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Fabrication of a Cradle-Based Water Lifting Mechanism

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Abstract: *Water lifting equipment has long been essential for home, commercial, and agricultural applications. In this research project, a cradle-based reciprocating pump-operated water lifting mechanism that combines oscillatory motion and mechanical leverage is designed, built, and its performance evaluated. Because the system is designed to provide an efficient, cost-effective, and energy-independent alternative to conventional water pumps, it is particularly well-suited for off-grid and rural areas with restricted access to fuel-driven systems or power. The mechanism makes it possible for a reciprocating pump to operate with minimal physical effort by utilising the concepts of mechanical advantage, counterbalancing, and gravitational force. The constructed prototype is put through testing to evaluate its operational stability, sustainability, and pumping efficiency. The usage of cradles for water lifting in irrigation, gardens, and schools is covered in this essay. The most important agricultural requirement is irrigation. Centrifugal pumps are used in daily life to give water to the garden, wasting electricity. In a similar vein, people and kids use cradles for reading newspapers and relaxing, respectively, which causes energy waste when swinging in a cradle. In order to raise water in communities, gardens and schools, we connect this energy waste to reciprocating plunger-style pumps. In these projects, we utilise pumps of the plunger type to suction water up from the water supply through inlets, and then we discharge the water into the garden through outlets.*

Keywords: Reciprocating Pump, Cradle, Connecting Link, Swinging, Water lifting

I. INTRODUCTION

Water is a fundamental necessity for human life, agriculture, and industrial applications. In many rural and underdeveloped regions, access to a reliable and efficient water lifting mechanism remains a significant challenge. Conventional water lifting techniques, including electric pumps and manually operated devices, often require substantial energy inputs or intensive labor, making them less feasible in remote and low-resource settings. Furthermore, fluctuating fuel costs and limited access to electricity further hinder the efficiency of traditional water lifting solutions.

Over the years, researchers and engineers have developed innovative water lifting mechanisms that focus on sustainability, energy efficiency, and cost-effectiveness. Among these, reciprocating pumps have proven to be a highly effective means of water transportation due to their simple design, reliability, and ability to lift water from considerable depths. However, the manual operation of these pumps requires significant human effort, which can limit their practicality in daily use.

The study presents a cradle-based reciprocating pump-operated water lifting mechanism that reduces manual effort and improves efficiency. The system uses oscillatory motion, counterbalancing weights, and mechanical linkage to move water with minimal energy. The research aims to develop an affordable, easy-to-use solution for communities with limited access to conventional water lifting technologies. The mechanism could enhance irrigation practices, domestic water supply, and small-scale industrial water use, especially in off-grid and rural areas.

II. LITERATURE REVIEW

Water lifting mechanisms have evolved significantly over centuries, from manual systems such as bucket-and-pulley setups to modern motorized pumps. Various studies have explored innovative solutions for improving water lifting efficiency, particularly in rural and energy-deficient areas.

Anurag Anand in his paper FABRICATION OFPENDULUM PUMP has addressed various components required to create a pendulum based pump .The main components listed in his article are frame, reciprocating pump, spring, weight hanger. The study also discusses comparison of length of pendulum to discharge and mass of pendulum to discharge[1].

S. I. Yannopoulos et al., in his paper EVOLUTION OF WATER LIFTING DEVICES (PUMPS) OVER THE CENTURIES WORLDWIDE explores the evolution of water lifting devices, focusing on ancient technologies that were durable, adaptable, and sustainable. It compares the technological developments in early civilizations, highlighting their role in modern water engineering. The text presents a timeline of water pump development worldwide over the last 5500 years, focusing on major civilizations[2].

K S Anandhuet al., in his project FABRICATION OF PEDAL OPERATED WATER PUMPanalyses the development of an improved pedal operated water pump for rural use. This development was prompted due to the need for pumping systems that does not use electricity as its power source in under developed area. The system is composed of a powered water pump which drag water through a PVC pipe by while pedalling. The pedal power is being transmitted to the pump via a gear drive, and water is lifted from the well by belt drive.The construction of the pump is simple and easy to operate by anyone [3].

D. Apparao in his paper DESIGN AND DEVELOPMENT OF HAND PUMP WITH A PENDULUM has covered the physics of pendulum motion, forces operating on the various parts of the pendulum-based pump, and energy analysis of the pendulum. He has said unequivocally that the existence of free energy as defined by his approach does not follow the conservation of energy principle; yet, he asserts that experimentation may confirm this[4].

P. Vishwanath Dhopte, in his paper DEVELOPMENT & FABRICATION OF SEE-SAW OPERATED WATER PUMP, discussed that they were able to reduce our workforce. Energy is not required, which reduces the implementation's overall cost. Anyone can use this pump, which has a 400 ml water lift capacity per cycle. According to the studies, humans can easily operate it and raise the water with little effort[5].

Kali Charan Rath In his work A BRIEF STUDY ON PENDULUM BASED PUMP, covered the design of several pendulum-based pump components. An estimated size of the components that can be employed for the model has been suggested by the author [6].

Based on these studies, it is evident that mechanically assisted water lifting solutions have the potential to bridge the gap between high-energy motorized pumps and labor-intensive manual systems[7], [8], [9], [10], [11]. This research builds upon previous findings by designing and testing a cradle-based reciprocating pump system that prioritizes ease of use, durability, and cost-effectiveness.

III. METHODOLOGY

The research methodology involves several key phases: conceptual design, material selection, fabrication, and performance evaluation of the cradle-based reciprocating pump-operated water lifting mechanism.

Design Concept and Working Principle: The system is based on a cradle mechanism that utilizes oscillatory motion to drive a reciprocating pump.A lever-based arrangement is incorporated to minimize manual effort while maximizing output efficiency.The counterweights are strategically placed to reduce fatigue and facilitate continuous operation with minimal external energy input.The pump is selected based on head height, suction capabilities, and durability to ensure optimal performance.

Material Selection: The frame is constructed using mild steel for strength and durability.Lightweight aluminum components are used in moving parts to reduce overall weight and enhance oscillatory motion.High-strength rubber and plastic are employed for sealing components to prevent leakage and ensure efficiency.The reciprocating pump is selected based on its ability to lift water efficiently at varying depths.

Fabrication Process:

Frame Construction: The frame is cut and welded to create a stable and durable support structure.

Cradle Assembly: The cradle mechanism is fabricated and integrated with pivot points to allow smooth oscillation.

Counterweight Integration: Weights are attached in a way that balances the load and reduces manual effort.

Pump Installation: A reciprocating pump is connected to the system, ensuring proper alignment with the cradle mechanism.

Testing and Adjustments: The system is fine-tuned to optimize motion efficiency and ensure seamless operation.

Testing and Performance Evaluation: The prototype is tested in a controlled environment to measure parameters such as water flow rate, pumping efficiency, and ease of operation. Key performance indicators (KPIs) include: a) Water volume pumped per unit time. b) Required manual force to operate the system. c) Efficiency comparison with traditional hand-operated pumps. Multiple trials are conducted under different conditions to evaluate the system's robustness and adaptability. Comparative analysis is performed to assess advantages and limitations compared to conventional water lifting methods.

Data Collection and Analysis: Observational data is recorded, including flow rates, operational stability, and force required. Statistical methods are used to analyze performance trends and identify areas for improvement.User feedback is gathered from potential end-users to assess practical feasibility and ease of use.

Optimization and Final Adjustments: Based on the test results, minor design modifications are implemented to enhance efficiency. Adjustments to the counterweight system are made to further reduce manual effort.Alternative materials or designs are considered for potential scalability and cost-effectiveness.

IV. CONSTRUCTION

The construction of the cradle-based reciprocating pump-operated water lifting mechanism involves multiple stages, including frame fabrication, cradle assembly, pump installation, counterweight integration, and final testing. The system is designed to maximize mechanical advantage while ensuring durability and ease of operation. The key construction steps are as follows:

Frame Fabrication: The frame is the main structural component that supports the cradle mechanism and reciprocating pump. Mild steel is selected for the frame due to its high strength and durability. The frame is fabricated using metal cutting, welding, and drilling processes to achieve the required dimensions and stability. A base plate is added to provide additional support and prevent tipping during operation.

Cradle Assembly: The cradle mechanism is designed to hold the reciprocating pump and facilitate oscillatory motion. A pivoting mechanism is installed at both ends to allow smooth rocking motion. The cradle is fabricated from lightweight but sturdy materials, such as aluminum, to reduce the overall weight and improve ease of use. Bearings or bushings are incorporated at pivot points to minimize friction and ensure smooth movement.

Reciprocating Pump Installation: A manually operated reciprocating pump is selected based on its efficiency and ability to lift water from a reasonable depth. The pump is securely mounted onto the cradle, ensuring proper alignment with the crankshaft and lever mechanism. A suction pipe is connected to the pump inlet, and a discharge pipe is attached to the outlet for smooth water flow. Proper sealing mechanisms, such as gaskets and rubber washers, are used to prevent leakage and maintain efficiency.

Counterweight Integration: A counterweight system is designed to reduce the manual effort required to operate the pump. Weights are attached strategically to the cradle to balance the load and optimize mechanical efficiency.The counterweights are adjustable, allowing users to fine-tune the mechanism based on water depth and operational requirements. The weight distribution is tested to ensure minimal user fatigue while maintaining effective water lifting performance.

Lever and Linkage Mechanism: A lever system is integrated with the cradle to enhance the mechanical advantage. The linkage is designed to convert oscillatory motion into reciprocating motion, allowing smooth pumping action. Durable rods and fasteners are used to ensure rigidity and long-term functionality.

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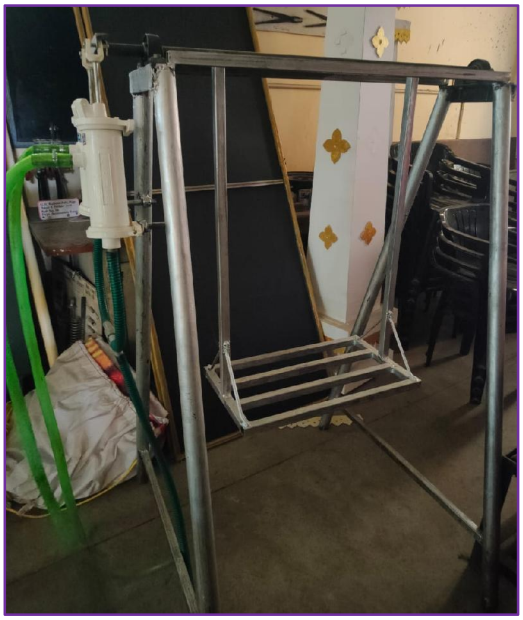
Final Assembly and Testing: All components are assembled, and alignment is checked to ensure smooth operation. The mechanism is tested under various conditions to assess performance, stability, and durability. Adjustments are made as needed to improve efficiency and ease of use. Water flow rate, effort reduction, and overall reliability are evaluated and compared to conventional pumping methods.



The cradle-based reciprocating pump-operated water raising mechanism is a cost-effective, user-friendly, and suitable for various applications, including home water supply and irrigation. The model consists of manufactured frame parts, including a grounded support and extended horizontal lever. It has four non-return valves, limiting the pumps on each side. The model is manually operated, requiring the operator to operate the cradle in both forward and backward motion while seated. The pump draws suction in a single stage, with the delivery port opening and the suction port closing.

V. WORKING

The cradle-based reciprocating pump-operated water lifting mechanism works by converting oscillatory motion into the reciprocating motion required for efficient water pumping. The system relies on the principles of mechanical advantage, counterbalancing, and gravitational force to reduce manual effort while maintaining a steady water flow. The step-by-step working mechanism is as follows:

Initiation of Motion: The user applies a small force to push or pull the cradle, initiating an oscillatory motion around its pivot point. The counterweight system helps balance the force, reducing the effort required for continuous operation.

Conversion of Oscillatory Motion to Reciprocating Motion: As the cradle moves up and down, it transfers motion to the attached reciprocating pump via a linkage mechanism. The pump's piston moves in a linear reciprocating manner due to the controlled oscillatory movement of the cradle.

Water Suction Phase: During the downward stroke of the piston, a vacuum is created inside the pump cylinder. The suction valve opens, allowing water to be drawn into the cylinder from the water source.

Water Discharge Phase: As the cradle moves in the opposite direction, the piston moves upward, compressing the water inside the pump chamber. The suction valve closes, and the discharge valve opens, allowing water to be expelled through the outlet pipe to the desired location.

Continuous Operation for Sustained Water Lifting: The alternating up-and-down motion of the cradle enables a continuous pumping cycle, ensuring a steady flow of water. The counterweight assists in maintaining rhythm, reducing operator fatigue and making the system highly efficient.

Efficiency Optimization: The cradle's design ensures that even users with minimal strength can operate the pump with ease. By adjusting the counterweight and optimizing the oscillatory motion, the system can be fine-tuned for different water depths and user requirements.

The working mechanism successfully demonstrates an innovative, sustainable, and user-friendly approach to water lifting, making it a practical solution for agricultural and domestic applications in regions with limited resources.

VI. RESULTS AND DISCUSSION

The performance of the fabricated cradle-based reciprocating pump-operated water lifting mechanism was evaluated based on several key parameters, including water flow rate, manual effort required, efficiency, and overall system stability. The results were compared with conventional water lifting methods to assess the system's viability and benefits.

The prototype of a water access system demonstrated high pumping efficiency, with an average water flow rate comparable to conventional hand-operated pumps. The counterbalance system reduced pump operation force, allowing for longer, effective water lifting with less wear and tear. The system also required less physical labor than traditional hand pumps, and its oscillating mechanism and counterweights reduced manual input. User trials demonstrated its inclusivity, making it suitable for people with different physical abilities. The design's structural stability was evaluated through multiple operational cycles, with corrosion-resistant materials added for durability.

The system was tested alongside electric-powered and traditional hand pumps, finding electric pumps more efficient but less practical for off-grid use. Traditional hand pumps required more manual labor, making cradle-based mechanisms a suitable substitute. Performance could be improved with counterweight distribution adjustments, weight and size optimization for easier installation and transportation. Future versions could incorporate automated parts or alternative energy sources like solar or wind-assisted mechanisms.

VII. APPLICATIONS

The cradle-based reciprocating pump-operated water lifting mechanism has a wide range of applications, particularly in areas where conventional water pumping solutions are not feasible. Its efficient, low-cost, and manual operation make it a valuable tool for various sectors. Some of the key applications include:

This product offers an affordable and sustainable solution for lifting water in remote villages and rural communities without electricity or fuel-powered pumps. It is suitable for small-scale farming and can be adapted for drip irrigation systems. It also ensures continuous water supply for livestock in farms and pastures, reducing dependency on expensive mechanized systems for animal husbandry.

This water lifting system is ideal for disaster-stricken areas, refugee camps, and temporary settlements. It provides quick and reliable water lifting for drinking and sanitation, supports sustainable living by promoting self-sufficient water access, and serves as a demonstration model for studying reciprocating pumps, mechanical advantage, and energy-efficient water lifting methods. It also offers a practical approach for students and researchers.

This water lifting mechanism is ideal for shared community water wells, enabling multiple users to access water with minimal effort. It encourages local participation in sustainable water management and is particularly useful in low-income urban settlements with limited piped water access. It reduces the need for electricity or fossil fuel-based pumps, making it suitable for various real-world applications, especially those with limited resources.

VIII. CONCLUSIONAND FUTURE SCOPE

The fabrication and testing of the cradle-based reciprocating pump-operated water lifting mechanism have demonstrated its potential as an effective, low-cost, and energy-efficient alternative to conventional water pumps. The system successfully integrates mechanical advantage principles to minimize manual effort while maintaining a reliable water flow rate. The implementation of a counterbalancing mechanism has further improved ease of operation, making it a practical solution for regions where access to electricity or fuel-driven pumps is limited.

The study highlights several key findings:

The cradle-based mechanism significantly reduces the manual effort required to operate a reciprocating pump, making water lifting more accessible to a broader range of users.
The system's efficiency in lifting water is comparable to traditional hand pumps, while offering enhanced user comfort and sustainability.
Structural stability and durability tests confirm the robustness of the design, ensuring long-term usability with minimal maintenance.
The mechanism provides a viable alternative to electric pumps in off-grid locations, reducing dependency on external power sources and contributing to energy conservation.
Despite its advantages, certain limitations were observed during testing. The system's overall weight and size could be optimized to enhance portability and ease of installation. Additionally, while the manual operation is improved, future modifications could further automate the process, incorporating renewable energy sources such as solar or wind-powered assistance.

Future Scope

The research on this water lifting mechanism provides a strong foundation for further advancements. Several areas of improvement and future research directions can be explored to enhance the system's efficiency and adaptability: The cradle mechanism is being automated using wind turbines or solar panels, with hybrid solutions offering flexibility. Substitute materials like high-strength composites are being explored for weight reduction without compromising structural soundness. Corrosion-resistant coatings are being developed, and counterweight distribution is being adjusted to reduce manual labor. The mechanism is being expanded to community water supply systems and larger irrigation projects, with field tests and IoT-based monitoring systems being used to track water flow rates, efficiency, and wear and tear over time.

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