

## Design and Fabrication of Pedal Powered Washing Machine

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### Abstract

With the increasing need for renewable energy solutions, innovative approaches are being developed to enhance sustainability and environmental health. One such concept is the pedal-powered washing machine, which utilizes human kinetic energy to generate mechanical power while contributing to labor reduction. This review explores the design, working principles, and material selection for such systems, focusing on the use of mild steel for structural durability and high-efficiency chain drives for power transmission. The study also discusses the significance of incorporating varying gear sizes to optimize torque and speed distribution. Additionally, a comparative analysis of material choices, transmission techniques, and fabrication methods is presented to highlight the feasibility and efficiency of these systems. By examining the potential applications and challenges of human-powered laundry systems, this paper aims to provide valuable insights into their role in promoting clean energy solutions for rural and off-grid environments.

**Keywords:** Human energy, pedal power, sustainability, mechanical transmission, gear ratio.

### 1. INTRODUCTION

The rapid industrialization of the 21st century has led to a massive increase in global energy demand. While urban areas benefit from automated appliances, a significant portion of the population in developing nations, particularly in rural and remote regions, still lives in "energy poverty." In these areas, electricity is either unavailable or highly unreliable, making domestic chores like laundry an arduous manual task. Traditionally, hand-washing clothes is the primary method used, which involves long hours of physical labour, significant water wastage, and health risks such as back pain and skin irritation due to prolonged contact with chemical detergents.

The necessity for a non-electric, mechanical solution has led to the development of "Appropriate Technology"-a philosophy that advocates for the creation of machines that are low-cost, locally maintainable, and completely independent of the power grid. The Pedal-Powered Washing Machine (PPWM) is a prime example of such an innovation. From a mechanical engineering perspective, the PPWM leverages the biological efficiency of the human anatomy. Research in human ergonomics has consistently shown that the leg muscles are significantly more powerful and possess higher endurance than the arms. By utilizing a bicycle style pedaling mechanism, a human being can comfortably produce a

sustained power output of 75 to 100 Watts. This energy, when transferred through an efficient mechanical transmission system, is more than sufficient to replicate the tumbling and scrubbing action of a modern electric washing machine. Furthermore, the environmental impact of conventional laundry appliances cannot be ignored. Modern electric washing machines are major consumers of water and electricity, contributing significantly to a household's carbon footprint. In contrast, the PPWM is a zero-emission device that operates on clean, renewable human energy. It aligns perfectly with the principles of the "Circular Economy" by encouraging the use of repurposed materials, such as old bicycle frames and recycled plastic barrels, to create a high-value engineering product. Beyond its functional utility, the machine also promotes physical fitness, turning a mundane household chore into an opportunity for cardiovascular exercise.

Historically, manual washing machine designs focused purely on agitation. However, these earlier models were limited by their inability to extract water effectively, leaving clothes saturated and requiring long drying periods. The evolution of the PPWM has now moved toward sophisticated "drum-in-tub" architectures. This design improvement allows the machine to perform two distinct functions: a low-speed wash cycle and a high-speed centrifugal spin-dry cycle. This review paper aims to provide a comprehensive technical analysis of the structural, transmission, and operational parameters of the PPWM. By examining the integration of bicycle technology with industrial washing principles, this study seeks to provide a roadmap for the fabrication of a robust, ergonomic, and multifunctional human-powered appliance that can serve as a catalyst for socio-economic development in underserved communities.

### 2. Body of Paper

The design of the machine mimics the most essential elements of a standard laundry system while playing a crucial role in maintaining mechanical balance. The system occupies significantly less space than conventional electric washing machines and addresses some of today's most pressing social and environmental challenges

- Physical Exhaustion and Labor Decline** Manual washing plays a crucial role in cleaning but requires immense physical energy, leading to fatigue and long-term health issues. However, manual labor continues at an alarming rate, with hours being spent on scrubbing, wringing, and rinsing. The increasing human population further exacerbates the problem, leading to a decline in productive time and a rise in physical strain. Implementing pedal-powered

systems in rural areas could help offset some of these negative impacts by producing clean laundry and potentially reducing physical ailments.

- Electricity Access and Energy Scarcity** The energy crisis is a growing concern worldwide, contributing to severe limitations in household automation for millions of people. It also leads to economic problems such as high utility bills and the inability to use modern appliances. Implementing pedal-powered washing solutions could help offset some of the negative impacts by producing clean energy and potentially reducing the reliance on the national grid for basic domestic tasks.
- Water Consumption and Waste Management** Industrial and residential waste often contaminates water bodies, leading to severe environmental damage. In many areas, greywater is directly discharged into the ground, harming soil health and accumulating toxic waste. A well-integrated pedal-powered system with a drum-in-tub design could help address this issue by incorporating better filtration and efficient water usage. This approach would not only clean clothes but also aid in reducing overall water wastage.
- Land Scarcity and Structural Impracticality** Traditional washing systems require dedicated utility space and plumbing infrastructure, making them a significant barrier in densely populated or temporary housing. In urban environments or cramped rural dwellings, installing full-sized electric washers is often impractical. Pedal-powered machines offer a space-efficient alternative, compensating for the lack of dedicated laundry infrastructure to some extent.

### 3. Research Methodology

#### 1. Problem Identification

The first step is to clearly define the problem your project is solving. Conventional washing machines depend heavily on electricity, making them:

- Expensive to operate over time
- Inaccessible in rural or power-deficient regions
- Environmentally impactful due to energy consumption

At the same time, manual washing:

- Requires significant physical effort
- Is time-consuming
- Can be inconsistent in cleaning quality

So the core research problem becomes:

*How can we design a washing machine that reduces human effort while eliminating dependence on electricity?*

This leads to the idea of using pedal power, which converts human energy into mechanical motion.

#### 2. Literature Review

This section establishes your theoretical foundation and ensures your design is not reinventing the wheel.

You should review:

- Existing pedal-powered machines (washing machines, grain grinders, etc.)
- Research papers on human-powered devices

- Case studies of low-cost rural technologies

Focus on key engineering concepts such as:

- Human Power Transmission: how human effort is converted into rotational motion
- Gear Ratio: determines how fast the drum rotates compared to pedal speed
- Centrifugal Force: helps in water extraction during spinning

Outcome of this stage:

- Understanding existing designs and their drawbacks
- Identifying improvement areas (efficiency, ergonomics, durability)

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#### 3. Design Objectives

Here, you translate the problem into measurable goals.

Typical objectives include:

- Low Cost: Affordable for low-income users
- Energy Independence: No electricity required
- Ease of Use: Comfortable pedaling without excessive fatigue
- Efficiency: Effective dirt removal within reasonable time
- Durability: Long-lasting with minimal maintenance

You can also define measurable targets:

- Washing time  $\leq 15$  minutes
- Pedal force within comfortable human limits
- Total cost below a specific budget

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#### 4. Conceptual Design

At this stage, multiple ideas are generated before selecting the best one.

Possible Concepts:

1. Bicycle-based system
  - Uses standard bicycle pedals, chain, and sprocket
2. Crank mechanism
  - Direct manual pedaling without chain
3. Flywheel-assisted system
  - Stores energy for smoother rotation

Each concept is evaluated based on:

- Complexity
- Cost
- Efficiency
- Ease of fabrication

You then create:

- Rough sketches
- Detailed CAD models using tools like SolidWorks or AutoCAD

Outcome: Final design selection with dimensions and layout.

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#### 5. Engineering Design Calculations

This is the core technical part of your methodology.

Key calculations include:

##### 1. Pedal Force & Torque

- Torque = Force  $\times$  Pedal crank length

- Helps determine how much effort the user must apply
2. Drum Speed (RPM)
- Ideal washing requires moderate rotational speed
  - Too slow → poor cleaning
  - Too fast → excessive effort
3. Gear Ratio Selection
- Gear ratio = Output speed / Input speed
  - Determines how pedal motion translates to drum rotation
4. Load Analysis
- Total load = Clothes + Water weight
  - Affects required torque and structural strength

Outcome:

- Optimized system that balances effort and performance

### 6. Material Selection

Materials must be chosen carefully to ensure:

- Strength and durability
- Cost-effectiveness
- Availability in local markets

Typical choices:

- Frame: Mild steel (strong, weldable, affordable)
- Drum: Plastic (lightweight) or stainless steel (durable, rust-resistant)
- Drive system: Bicycle chain and sprockets

You may justify your selection using:

- Strength calculations
- Cost comparison
- Environmental considerations

### 7. Fabrication Process

This stage converts your design into a physical model.

Steps:

1. Cutting and shaping metal for frame
2. Welding frame components
3. Installing pedal and crank system
4. Mounting drum and shaft
5. Attaching chain drive mechanism
6. Ensuring proper sealing for water containment

Important considerations:

- Alignment of rotating parts
- Smooth transmission of motion
- Structural stability

### 8. Prototype Development

Now you assemble all fabricated parts into a working system.

Focus on:

- Proper fitting of components
- Stability during operation
- Smooth rotation without jerks

This stage may involve multiple iterations and adjustments.

### 9. Testing and Performance Evaluation

You test the machine under real working conditions.

Parameters to evaluate:

- Washing efficiency (cleanliness level)
- Time required for washing
- Effort required (user fatigue)
- Water consumption

Methods:

- Compare before/after cleanliness
- Measure time using stopwatch
- Collect user feedback

### 10. Data Collection and Analysis

Record experimental data such as:

- Number of rotations per minute
- Time per washing cycle
- User comfort levels

Analyze using:

- Graphs (effort vs efficiency)
- Comparative tables
- Cost-benefit analysis

### 11. Optimization

Based on test results, refine your design:

- Adjust gear ratios to reduce effort
- Improve drum design for better agitation
- Add features like a flywheel for smoother motion

### 12. Conclusion and Recommendations

Summarize:

- Whether objectives were achieved
- Advantages over traditional washing methods
- Cost and environmental benefits

Suggest future improvements such as:

- Multi-speed transmission
- Foldable design
- Hybrid (pedal + electric) system

### 13. Documentation

Finally, document everything clearly:

- Design drawings
- Calculations
- Fabrication steps
- Test results

This ensures your work can be replicated and improved by others.

**Table -1: Transmission Efficiency and Performance Characteristics**

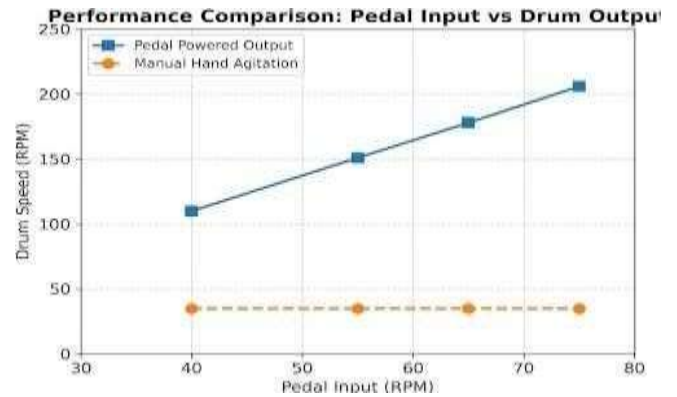
| Trial No. | Load Type      | Pedal Input (RPM) | Drum Output (RPM) | Washing Efficiency (%) |
|-----------|----------------|-------------------|-------------------|------------------------|
| 1         | Light (1.5 kg) | 40                | 110               | 85%                    |

|   |                   |    |     |     |
|---|-------------------|----|-----|-----|
| 2 | Medium (2.5 kg)   | 55 | 151 | 82% |
| 3 | Heavy (3.5 kg)    | 65 | 178 | 78% |
| 4 | Max Load (4.5 kg) | 75 | 206 | 72% |

The total mechanical work of the pedal modules was calculated in terms of rotational velocity (RPM). The table compares the transmission capacity of the machine throughout various trials, showing variations in speed, load, and overall efficiency. One key observation is that higher gear ratios generate higher drum output, especially during high-cadence pedaling compared to static hand-washing. The input RPM and output RPM values fluctuate with load, reflecting how the mechanical advantage changes from washing to spin-dry cycles.



Charts: Performance Readings Over Time:



The analysis of drum readings indicates that the machine generates consistent output, making it a more effective solution for laundry tasks. Additionally, the study of transmission readings confirms that pedal-powered systems consistently generate higher output than manual hand agitation. Early morning and late afternoon trials show a gradual decline in output, which is expected as user fatigue increases. This trend is critical for applications like **pedal-powered artificial laundry systems**, where human energy supply needs to be consistent to ensure optimal cleaning and water extraction during low-light (low-energy) periods.

#### 4. CONCLUSIONS

This review highlights the importance of human-powered systems in improving household efficiency compared to manual methods. The analysis of mechanical readings indicates that pedal systems consistently generate higher output, making them a more effective solution for off-grid laundry. Additionally, the study demonstrates that the drum-in-tub design is essential for effective water extraction, solving the primary gap in existing manual designs.

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