

Pedal Powered Washing Machine (PPWM)

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Abstract: Pedal Powered Washing Machine (PPWM) is a low cost washing machine made up of easily and readily available scrap parts in daily life. It is a machine which generates power through human pedaling and with the drive mechanism, converts the pedaling motion into required rotary motion of the drum. Its innovation lies in its simple design, use of inexpensive parts, very low repairing and maintenance cost, affordability to each member of the society and it does not affect the environment. Our team intends to directly address the problems faced in washing clothes, and thus have developed a new design for easy effort in washing, rinsing and drying clothes. PPWM is a completely new concept, which in its one laundry cycle does washing, rinsing and drying of clothes similar to that of an automatic washing machine available in the market.

Index Terms: Bicycle Chain, Drive Selector, Drying, Pedal Power, Pedaling Rate, Rack and Pinion, Rinsing, Slider Crank Mechanism, Sprockets, Washing.

1 INTRODUCTION

HE project covers one of the daily house-hold activities (washing clothes) but solves a lot of other problems with it as well. We all wash clothes either by our hands or use power driven washing machines. Over the years, this has been either a very strenuous and time consuming or an expensive process. The project intends to solve the problem faced by so many persons in their day-to-day life. In the rural areas where electric supply is unavailable and expensive, powered washing machines becomes almost impractical. Several attempts have been made to develop a solution for these areas and to solve these problems, but either the project in itself becomes very expensive, or the repair and maintenance of the machines require a lot of money and imported parts to replace. Thus the project has the following objectives –

- Provide a low cost machine.
- A very effective machine which is not only cheap but has low maintenance cost. It should have readily available components and should be ergonomically efficient.
- Wash any type of cloth.
- Must have all the mechanisms – Washing, Rinsing, and Spinning.

2 UNDERSTANDING PEDAL POWER

Throughout history, human has applied energy through the use of arms, hands and back. With the invention of bicycle and pedaling, legs also began to be considered as a means to develop power from human muscles. A person can generate four times more power by pedaling than by hand cranking. At the rate of 1/4hp, continuous pedaling can be done for only short periods, about 10 minutes. However, pedaling at half this power (1/8hp) can be sustained for around 60 minutes.

Pedal power enables a person to drive devices at the same rate as that achieved by hand cranking, but with far less effort and fatigue. Pedal power also lets one drive devices at a faster rate than before, or operates devices that require too much power for hand cranking. Over the centuries, the treadle has been the most common method of using the legs to produce power. Treadles are still common in the low-power range, especially for sewing machines. The maximum power output from treadles is very small; perhaps only 0-15 percent of what an individual using pedal operated cranks can produce under optimum conditions.

2.1 Pedal Power Levels

The power levels that a human being can produce through pedaling depend on how strong the pedaling person is and on how long he or she needs to pedal. If the task to be powered will continue for hours at a time, 75 watts mechanical power is generally considered the limit for a larger healthy non-athlete. A healthy athletic person of the same build might produce up to twice this amount. A person who is smaller and less well nourished, but not ill, would produce less; the estimate for such a person should probably be 50 watts. The graph in Fig. 1 shows various record limits for pedaling under optimum conditions. The meaning of these curves is that any point on a curve indicates the maximum time that the appropriate class of person could maintain the given average power level.

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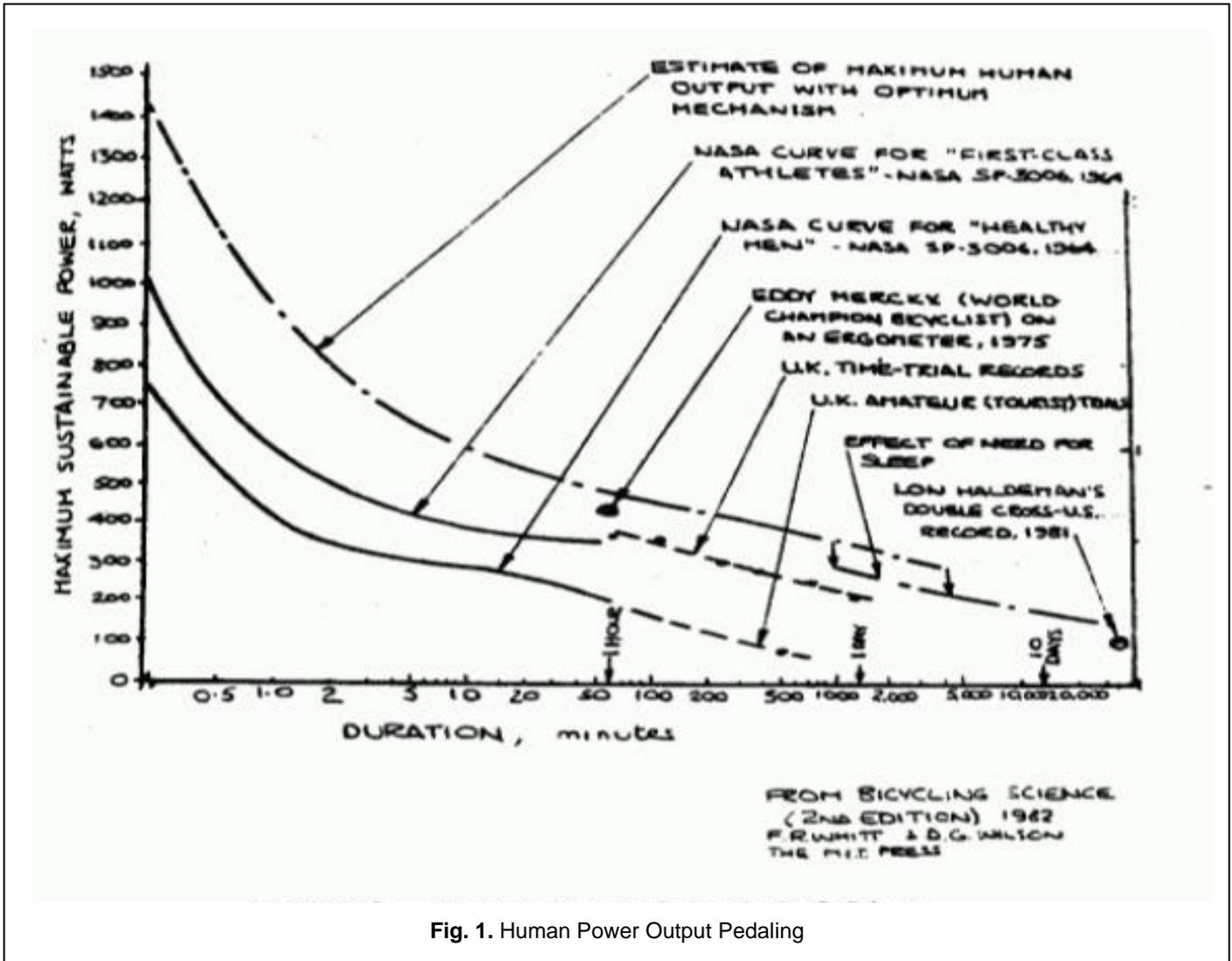


Fig. 1. Human Power Output Pedaling

2.2 Pedaling Rate

Human beings are very adaptable and can produce power over a wide range of pedaling speeds. However, people can produce more power--or the same amount of power for a longer time--if they pedal at a certain rate. This rate varies from person to person depending on their physical condition, but for each individual there is a pedaling speed somewhere between straining and flailing that is the most comfortable, and the most efficient in terms of power production. A simple rule is that most people engaged in delivering power continuously for an hour or more will be most efficient when pedaling in the range of 50 to 70 revolutions per minute (rpm). See Fig. 2. For simplicity's sake, we will use 60 rpm, or one revolution of the pedal cranks per second, as an easy reference value for estimates of the gear ratios required to drive a given load.

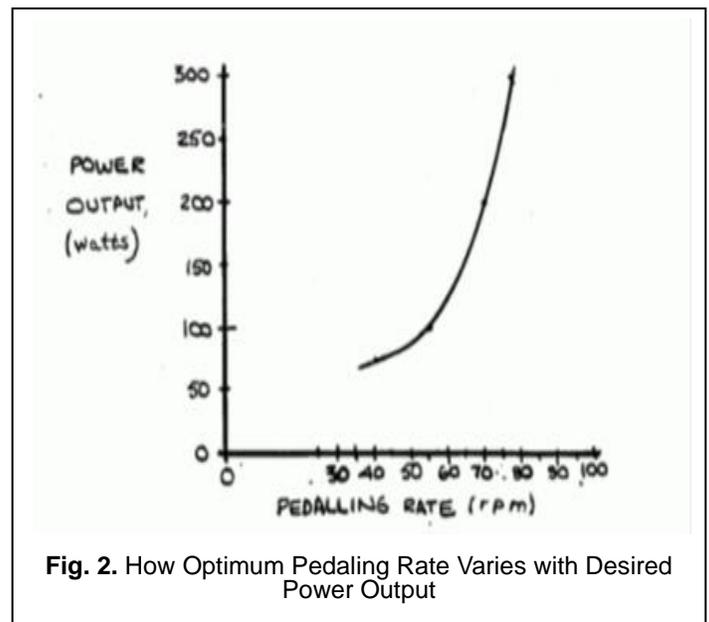


Fig. 2. How Optimum Pedaling Rate Varies with Desired Power Output

TABLE 1
Operating Specifications of a Conventional Washing Machine

Process	Time Taken	RPM Required
1. Washing	30 min	20 rpm
2. Rinsing	5 min	500 rpm
3. Drying	15 min	1000 rpm

3 OPERATING PARAMETERS

It can be seen from TABLE 1 that the total time required for the entire process is 50 minutes. For, comfortable and efficient power production through pedaling the pedaling rate is taken as 60 rpm. From Fig. 2, it can be seen that a healthy person produces 125 Watts of power when pedals at 60 rpm under optimal conditions. As, the cycle time is 50 minutes, it can be seen from Fig. 1 that maximum sustainable power developed by a healthy man is around 200 Watts. Thus, pedaling at 60 rpm and developing 125 Watts power provides considerable factor of safety for the pedaler. Now, keeping the input power constant at 125 W and using different speeds as required for different processes, the torque available at the tub are- for washing the torque available is 59.68Nm, for rinsing the torque available is 2.38Nm and for drying the torque available is 1.19Nm. Minimum torque is the deciding factor for determining the capacity of washing machine as same load of clothes remains during all the three processes. Thus, the capacity of the machine is calculated to be around 1.2 kg.

4 DESIGN

Clothes are washed in pedal powered washing machine like in any other washing machine in 3 basic steps:

1. Washing
2. Rinsing
3. Spin drying

4.1 Design of Wash Mechanism

The washing of clothes in front loading washing machines requires that the tub of the washing machine executes rotations in both senses i.e. clockwise for some time, then anti-clockwise for some-time and then again clockwise and so on. The shaft connected to the bicycle rotates in one direction only so some mechanism had to be designed by which the sense of rotation could be changed i.e. the power obtained from a shaft rotating in one direction had to be modified so as to execute rotation in both senses in a periodic way. Thus rack and pinion arrangement was used. In this mechanism the rack would reciprocate and a pinion would mesh with the reciprocating rack, as the direction of motion of the rack changes, the sense of rotation of the pinion would also change and the required objective shall be accomplished. The reciprocating motion of the rack from a shaft rotating in one direction could be achieved in two ways:

- i. Quick Return Mechanism
- ii. Slider Crank Mechanism

Major drawbacks of Quick Return Mechanism:

1. It gave unequal time for both senses of rotation i.e. rotation in one sense was done faster than rotation in the other sense.
2. It did not lead to uniform motion of the tub which could degrade the quality of wash.
3. It was a very bulky setup to implement.
4. Use of bulky setup would unnecessarily increase the cost of the product by increasing the material, labor and machining costs.
5. Use of bulky setup would also increase the pedal effort significantly and therefore it would not be ergonomically feasible.

Therefore quick return mechanism was eliminated as an option for the wash drive mechanism. Slider Crank Mechanism was then considered for converting the rotary motion of the output shaft of the bicycle into the reciprocating motion of the rack by which the pinion connected to the rack would execute rotary motion in both senses.

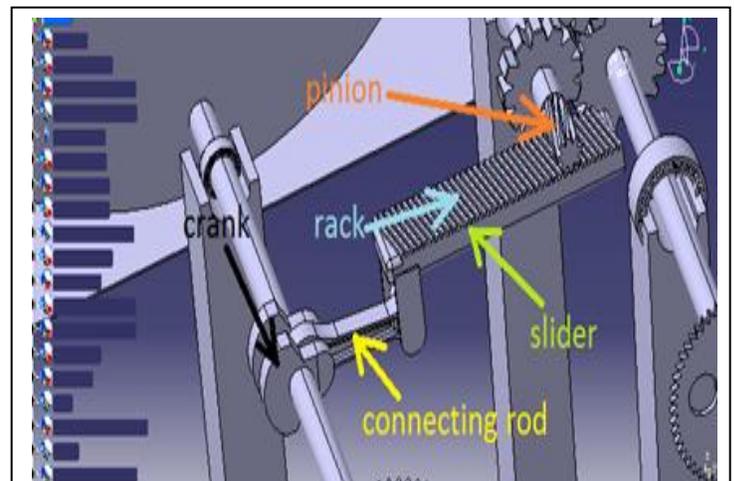


Fig. 3. The CATIA Model of the Wash Mechanism

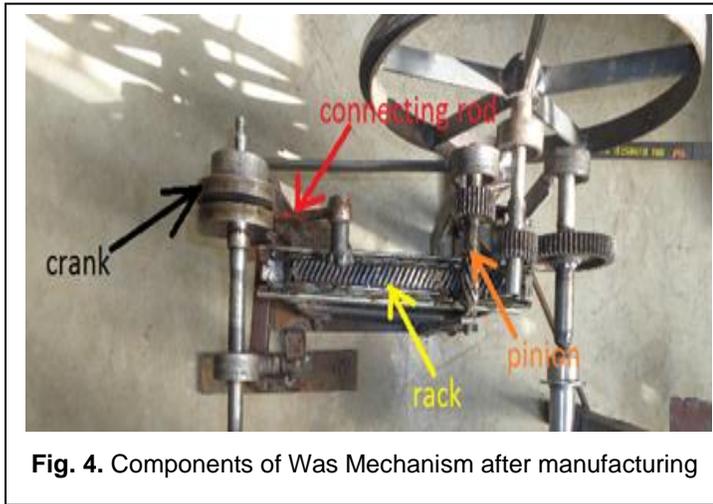


Fig. 4. Components of Was Mechanism after manufacturing

mode of power transmission to the tub. Although the load on the tub remains constant for all the processes, the washing process requires slow agitating motion with speed around 20 rpm. Rinsing and Drying processes require comparatively higher speeds. The power available at the tub is constant which is 125 W. The capacity of the tub is 1.2 kg and the torque required for washing is 1.19Nm. Thus, the power required for washing is,

$$\begin{aligned}
 P &= \frac{2\pi NT}{60} \\
 &= \frac{2\pi(20)(1.19)}{60} \\
 &= 2.5 \text{ Watt}
 \end{aligned}$$

For transmitting the drives to the final tub three options were available- gear drive, chain drive and belt drive. The use of gear drive or chain drive would lead to jerks at the instants the sense of rotation changes but the use of belt drive allows the tub to slip over the belt and come to stop and rotate in the other sense smoothly. Therefore, belt drive is used as the

The excess of power available is wasted. As, the washing process continues for 30 minutes a lot of energy is wasted. This energy can be used effectively by increasing the loading of the machine during washing.

TABLE 2
Power Required for Each of the Three Processes of PPWM

Process	RPM Required	Torque Available	Power Required
1. Washing	20 rpm	59.68 Nm	2.5 W
2. Rinsing	500 rpm	2.38 Nm	62.5 W
3. Drying	1000 rpm	1.19 Nm	125 W



Fig. 5. The Working Model of PPWM Design

As can be seen from the image above, the output from the bicycle goes into a small sprocket which drives a bigger sprocket. There is one shaft connected to the smaller sprocket and there is another shaft connected to the larger sprocket. The velocity is higher at the smaller sprocket while it is lesser at the larger sprocket. As higher speeds is required for rinsing and spin dry processes, the drive is taken from the rinsing and spin gear connected to the smaller sprocket and the shaft connected to the larger sprocket has crank at one end which reciprocates the rack by the help of a connecting rod. The pinion connected to the rod finally provides the output drive for the wash mechanism.

4.2 Design of Rinse and Spin dry Mechanism

For the rinsing and spin dry the tub needs to rotate in one direction only. One of the important parameters for rinse and spin dry processes is the speed at which the tub rotates. Since there was no need for us to change the sense of rotation for rinsing and spin dry processes, it could be achieved simply by meshing of gears having the proper gear ratio. In the case of pedal powered washing machine, we required a reduction ratio of 2 for the spin and rinsing processes, so appropriate gears were made to mesh and the drive was finally sent to the tub to execute rotations at high speeds for the rinsing and spin dry processes.

4.3 Design of Drive Selector

In order to switch between the wash mode and the rinse and spin dry mode a drive selector was designed by the use of which the tub could be made to rotate in the desired mode by the user. The drive selector has a very simple design; it consists of a hollow pipe on which a gear (drive selector gear) is mounted. The hollow pipe has a hole for a bolt to pass through. This hollow pipe can move over a solid pipe which has holes in two positions where the hollow pipe can be bolted. In one of the positions, the drive selector gear meshes with the spin and rinse gear as shown in the image and in the other position it meshes with the wash gear. Accordingly the tub rotates in the desired mode.

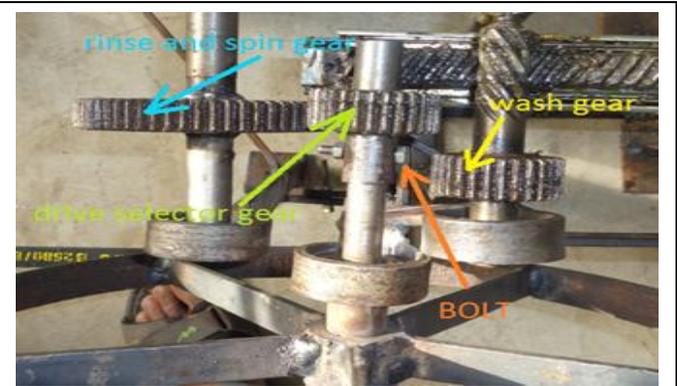


Fig. 6. Meshing of gears and the Drive Selector

5 COMPONENTS USED

- **Hero Ranger Swing** cycle was selected for pedaling purpose. It has **Shimano Sis** 18 gears arrangement which provides varied gear ratios and speed.
- The pedaling crank is connected to a compound sprocket assembly containing **3 sprockets** with **48, 38 and 28** teeth respectively.
- The rear hub is connected to a compound sprocket assembly containing **6 sprockets** with **28, 24, 21, 18, 16 and 14** teeth respectively.
- A rear hub sprocket with **18 teeth**, a **44 teeth** front sprocket and a chain is also used from a scrap bicycle.
- Also, two scrap gears are used with **32 and 65** teeth respectively.
- Crankshaft assembly: BAJAJ Priya Scooter.
- Rack and pinion from the steering assembly of Force Minidor.
- Sliders commonly used in drawers.
- Ball bearings and Scrap mild steel for stands and base.
- A custom made pulley which is made of mild steel strips. It is welded and turned on lathe.

Thus the whole drive with the calculations done above is shown as below –

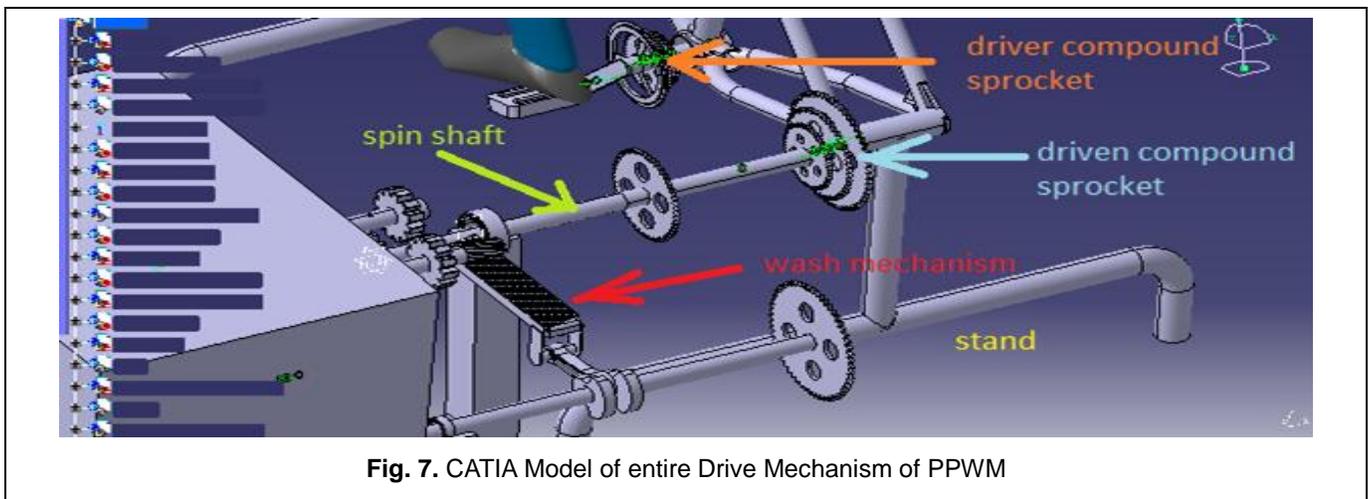


Fig. 7. CATIA Model of entire Drive Mechanism of PPWM

6 AVAILABLE SPEED AFTER FINAL DESIGN

6.1 Wash Mechanism

In wash mechanism, the 28 teeth pedaling crank sprocket is meshed with the 28 teeth rear hub sprocket. If the peddler pedals at 60 rpm, there is no reduction and the power is transmitted to next hub sprocket. Here, the 18 teeth sprocket is chained to a 44 teeth sprocket which gives a reduction of **2.44 times**. Thus, the 60 rpm speed is reduced to **24.59 rpm**. After the crank slider mechanism, the angular velocity of **24.59 rpm** is increased to **75.73 rpm**. This is then transferred to the drive selector with no reduction. Therefore, the speed of pulley

during wash mechanism is **75.73 rpm** when the pedaling rate is 60 rpm. If speed of 20 rpm is required during washing, then the pedaling rate should be **15.84 rpm**.

6.2 Rinse Mechanism

In rinsing mechanism, the 48 teeth pedaling crank sprocket is meshed with the 14 teeth rear hub sprocket. This gives a reduction of **3.42 times**. Thus the 60 rpm speed is increased to **205.2 rpm**. If the peddler pedals at 60 rpm, with the reduction above calculated, the power is transmitted to the gear (having 65 teeth) attached to the shaft containing rear hub sprocket.

Table 3
Pedaling rate required according to the proposed design

Process	RPM Required	Pedaling rate required according to the proposed design
1. Washing	20 rpm	15.84 rpm
2. Rinsing	500 rpm	71.98 rpm
3. Drying	1000 rpm	143.95 rpm

comes to be around Rs. 6000/- (Varies depending on the market survey, and on the market conditions). Here, the 65 teeth gear is meshed to a 32 teeth gear which gives a reduction of **2.03 times**. Thus, the 205.2 rpm speed is increased to **416.81 rpm**. This is then transferred to the drive selector with no reduction. Therefore, the speed of pulley during rinse mechanism is **416.81 rpm** when the pedaling rate is 60 rpm. If speed of 500 rpm is required during rinsing, then the pedaling rate should be **71.98 rpm**.

This is then transferred to the drive selector with no reduction. Therefore, the speed of pulley during rinse mechanism is **416.81 rpm** when the pedaling rate is 60 rpm. If speed of 1000 rpm is required during rinsing, then the pedaling rate should be **143.95 rpm**.

6.3 Spin Mechanism (Drying)

In rinsing mechanism, the 48 teeth pedaling crank sprocket is meshed with the 14 teeth rear hub sprocket. This gives a reduction of **3.42 times**. Thus the 60 rpm speed is increased to **205.2 rpm**. If the peddler pedals at 60 rpm, with the reduction above calculated, the power is transmitted to the gear (having 65 teeth) attached to the shaft containing rear hub sprocket. The 65 teeth gear is meshed to a 32 teeth gear which gives a reduction of **2.03 times**. Thus, the 205.2 rpm speed is increased to **416.81 rpm**.

From Figure 2 it can be counterchecked that the required pedaling rate produces required power for each of the three processes viz. washing, rinsing and drying.

7 FABRICATION

A working model of PPWM was fabricated using the selected scrap components as mentioned in the design. The machine was fabricated to study the design feasibility and the efficiency of the working model. It was found that PPWM can be easily manufactured in a workshop using scrap components and conventional manufacturing processes. Manual Metal Arc Welding (MMAW) was key manufacturing process used. Other operations such as lathe works, press fitting, cutting and grinding of scrap metals etc. were also done. The fabrication of the model provided the cost estimate for the machine. The total cost of PPWM (including materials, machining, and components)

8 ADVANTAGES

PPWM offers certain advantages over a standard (simple) washing machine used. Listed below are some of the advantages –

- Eco friendly and non-polluting in every way.
- Less noisy
- The machine has low manufacturing cost. It is highly economical and affordable to all class of people.
- Works without electricity so it can be an ideal machine for the people in the electricity deficient Indian villages
- Less tiring than conventional washing techniques by hand. This would greatly contribute in increasing the productivity of the manual laundries all over the world.
- Lesser chances of failure than electronic washing machine as the mechanical systems used in the machine have stood the test the time.
- More reliable: Due to simplicity of design the chances of failure are reduced drastically thus making the machine all the more reliable.
- Lesser maintenance required: Maintenance of PPWM involves mostly lubricating the various parts which can be done even at home so maintenance cost are drastically cut down.
- Zero operating cost: Since the machine is manually driven.
- Very effective in protecting the hands of washer men from the harmful effects of the chemicals in the detergents.
- It would help to reduce the physical stress which is applied on the hands during washing clothes.
- It encourages pedaling which is a good physical exercise and keeps oneself fit. A person now can easily wash

clothes while performing daily exercise which would save time.

- It is a product made up of recycled scrap.

9 SCOPE FOR FUTURE WORK

Although the working model of the drive of PPWM is fabricated and implemented, there is a scope of further work in the project which has not been undertaken. There are a number of ideas where the loss of power can be reutilized and the design can be modified for better performance. Some of them are listed below:

9.1 Energy Storage

The energy being wasted during washing can be stored using flywheel and can be used at the time of spin drying. This would reduce the effort required during drying and would increase the overall capacity of the machine as more energy would be available during spin drying.

9.2 Increasing Washing Capacity

The capacity of washing can be increased so that more clothes can be washed, thus utilizing the wasted energy. It has a disadvantage that all the clothes would not be rinsed and dried simultaneously in the same cycle. The capacity of rinsing and drying is low as compared to washing. Thus, increasing the washing capacity would require the rinsing and drying of the clothes to be done in turns. The machine would then no longer complete the entire laundry process in one cycle

9.3 Designing a Multipurpose Machine

The energy wasted during washing can be utilized in most fruitful way by using it in another household machine which would work simultaneously as the washing goes on. Load on the new machine would be such that entire energy is consumed and not wasted. The excess energy can be used to generate electricity to charge battery. It can be used to operate pedal powered pumps. Many machines operated on pedal power have been developed such as, Cassava graters, Coffee/grain hullers, cracking of oil palm nuts, Potter's wheels, Flexible shaft drive for portable grinders, saws, etc., Tire pumps, Sewing machines.

9.4 Designing and Implementing the Drain Valve mechanically

A normal washing machine uses an electronic control valve in the drainage system to control the flow of waste water out. This valve can be designed mechanically using bicycle brakes. The brakes would block the rubber outlet pipe when the clothes are being washed, rinsed or dried. The blockage would open to make the waste water flow out after a washing cycle or during drying.

10 CONCLUSION

The main objective is to provide a product with an alternative way to wash clothes when there is no electricity. It has to be understood that in rural areas, it is a very stressful and laborious task. So the product which is a pedal driven machine, it satisfies the need of rural people by giving them an alternative way of washing clothes which is quick, cost-effective and eco-friendly. The product designed has zero operating cost, cost-effective, and it can be used with minimal effort.

ACKNOWLEDGMENT

The authors wish to thank Dr. Arbind Kumar, Head of the Department, Mechanical Engineering, BIT Mesra for his consistent support and key guidance in the research work and project carried out. The authors also extend their thanks to Mr. Sharma and Mr. Bablu for his help in the fabrication work carried out. Finally the authors thank their friends, relatives, parents for their constant help, support and guidance in the research work.

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