Design & Fabrication of Manually Driven Pedal Powered Washing Machine

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ABSTRACT
Cloth washing is one of the essential parts of the life but it is considered undesirable because of the involvement of efforts, time, energy and cost. Nowadays a wide variety of washing machines are available in the market and there is a tough competence among the manufacturers. The cost of washing machine varying from Rs.10,000 to 1,50,000 depending upon features and capabilities. Very costly washing machines are equipped with facility of dry cleaning too. All of the washing machines available in the market are electric power driven and basic principle of their operation depends upon creation of the turbulent flow of detergent around the dirty clothes. Drying of the clothes is based upon rotation of wet clothes at very high rpm so that water droplets can be separated out due to centrifugal action. In our country where approximately 70% population is living with very poor economic status, those people cannot have a washing machine because of cost constraints and unavailability of electricity due to any reason. The present work is an attempt to develop a concept to make a cloth washing mechanism which can meet out the requirements of above mentioned 70% population of the nation. Working principle of this concept is no more different from available similar type of machine with a difference driving mechanism of the machine. The objective of bringing down the initial cost and operating cost of washing machine is almost achieved in present work within the limitation of work as mentioned.
Key word: CWT, CEA, 1. Introduction

A washing machine (laundry machine, clothes washer, or washer) is a machine designed to wash laundry, such as clothing, towels, and sheets. The term is mostly applied only to machines that use water as the primary cleaning solution, as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners. Washing entails immersing, dipping, rubbing, or scrubbing in water or other liquids, usually accompanied by soap, detergent, or bleach.

1.1 Background

Laundering by hand involves beating and scrubbing dirty textiles. Clothes washer technology (CWT) developed as a way to reduce the manual labour spent, providing an open basin or sealed container with paddles or fingers to automatically agitate the clothing. The earliest machines were hand-operated and constructed from wood, while later machines made of metal permitted a fire to burn below the washtub, keeping the water warm throughout the day's washing (the entire process often occupied an entire day of hard work, plus drying and ironing).The earliest special-purpose washing device was the scrub board, invented in 1797.As electricity was not commonly available until at least 1930, some early washing machines were operated by a low-speed single-cylinder hit and miss gasoline engine.

Fig.1 .Hand driven washing machine

Fig. 2 Motor driven washing machine

1850s, steam-driven commercial laundry machinery was on sale in the US and UK. The rotary washing machine was patented by Hamilton Smith in 1858.
Because water often had to be hand carried, heated on a fire for washing, then poured into the tub, the warm soapy water was precious and would be reused, first to wash the least soiled clothing, then to wash progressively dirtier laundry. Removal of soap and water from the clothing after washing was originally a separate process. After rinsing, the soaking wet clothing would be formed into a roll and twisted by hand to extract water. To help reduce this labour, the wringer/mangle machine was developed, which used two rollers under spring tension to squeeze water out of clothing and household linen. Each laundry item would be fed through the wringer separately. The first wringers were hand-cranked, but were eventually included as a powered attachment above the washer tub. The wringer would be swung over the wash tub so that extracted wash water would fall back into the tub to be reused for the next load. As the term "mangle" implies, these early machines were quite dangerous, especially if powered and not hand-driven. A user's fingers, hand, arm, or hair could become entangled in the laundry being squeezed, resulting in horrific injuries. Safer mechanisms were developed over time, and the more hazardous designs were eventually outlawed. The modern process of water removal by spinning did not come into use until electric motors were developed. Spinning requires a constant high-speed power source, and was originally done in a separate device known as an "extractor". A load of washed clothing would be transferred from the wash tub to the extractor basket, and the water spun out in a separate operation. These early extractors were often dangerous to use, since unevenly distributed loads would cause the machine to shake violently. The mounting the spinning basket on a free-floating shock-absorbing frame to absorb minor imbalances, and a bump switch to detect severe movement and stop the machine so that the load could be manually redistributed.
The automatic washer combines the features of these two devices into a single machine, plus the ability to fill and drain water by itself. It is possible to take this a step further, and to also merge the automatic washing machine and clothes dryer into a single device, called a combo washer dryer. In the early 1990s, upmarket machines incorporated micro controllers for the timing process. These proved reliable and cost-effective, so many cheaper machines now incorporate microcontrollers rather than electromechanical timers. Miele, from West Germany, was a top of the line front-load washer, and was introduced in Kananaskis, Alberta by Glenn Isbister, starting a revolution in laundry in Canada. In 1994, Staber Industries released the System 2000 washing machine, which is the only top-loading, horizontal-axis washer to be manufactured in the United States. The hexagonal tub spins like a front-loading machine, only using about third of the water as conventional top-loaders. This factor has led to an Energy Star rating for its high efficiency. In 1998, New Zealand based company Fisher & Paykel introduced its Smart Drive washing machine line in the US. This washing machine uses a computer-controlled system to determine certain factors such as load size and automatically adjusts the wash cycle to match. It also used a mixed system of washing, first with the "Eco-Active" wash, using a low level of recirculated water being sprayed on the load followed by a more traditional style wash. Other variations include the Intuitive Eco, which can sense the water level and type of fabric in the wash load, and the agitatorless AquaSmart line. The Smart Drive also included direct drive brushless DC electric motor, which simplified the bowl and agitator drive by doing away with the need for a gearbox system.
In 2001, Whirlpool Corporation introduced the Calypso, the first vertical-axis high efficiency washing machine to be top-loading. Simultaneously, water containing detergent was sprayed on to the laundry. The machine proved to be good at cleaning, but gained a bad reputation due to frequent breakdowns and destruction of laundry. The washer was recalled with a class-action lawsuit] and pulled off the market. In 2003, Maytag introduced their top-loading Neptune washer. Instead of an agitator, the machine had two wash plates, perpendicular to each other and at a 45 degree angle from the bottom of the tub. The machine would fill with only a small amount of water and the two wash plates would tumble the load within it, mimicking the action of a front-loading washer in a vertical axis design. In the early first decade of the 21st century, the British inventor James Dyson launched the Contra Rotator, a type of washing machine with two cylinders rotating in opposite directions. It was claimed that this design reduces the wash time and produces cleaner results. However, this machine is no longer in production. In 2007, Sanyo introduced the first drum type washing machine with "Air Wash" function. This washing machine uses only 50 L of water in the recycle mode. In 2008, the University of Leeds created a concept washing machine that uses only a cup (less than 300ml) of water to carry out a full wash. The machine leaves clothes virtually dry, and uses less than 2 per cent of the water and energy otherwise used by a conventional machine, but requires 20 kg of re-usable plastic chips in each load. As such, it could save billions of liters of water each year.
Features available in most modern consumer washing machines:

- Predefined programs for different laundry types
- Variable temperatures, including cold wash
- Rotation speed settings
- Delayed execution: a timer to delay the start of the laundry cycle

Additionally some of the modern machines feature:

- Child lock
- Time remaining indication
- Steam

Future functionalities will include energy consumption prognosis before starting the program, and electricity tariff induced delayed start of the machines. Integration into home local (wireless) networks will allow to monitor energy demand via different clients like computers or smart phones.

1.2 Top loaded versus front loaded washing machine

1.2.1. Top loaded washing machine

The top-loading design or vertical-axis clothes washer, most popular in Australia, New Zealand, Canada, the United States and Latin America, places the clothes in a vertically mounted perforated basket that is contained within a water-retaining tub, with a finned water-pumping agitator in the center of the bottom of the basket. Clothes are loaded through the top of the machine, which is covered with a hinged door. During the wash cycle, the outer tub is filled with water sufficient to fully immerse and suspend the clothing freely in the basket. The movement of the agitator pushes water outward between the paddles towards the edge of the tub. The water then moves outward, up the sides of the basket, towards the center, and then down towards the agitator to repeat the process, in a circulation pattern similar to the shape of a torus. The agitator direction is periodically reversed, because continuous motion in one direction would just lead to the water spinning around the basket with the agitator rather than the water being pumped in the torus-shaped motion. Some washers supplement the water-pumping action of the agitator with a large rotating screw on the shaft above the agitator, to help move water downwards in the center of the basket.

Top-loaders are not well-suited to cleaning large objects such as pillows or sleeping bags due to the tendency for them to just float on the surface of the water without circulating, and the aggressive agitator action can damage delicate fabrics. In most top-loading washers, if the motor spins in one direction, the gearbox drives the agitator; if the motor spins the other way, the gearbox locks the agitator and spins the basket and agitator together. Similarly if the pump motor rotates one way it recirculates the sudsy water; in the other direction it pumps water from the machine during the spin cycle. Because they usually incorporate a gearbox, clutch, crank, etc., top-loading washers are mechanically more complex than front loading machines but are generally lower maintenance since there is no need for a door seal (described below). However, the electromechanical components in conventional top-load washers have largely reached maturity.

The top-loader's spin cycle between washing and rinsing allows an extremely simple fabric softener dispenser, which operates passively through centrifugal force and gravity. The same objective must be accomplished by a solenoid-operated valve on a front loader. Another advantage to the top loading design is the reliance on gravity to contain the water, rather than potentially trouble-prone or short-lived front door seals. As with front-loading washers, clothing should not be packed tightly into a top-loading washer. Although wet cloth usually fits into a smaller space than dry cloth, a dense wad of cloth can restrict water circulation, resulting in poor soap distribution and incomplete rinsing. Extremely overloaded top-loading washers can either jam the motion of the agitator and overload or damage the motor or gearbox, or tear fabrics. Extreme overloading can also push fabrics into the small gap between the underside of the agitator and the bottom of the wash basket, resulting in fabrics wrapped around the agitator shaft, possibly requiring agitator removal to unjam.

1.2.2. Front loaded washing machine

The front-loading design or horizontal-axis clothes washer, most popular in Europe and the Middle East, mounts the inner basket and outer tub horizontally, and loading is through a door at the front of the machine. The door often but not always contains a window. Agitation is supplied by the back-and-forth rotation of the cylinder and by gravity. The clothes are lifted up by paddles on the inside wall of the drum and then dropped. This motion flexes the weave of the fabric and forces water and detergent solution through the clothes load. Because the wash action does not require the clothing be freely suspended in water, only enough water is needed to moisten the fabric. Because less water is required, front-loaders typically use less soap, and the aggressive dropping and folding action of the tumbling can easily produce large amounts of foam. Front-loaders control water usage through the surface tension of water, and the capillary wicking action this creates in the fabric weave. A front-loader washer always fills to the same low water level, but a large pile of dry clothing standing in water will soak up the moisture, causing the water level to drop. The washer then refills to maintain the original water level. Because it takes time for this water absorption to occur with a motionless pile of fabric, nearly all front-loaders begin the washing process by slowly tumbling the clothing under the stream of water entering and filling the drum, to rapidly saturate the clothes with water. Front-loading washers are mechanically simple compared to top-loaders, with the main motor normally being connected to the drum via a grooved pulley belt and large pulley wheel, without the need for a gearbox, clutch or crank. But front-load washers suffer from their own technical problems, due to the drum lying sideways. For example, a top loading washer keeps water inside the tub merely through the force of gravity pulling down on the water, while a front-loader must tightly seal the door shut with a gasket to prevent water dripping onto the floor during the wash cycle. This access door is locked shut during the entire wash cycle, since opening the door with the machine in use could result in water gushing out onto the floor. For front-loaders without viewing windows on the door, it is possible to accidentally pinch fabric between the door and the drum, resulting in tearing and damage to the pinched clothing during tumbling and spinning. Nearly all front-loader washers for the consumer market must also use a folded flexible bellows assembly around the door opening, to keep clothing contained inside the basket during the tumbling wash cycle. If this bellows assembly were not used, small articles of clothing such as socks could slip out of the wash basket near the door, and fall down the narrow slot between the outer tub and basket, plugging the drain and possibly jamming rotation of the inner basket. Retrieving lost items from between the outer tub and inner basket can require complete disassembly of the front of the washer and pulling out the entire inner wash basket. Commercial and industrial front-loaders used by businesses (described below) usually do not use the bellows, and instead require all small objects to be placed in a mesh bag to prevent loss near the basket opening. This bellows assembly around the door is the source of problems for the consumer front-loader. The bellows has a large number of flexible folds to permit the tub to move separately from the door during the high speed extraction cycle. On many machines, these folds can collect lint, dirt, and moisture, resulting in mold and mildew growth, and a foul odour. Some front-loading washer operating instructions say the bellows should be wiped down monthly with a strong bleach solution, while others offer a special "freshening" cycle where the machine is run empty with a strong dosing of bleach. In the past, suggested remedies have included adding vinegar to the laundry detergent, running an empty cycle with bleach every few weeks, wiping the door gasket with a diluted bleach solution every other week, and leaving the front-loading washer door ajar between loads. Recent studies of consumer reviews posted across the internet show a trend for US front-loading washers to have bearing failure problems, usually within the first 6 years. Repair costs are close to replacement cost, causing the consumer to replace rather than repair. Typical symptoms are louder noises while spin-rinsing. or soiled clothes shortly before complete failure, if the bearing grease gets into the inner tub. The expected life of today's washing machine has decreased by about 10 years compared to 30 years ago. The underlying cause is a tendency of US consumers to buy a washing machine at the lowest price, which has caused manufacturers to drastically lower their quality standards. Today's "disposable" machines have shorter life spans, and only one year warranties are offered. Compared to washing machines of the 1970s that lasted about 15 years, the same quality machine would cost about $2300 today, adjusted for inflation. Europeans generally spend two to three times more money for better built laundry machines. Compared to top-loading washers, clothing can be packed more tightly in a front loader, up to the full drum volume if using a cottons wash cycle. This is because wet cloth usually fits into a smaller space than dry cloth, and front loaders are able to self-regulate the water needed to achieve correct washing and rinsing. Extreme overloading of front-loading washers pushes fabrics towards the small gap between the loading door and the front of the wash basket, potentially resulting in fabrics lost between the basket and outer tub, and in severe cases, tearing of clothing and jamming the motion of the basket.

1.3. Need

In developing countries, rural women are among the least privileged. Women are both essential to the family unit and integral to the economy, yet they rarely have equal opportunities for education, career development, or social status when compared to men. One factor behind the inequality is the long list of responsibilities that traditionally fall to women. Not only do women perform agricultural duties and care for livestock alongside men, but women are also responsible for many domestic chores. Usually, new technology improves people’s efficiency, but women benefit less from new technology for several reasons. First, women’s duties are neglected by technological improvement efforts because domestic chores are often seen as cultural obligations for women so little effort is expended to diminish them. Second, foreign aid in the form of appropriate technologies is unevenly distributed because women are often considered less technically competent than men. Factors like these tend to prevent the development of improved technology for women’s uncompensated, time-consuming, and laborious tasks. Our team intends to directly address the plight faced by women by developing a pedal-powered washing machine.

An average woman may do two to three loads per week for a family of about five children and her husband. It generally takes at least 8 hours of washing time, not including the extra time needed to walk to the public washing reservoir or hang up clothes to dry. Additionally, while washing clothes by hand, women spend hours leaning over a concrete basin. Clothes are washed by laboriously scrubbing each section of cloth over a cement washboard with their hands immersed in detergents that are harmful to the skin. The detergents are chemically harmful to their hands, and the motion of scrubbing is straining to the muscles.

Some types of synthetic detergents still use inorganic phosphates, which are environmentally dangerous. The phosphates known as aluminosilicates cause a condition in water known as eutrophication. This condition enables algae to grow at a rapid rate. This diminishes levels of oxygen in water, leaving the water incapable of supporting other aquatic life. Artificial colorants used in synthetic detergents are sometimes made from petroleum products. These artificial colorants are not biodegradable and, therefore, stay in the environment indefinitely. Some artificial dyes and colorants can irritate skin, eyes and cause allergic reactions in mammals and fish. Some artificial dyes are thought to be hazardous to the health of humans and possibly cause cancer. Colorants serve no useful purpose in detergents. Some synthetic detergents contain ingredients knows as optical brighteners. These synthetic chemicals do not make laundry cleaner, but instead contribute to an optical illusion that makes fabric appear whiter and brighter. Aminotriazine or stilbene based whiteners are of particular concern for humans. These optical brighteners possibly cause reproductive and developmental problems. Synthetic ingredients in optical brighteners can cause skin sensitivity and allergic reactions as well. One of the most important things for those suffering from eczema is finding a good laundry detergent. Ironically, eczema can be caused by some detergents, so the last thing you need is something to irritate the condition even more. Watch out for laundry detergents that contain enzymes, because they can by highly irritating to eczema. Body lice, unlike head lice however, live in clothing and lay their eggs (nits) on cloth fibres. Body lice move from clothing to the skin surface to feed. Because body lice eggs are attached to clothing, these lice are generally not a concern where clothes are routinely washed. Severe outbreaks of body lice, and associated louse-borne diseases, have historically occurred during wars, in prisons, on crowded ships, and under similar crowded and unsanitary situations but are less common today. While

Fig.3 women washing clothes manually

These chemicals may not be on the label, recent studies show many of them to be proven cancer causing toxins. They build up in your skin, and may cause serious health problems like asthma, allergies, and even cause cancer. The chemicals in laundry detergents can irritate skin, eyes and the respiratory system; disrupt hormones; and cause allergies, according to SixWise.com. Some, such as naphthas, have been linked to cancer.

In December 2011, over 300 million Indian citizens had no access to electricity. Over one third of India's rural population lacked electricity, as did 6% of the urban population. Of those who did have access to electricity in India, the supply was intermittent and unreliable. The per capita average annual domestic electricity consumption in India in 2009 was 96 kWh in rural areas and 288 kWh in urban areas for those with access to electricity, in contrast to the worldwide per capita annual average of 2600 kWh and 6200 kWh in the European Union.

India currently suffers from a major shortage of electricity generation capacity, even though it is the world's fourth largest energy consumer after United States, China and Russia. Expanding access to energy means including 2.4 billion people: 1.4 billion that still has no access to electricity (87% of whom live in the rural areas) and 1 billion that only has access to unreliable electricity networks. We need smart and practical approaches. Despite an ambitious rural electrification program, some 400 million Indians lose electricity access during blackouts. While 80% of Indian villages have at least an electricity line, just 52.5% of rural households have access to electricity. In urban areas, the access to electricity is 93.1% in 2008. The overall electrification rate in India is 64.5% while 35.5% of the population still live without access to electricity. Despite the efforts of the state and the central government, nearly 40% of Orissa villages are yet to be electrified. People in these villages will consider themselves fortunate if they could see a spark of electricity even at the end of this five-year plan. According to the data available in the Central electricity Authority (CEA), out of 47,529 inhabited villages, 28,871 or around 60% villages were electrified by the end of 2008-09.

In Jajpur, Puri, Jharsuguda, Balasore, Bargarh, Cuttack and Jagatsinghpur are leading districts to electrify more than 90% of their villages. On the other hand, the Naxal-affected Malkangiri is placed at the bottom of the list with only 6% of its villages are electrified. Koraput, Raygada, Boudh, Kandhamal and Nabarangpur are the other districts with only less than 20% of their villages have been electrified.

A pedal-powered washing machine would allow women to wash clothes faster and with less strain. When asked what they would do with their free time, women said that they would try to generate income by making crafts or food to sell. Young daughters who help their mothers with domestic chores may also have the opportunity to concentrate more on their studies. Conditions vary in developing countries, but women in many regions are washing clothes manually while they could be doing more profitable or rewarding work elsewhere.

1.4. General Design Specifications

The most important aspect in the design of the machine is its ability to perform as a device that eases the task of washing clothes. In order to be a viable solution in rural areas, the machine should be able to deliver the same quality of washing without adding excessive overheads (in terms of water use, clothing wear, effort required to operate, etc.). Thus the design and operation of the machine should be firmly grounded in the physics of clothes washing, with a special emphasis on the mechanical aspects (since water temperature and detergent composition are likely to vary).We also identified a number of secondary goals with varying degrees of importance that could help make the machine more useful and thus more successful. The ability to spin-dry clothes would increase water economy by requiring fewer wash cycles, and could relieve the strenuous task of manually wringing the clothes before they are hung to dry. If the layout of the machine allowed the user to perform manual work (hand-craft, food preparation, etc.) while pedalling, we could further reduce the amount of time consumed by washing. A number of safety features should also to be included in order to mitigate the inherent safety issues involved in a chain-driven machine. If the machine was to be used in a home, insuring its portability of would allow it to be shared among families, transported close to a water source for operation, or used in households where space is limited. Another set of specifications for load sizing, water usage and pricing, depend on the targeted community. Since we are expecting the amount of laundry to vary between families, an initial size was selected based on existing washing machines, and designs allowing for easy re-sizing were preferred.

- **Cleaning**: Machine-washed clothes must be as clean as those hand-washed for 5 minutes
- **Gentleness**: Must wear clothes at slower rate than hand-washing [hole/tear growth]
- **Capacity:** Minimum 5lb of clothes/load – should be easy to re-size.
- **Water**: Effective washing must occur in soft and hard water at temperatures from 70-120_F
- **Water usage**: Maximum 15L water / 1kg clothes
- **Active pedalling time for effective washing**: Maximum 20 minutes each for wash and rinse cycles
- **Total operation time**: Maximum 3 hours, including fetching water, filling, washing, draining, and cleaning machine
- **Power**: Maximum 100W (comfortable level of human-power output)
- **Cost**: Maximum $150 (comparable to cost of other MP machine)
- **Lifetime of structure**: 5 years, assuming daily use
- **Manufacturing location**: local market
- **Materials**: local (wood, wieldable metals, oil drum, bicycle parts, etc.)
- **Dimensions**: [less than combined size of a bicycle and commercial washing machine]
- **Weight**: Maximum 30kg, or 45kg if it has wheels (1 woman can move it indoors so it cant be stolen or damaged).
- **Culturally acceptable**: Suitable appearance, user position and motion such that most women are willing to use the machine.[1]

2. Development of concept of manually driven pedal powered washing machine

2.1 Prior Art

There are existing solutions to the clothes washing problem, but no existing technology is both practical and affordable for people in our target community. Existing solutions are either designed for industrialized nations with running water and electricity, or they are not practical for rural setting where replacement parts are difficult to find. Commercial washing machines have existed for many years, but they are expensive and require electricity to operate. Sometimes, they are available in urban settings, but the average family cannot afford to purchase one. In rural areas, commercial washing machines are not an option because electricity may be unavailable or extremely expensive. A number of groups have modified commercial washing machines to power them with human power. They attached a pedal-drive mechanism to the washing machine drum and attached a suspension system. This technique is not feasible in rural areas of developing nations because washing machines and their old components are usually difficult to find.

Commercial hand-cranked washing machines do exist, but they are not intended for continuous use; they are designed for travelling or camping trips. Price and its use will be limited by the lack of replacement parts.

In the past, some attempted to make a pedal-powered washing machine from locally available materials, but it was unsuccessful. They built a prototype with a vertical axis agitator, but it did not wash clothes well, it did not have spin dry capability and it consumed a great deal of water. Although it recognizes the demand for pedal-powered washing machine, it does not have the resources or time to design prototyping and refine a new device.

2.2 Probable Design Alternatives

The team evaluated a number of mechanisms that could serve as the basis for the washing machine. Initial concepts were developed starting from the mechanical requirements of laundry washing, with inspiration drawn from existing and historical washing machines.

2.2.1. Vertical-Axis Agitator: The usual washing machine found in American homes consists of two vertical-axis concentric tubs. The inner tub, which holds the clothes, has densely-spaced perforations which allow the water to run in and out easily. Soap and water are kept inside the outer tub during the wash cycle. A central agitator alternating directions induces friction between the clothes to mechanically remove dirt and stains. For the spin cycle, water is emptied from the outer drum and the inner drum is spun to centrifugally extract water from the clothes.

Fig. 4 vertical axis agitator

2.2.2. Horizontal-Axis Tumbler: Commonly used in European homes, this washer also uses two concentric tubs; however their revolution axis is horizontal.

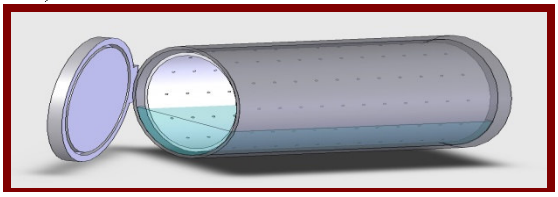

Fig.5 Horizontal axis tumbler

Instead of using an agitator, the horizontal washer utilizes fins along the inner barrel that lift the clothes on the side of the drum, and let them fall back in the water on top of other clothes. Cycling the clothes through the water in this fashion eliminates the need for rapid changes in the direction of rotation of the agitator, which results in lower energy requirements. Since the drum is only filled up to one third with water, the machine realizes a sizeable water economy.

2.2.3. Tilted-axis Tumbler: A tub spinning at a inclined axis using a helical fin would perform the same kind of action, in a fashion similar to a cement mixer.

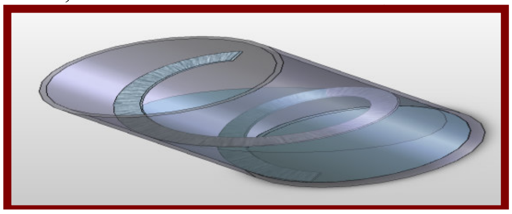

Fig.6 Tilted axis tumbler

The tilted design (fig.2.3) would allow for easier addition of water and clothes. No known commercial washers use this mechanism. Manufacturing of the helical fin proved to be problematic, and the other construction benefits we were hoping for in the tilted axis design did not end up materializing themselves. No conclusive cleaning experiments were performed using this design.

3. Final Design of washing machine

Our final design resembles a commercially available horizontal axis washer. The inner drum which holds the clothes is currently constructed by modifying a plastic utility tub. Tubs like these are widely available at scrapper, but could easily be substituted for other types of buckets, perforated sheet metal or mesh, depending on availability.

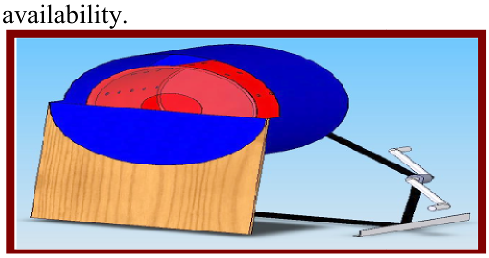

Fig.7 Basic design

The inner drum is perforated, so that spinning the drum will extract water from the garments. There are also three triangular fins inside the inner drum that agitate the clothes during the wash cycle. The main structure of the machine consists of a simple tube frame. The frame can be built by modifying an existing bicycle frame. The inner drum is mounted on one side of a pedal shaft. Rotational force turns the drum via a drive gear attached to the opposite side of the pedal shaft. A bicycle chain connects the gear at the drum to a set of pedals mounted on the frame. The operator loads and unloads clothing from the inner drum through a cut out on the side of the outer barrel. The operator drains the soapy water and rinse water by opening a drain value at the bottom of the barrel. The operator can use her hands to do manual work like weaving while pedalling the machine. Women expressed interest in this particular feature.

Fig.8 Pedal powered washing machine

3.1. Three dimensional design in CATIA

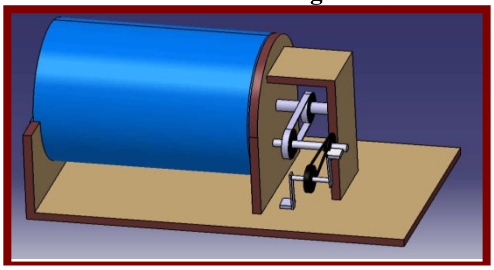

Fig.9showing power transmission

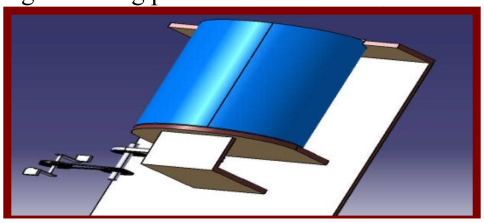

Fig.10 top view

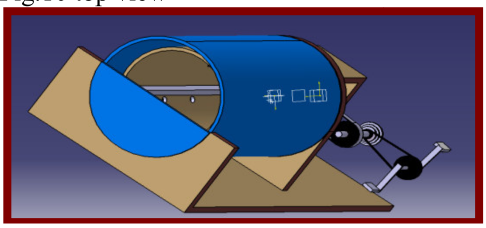

Fig.11 showing inner side of drum

3.2. Analysis

3.2.1. Gearing

The machine uses a regular mountain bicycle transmission which can provide different gear ratios. The user is expected to turn the pedals of the machine at about 60 rpm for the wash cycle, and a higher 110 rpm during the dry cycle, where the lack of resistance from water makes pedalling easier (continuous pedalling is not necessary in this case). With a inner drum diameter of 36c.m., pedalling at 60rpm results in a angular acceleration on the clothing of about 14.4 s^{-2}, which results in efficient clothing tumbling. For the spin cycle, the user would switch to the highest available gear, and a pedal speed of 100 rpm results in an acceleration of 52.88 s^{-2}. This has been shown to extract 50% of the water from wet cotton clothing (remaining water weight in clothing is approximately 90% of the dry fabric weight -comparable to commercial vertical axis washing machines).

3.2.2. Water usage

The diameter of the outer tub is 52 cm and length 50 cm. Our machine is not optimally efficient in terms of water use, since the plastic construction of the inner drum required larger clearance between the two tubs in order to prevent contact during the spin cycle. The front of the outer drum also extends considerably past the front of the inner drum to provide easy access for clothes. With approximately 1/3 of the capacity of the outer drum filled with water, the machine requires about 35l of water. Half of the total water usage for one load of laundry is used for the wash cycle, while the other half is used for the first rinse cycle. The water from the second rinse cycle, containing just soap, can be reused for washing the next laundry load. We expect that clever design would allow for sizeable reduction in the water requirement in the next prototype.

3.2.3. Cost

The majority of the cost of the initial prototype is found in the price of the outer barrel, bicycle parts and carpenter work. We are expecting however that almost all machines would be constructed from re-used barrels, such that the cost would not be prohibitive. However, like other, our machine does not require sacrificing a useful bicycle, and can be constructed from a bicycle which is no longer useful in a transportation role. The drive train, which is the main part of the bicycle used in our design, is usually much more resilient and remains functional after the frame; fork or wheels of the bicycle have exceeded their lifetime. Taking all these factors into account, the maximum component price for the washing machine is estimated to be around Rs 9000, but expected to be considerably less if the outer drum and bicycle parts can be acquired used. The manufacturing cost can has not been determined since an optimum assembling sequence has not been identified.

4. Results and Discussion

Most of the components being proposed for physical demonstration of the concepts are taken from different parts of different similar types of articles like washing machine, bicycle, oil drum .So no load related calculation ate shown for their design. It is assumed that all of these components will work satisfactorily in the physical demonstration of this concept.

4.1 Bill of material

Note: the cost estimation cannot be done with 100% certainty because price of different material used in the washing machine are highly fluctuating. In this work, a rough estimation of the cost is being reported on the basis of market survey done in the month of March and April in 2012. Approximate cost of different components are shown in table 1

Table-1 List of items

S.NO.	Name of the item	Quantity	Estimated cost (Rs.)
1.	Wooden board	2	1000
2.	Drum & jar	1each	1500
3.	Aluminium plate	1	300
4.	Two nylon bush & shaft	2each	500
5.	Iron pipe & stand	1 each	300
6.	Cycle frame	1	1200
7.	Gear set	1	1000
8.	Pedal crank	1	100
9.	Chain set	2	200
10.	2 flywheel	2	200
11.	3 triangular wooden fins	3	100
12.	Wooden screw & nut bolts	As per need	200
13.	Fevi-quick	1	200
14.	Pipe, socket, & bracket		200
	Total cost		Rs. 7000/-

Table-2 Different parameters of model

S. No.	Parameter	Dimension
1	Inner drum diameter	36cm
2	Outer drum diameter	52cm
3	Length of inner drum	37cm
4	Length of outer drum	50cm
5	Height of shaft	39cm
6	Distance between shaft and cycle	50 cm
7	Height of base above ground	6 cm
8	Length of base	93 cm
9	Width of base	67 cm
10	Height of seat	80 cm
11	Height of handle	76cm
12	Total volume of outer drum	106L
13	Total volume of inner drum	37.6L

4.3. Ease of Use

Washing machine will be easy to use by younger and older women. After loading the machine, washing requires three cycles. Between each cycle, the drum spins quickly to draw the water out of the clothing, as it drains out of the drum. In the first cycle, water and detergent are added to the drum. The operator pedals the machine for roughly 25 minutes, spins, and drains the water. The next two cycles are rinse cycles. In each rinse cycle, the operator pours clean water into the machine, pedals for 10 minutes, spins, drains the drum. After the last rinse cycle, the operator spins the clothes dry and saves the slightly soapy water for the next wash cycle. Our research into existing washers and our earlier prototypes indicate that the power required for washing and spinning is relatively low. We demonstrated that it is not difficult to spin a perforated plastic drum up to extraction speeds with clothes inside. For these experiments, we used a geared transmission from a bicycle. Both younger and older women can generate enough power for the wash and spin cycles. We estimate this power to be 50-75 watts. While familiarity with pedalling in general and the machine in particular will reduce the effort expended by the user, no prior experience will be necessary for its operation. The ability to change gearing ratios will allow some level of tuning to individual users and also allow for shorter wash times with more power input or conversely less strenuous operation if the user can pedal for a longer amount of time.

4.4. Advantages

4.4.1. Efficiency: It is much more efficient to wash clothes using the pedal washing machine than to use the manual washing tanks. The machine washes and dries many clothes concurrently whereas each item must be washed individually in the wash tank. It also requires less energy when compared to vertical axis washing machines. The horizontal axis of rotation in the washing machine uses less power because it rotates continuously without changing directions. The operator does not need to combat the momentum and drag forces of a barrel full of water. The washing machine is also more comfortable to use than the washing tanks. The operator does not need to lean over the washing tank and submerge her hands in the soapy water. Instead, the operator sits on the washing machine's seat and pedals most of the time. She only needs get up to load the machine, change the water and unload the machine. This leaves her hands free to work on making crafts and keeps them out of the harmful detergent.

4.4.2. Affordability: A natural location to install a Washing machine is at the public washing stations. The women already use the washing stations and they will be able to share the washing machine among the entire community. With a common washing machine, an individual family will not need spend a large sum of money for a home washing machine. Those who would not normally be able to afford such a device would be able to use one for free or for a small fee. A Washing machine is also inexpensive to operate because the user does not need to pay for power. This is especially important in places where electricity is extremely expensive. We have minimized the use of other materials like angle iron and wood to reduce the cost to the end customer.

4.4.3. Easy to Build and Maintain: Unlike any of the other alternatives, the Washing machine uses locally available materials or recycled bicycle parts. It can be produced in any area that has prevalent bicycle technology and things like plastic buckets. Since the parts are widely available, the Washing machine can serve as a basis for local entrepreneurs to start micro-enterprises which would stimulate the local economy. Another advantage of using locally available parts is that the Washing machine is easy to repair. It is mechanically simple enough that any bicycle repair shop would be able to service the pedal-drive.

4.5. Testing

This machine Work tested the concept by washing 4 T-Shirts and 2 Capris constituting the weight of dry cloth approximately 2Kg. The detergent used was one of the commonly recommended detergents for washing machine. We use the water approximately 35L. The washing time was 15 min after that the detergent was drained out through gravity and fresh water used to rinsed the cloth. Then clothes are dried by draining out the absorbed water for this purpose there is a need to pedal the machine at higher rpm. The capability of machine to dry out the clothes depends upon rpm. So the extent of dryness is not better than the manual squeezing of the clothes. The total washing time observed approximately 30mins. After completion of the washing cycle clothes were observed satisfactory clean. The whole exercise is equivalent to doing cycling for a period of 30min at speed of 20km/hr.

5. Conclusion

The machine must be inexpensive and easy to build if it will be adopted into the community. We recognized this need and designed the machine from the start with low cost in mind. The machine will only contain parts that are readily available in rural areas. This eliminates the need to order or import components just for the washing machine. The machine also uses bicycle parts for all the precision parts. These parts are very inexpensive because rural areas have a surplus of unused bicycle parts. The pedal-powered washing machine is quite different from the community's current method of washing clothes; the community may be reluctant to try the new machine. To help encourage the adoption of the washing machine, we will run multiple trials with local women so we can adjust the design to meet their needs. We will run the trial periods with groups like the women's cooperative who are already familiar with pedal powered machines; they have already proved they are willing to try new technologies. If women in the cooperative accept and use the machines, then they will serve as spokes-people for the new machine in their local community. Their support will greatly increase the credibility of the machine so that local people will be willing to try it. We achieved what we desired i.e. to build a manually driven pedal powered low cost washing machine using locally available materials and performing necessary function of washing and rinsing with ease. Our washing machine doesn't consume electricity. The washing machine can be used by the urban people also while workout and exercises. It can serve dual purposes. While cycling, the clothes can be washed utilizing the pedalling of the human being. If the production of this washing machine is done at commercial scale then the total production cost of the machine can be reduced to 40% of estimated cost.

6. Scope for further improvement

Use of chair in place of cycle frame: For making washing of clothes more comfortable, the cycle frame can be replaced with a chair. Use of chair will be more convenient for women.

- **Use of Back Wheel of Bike:** The required rotation speeds during the wash cycle are not especially high. The aim is to agitate the fibers in the cloths and work the water fully into and through the fabric. This is done by tumbling the clothes within the drum and if the speed was too high the clothes would remain static pressed against the side of the drum by centrifugal forces. On the other hand, this is exactly what's needed during the spin cycle in order to drive out the water. A cyclist typically cranks the pedals at about 50 to 100 RPM. The highest gearing ratio on a typical bike is about 3:1 (eg. 52 teeth to 14 teeth). If we want spin speeds of 1,000 rpm then we'll require the final gearing ratio be closer to 20:1. We'll achieve that by using the back wheel of the bike as a massive pulley (26 or 27 inches in diameter). We'll then use a large fan belt to drive a smaller pulley which will be connected to the drum via the two universal joints. If our final pulley is 3 inches in diameter then the wheel to pulley ratio is about 9:1 and the total gearing about 27:1! A larger pulley would make more sense, perhaps closer to 5" for a final ration of about 15:1.
- **Double Supported Inner Barrel**: The inner barrel will be supported at both ends fixed to a rotating shaft. Since the first prototype had one open end to allow for side-loading, alternative loading mechanisms must be designed. One option is to have a trap door in both the inner and outer barrels. Another is to make one of the supports for the inner barrel movable so that the inner barrel can still be opened and accessed from the side.
- **Welded steel structure**: To reduce the assembly time and prevent others from tampering with it in public areas, the structure will be made out of welded angle iron. Welding fixtures may be designed to make it easier to weld several structures with proper alignment of components. The welded structure will add to the weight of the machine, making it inherently less likely to vibrate. The steel structure may also be cemented into the ground to ensure stability and security of the machine from theft.
- **Different Materials for Outer Barrel:** We are considering using a steel oil drum so it can be welded directly to the structure. Welded attachment points would not require any bolt holes that need to be sealed. The oil drum may also be shortened by cutting off the end, and welding on a steel lid. Steel would also be more rigid than the plastic drum we used for the initial prototype, so it would be easier to align the barrels and avoid collisions during rotation. We are also considering using a cement basin that has the structure incorporated into it. This would make the machine much easier to manufacture because most of the machine would be a single intact piece.
- Steering Column or Industrial Bearings: Since our washing machine does not currently have a use for the steering columns they receive, it would nice to incorporate it into the washing machine design so the component would not go to waste. If we find that bicycle bearings are not suitable to support the load, we may use industrial bearings with greater tolerances and load capacities.
- **Extend Barrels Axially**: We are assuming that extending the barrel axially will not greatly increase the effort that must be exerted to rotate the barrel. Having longer barrels would increase the capacity of the machine and the amount of clothes that may be washed at one time. There are possibilities for dividing the outer barrel so that there are two compartments, which would allow for washing to occur on one side and rising occurring on the other with the same shaft rotating two separate inner barrels.

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