C + T_D)$$

$$Z = \frac{(\frac{P}{2}\text{cosec}\frac{180}{T_C} - \frac{P}{2}\text{cosec}\frac{180}{T_D})}{X}$$

IV.RESULTS

This section presents the result of the input and output data. The results were obtained based on both the evaluation of the models presented in the fabricated design. The input and output data are tabulated for clarity to show the dependence of some parameters on the others.

4.1 Input Parameters

The input parameters represent the known values from which the general design was based on. It includes the operational speed of the human to produce the required to the potter's wheel.

Table 4.1 Input Parameters for the Analysis

Sr. No.	PARAMETER	SYMBOL	VALUE	UNIT
1	Human Input Rotational Speed	ω_A	60	RPM
2	Number of teeth on Driver Bevel Gear	T_A	25	
3	Number of teeth on Driven Bevel Gear	T_B	20	
4	Number of teeth on Sprocket	T_C	52	
5	Number of teeth on Freewheel	T_D	18	
6	Avg. Mass of potters	M	60	Kg
7	Operational Time	T	60	Mins

The power that is used during the pedal to rotate the potter's wheel mostly depends on the pedalling speed of the individual.

4.2 Output Parameters

Table 4.2 shows the results obtained from the evaluation of the models. It shows the summary of the output data of the analysis of the machine which include the selection of the bevel gears and chain drive of the machine etc.

Table 4.2 Output Parameters after the Analysis

Sr. No.	PARAMETER	SYMBOL	VALUE	UNIT
1	Input Force	F	0.09309	N
2	Speed Ratio	SR	0.8	
3	Speed of Bevel Gear B	ω_B	75	Rpm
4	Speed of Sprocket	ω_C	75	Rpm
5	Speed of Freewheel	ω_D	216.66	Rpm
6	First Stage Gear Ratio	G_{R1}	1.25	
7	Second Stage Gear Ratio	G_{R2}	2.89	
8	Overall Gear Ratio	G_R	3.6125	
9	Chain Pitch	P	12.87	Mm
10	Chain Centre Distance	X	157	Mm
11	Chain Length	L	713.3	Mm

V. Conclusion

In conclusion, the above project is done considering different factors like the ergonomic design of the potter's wheel as well as considering factors like the efficiency, technology and the geographical limitations and advantages. The machine can be used efficiently used in urban as well as rural areas, since the device is manually operated. The device can be operated by the unskilled workers provided with its quality metal frame and its dimensions giving it an ergonomic design. The manual operated device can alter the speed of the wheel efficiently as well. This device reduces time greatly needed to create the potter's wheel. Finally, all the components and their calculations are done to greatly increase the efficiency of the device producing great result.

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