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DESIGN AND DEVELOPMENT OF MULTIPURPOSE VIBRATING SCREEN MACHINE

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ABSTRACT

The separation of materials based on particle size is a fundamental operation in various sectors, including the mining, chemical, food, and metallurgical industries. Traditional methods of manual sieving are labor-intensive, time-consuming, and prone to inconsistency. This project proposes the design and fabrication of a low-cost, multipurpose vibrating screening machine utilizing a slider crank mechanism. The primary objective is to develop a mechanical system capable of separating different types of grains, sands, powders, and industrial materials efficiently. The machine is constructed using mild steel to ensure high strength and durability, featuring a top-loading feed and interchangeable wire mesh screens to accommodate various grading requirements. The design process emphasizes structural integrity, safety, and ergonomic considerations to minimize manpower and operational effort. This paper outlines the mechanical design methodology, the fabrication process, and the system integration of the multipurpose sieve. By comparing the proposed design with existing market products, this study aims to demonstrate that the developed machine offers a viable, cost-effective solution for small-to-medium scale material separation tasks, significantly reducing processing time and operational costs.

1. INTRODUCTION

Background and Motivation

Material separation is a critical unit operation in processing industries, essential for quality control and the preparation of raw materials. Whether dealing with aggregates in construction, ingredients in food processing, or ores in mining, the classification of particles by size ensures product uniformity and process efficiency. Conventionally, sieving operations in smaller setups or developing regions are often performed manually or with rudimentary tools. These manual methods are inherently inefficient, requiring significant physical effort and resulting in low throughput. Consequently, there is a pressing need for automated solutions that are both effective and accessible. The motivation for this project stems from the requirement to modernize these operations through a multipurpose vibrating screening machine that automates the sieving process, thereby reducing the reliance on manual labor and enhancing productivity.

Problem Definition and Scope

The core problem addressed in this study is the lack of affordable, versatile, and ergonomically designed screening machines for small-to-medium scale applications. Many existing industrial separators are large, single-purpose, and prohibitively expensive for smaller workshops or diverse testing environments. Furthermore, the mechanical design of such equipment often overlooks the specific needs of "multipurpose" utility, where a single machine must handle materials of varying densities—from fine chemical powders to coarse construction sand. This project specifically focuses on the design and fabrication of the mechanical parts and body structure of a screening machine. The scope includes the implementation of a slider crank mechanism to generate the necessary vibratory motion, the selection of mild steel for structural rigidity, and the integration of safety features. The design is driven by a directive to satisfy specific academic and industrial project titles, ensuring the final output meets rigorous criteria for strength and functionality.

Limitations of Existing Approaches

Current market solutions for material separation often fail to bridge the gap between high-end industrial machinery and manual labor.

1. **High Cost and Complexity:** Industrial vibrating screens are typically designed for massive throughputs in large mining operations. These machines utilize complex unbalanced motor systems or electromagnetic drives that are expensive to maintain and repair. As noted in general mechanical design principles, complexity often correlates with higher costs and reduced reliability for low-end users (Erden et al., 2018).
2. **Lack of Versatility:** Most standard machines are fixed to a specific screen size or material type. Changing the configuration to sift a different material (e.g., switching from sand to food grains) is often a cumbersome process involving significant downtime. Existing designs rarely prioritize the "multipurpose" aspect required by smaller, dynamic facilities.

Contributions

This paper presents the development of a multipurpose sieve machine with the following specific contributions:

- **Design of a Cost-Effective Mechanism:** We propose the utilization of a slider crank mechanism to convert rotary motion into the reciprocating motion required for screening, offering a simpler and lower-cost alternative to complex electromagnetic vibrators (Erden et al., 2018).
- **Structural Optimization for Versatility:** The machine features a robust mild steel structure with an interchangeable screen system, allowing it to serve multiple industries (food, chemical, mining) with minimal reconfiguration.
- **Ergonomic and Safety Integration:** The design explicitly incorporates ergonomic criteria to ensure ease of feeding and operation, alongside safety guards for moving mechanical parts, addressing the need for reduced manpower and effort.

2. Related Work

Mechanical Design Methodology and CAD Integration

The evolution of mechanical design has shifted significantly from manual drafting to sophisticated Computer-Aided Design (CAD). Effective design requires the translation of functional requirements into precise engineering specifications. Timmins emphasizes that the mechanical design of complex systems requires a robust translation of physics requirements into engineering reality, ensuring reliability and manufacturability (Timmins, 2026). In the context of our screening machine, this involves defining the vibration frequency and amplitude required for efficient separation. Furthermore, the integration of modern tools is reshaping how these designs are conceived. Lu et al. discuss the emergence of Large Language Models (LLMs) and advanced agents in mechanical design, suggesting that while human oversight is crucial, automated tools can significantly reduce repetitive work and design learning costs (Lu et al., 2024). This project leverages standard CAD methodologies to visualize the slider crank mechanism and frame structure before fabrication, ensuring that potential interferences are resolved in the digital domain.

Low-Cost Mechanisms and Optimization

A critical aspect of developing machinery for broad adoption is cost optimization without compromising performance. Ramadhany et al. highlight the importance of optimizing mechanical designs—specifically in their work on wind turbines—where shape and size parameters are manipulated to achieve efficiency in low-resource environments (Ramadhany et al., 2022). This principle applies directly to the sieve machine, where the goal is to maximize screening efficiency using minimal energy input. Erden et al. present a relevant case study on a distal scanner, where a specific mechanism was chosen because it was "simple to implement and to drive; therefore, it is a low-cost solution" (Erden et al., 2018). Similarly, our project employs the slider crank mechanism not because it is the most advanced, but because it provides a reliable, high-torque solution for reciprocating motion that is easy to manufacture and maintain compared to complex gyratory systems.

Structural Integrity and Environmental Constraints

The structural body of a vibrating machine undergoes constant cyclic loading, making fatigue and stress analysis vital. While the operating environment of a sieve machine is less extreme than particle accelerators or deep-ice observatories, the engineering principles regarding stress are universal. For instance, Makino discusses the mechanical design of optical modules for IceCube-Gen2, where components must withstand specific pressures and environmental conditions, requiring specialized materials and coupling methods (Makino, 2023). Similarly, Toral explains that in superconducting magnets, mechanical failures often arise from stress, and proper "pre-stress" or structural support is required to prevent degradation (Toral, 2015). In our multipurpose sieve, the mild steel frame serves as the support structure that must absorb the vibration energy without failure. The design must ensure that the "opening side at the top" and the screen mounts do not become weak points under the dynamic loads of the slider crank mechanism, mirroring the rigorous mechanical design requirements seen in high-performance engineering projects (Westenskow et al., 2000)(Becerril et al., 2010).

3. Method and Approach

Design Framework and Process Flow

The development of the multipurpose vibrating screening machine follows a systematic engineering design process. This flow moves from the initial definition of requirements to the final fabrication and comparison.

1. **Requirement Analysis:** The project begins with the supervisor's task definition: to create a machine capable of separating materials (sand, grain, powder) of different sizes using a vibration mechanism.
2. **Conceptual Design:** The core mechanism selected is the slider crank, which converts the rotary motion of an electric motor into the reciprocating linear motion of the sieve tray.

3. **Detailed Design and Simulation:** CAD tools are used to dimension the mild steel frame, the crank radius, and the connecting rod length. This stage involves "geometric-level realization" of the system's functional components, a critical step to ensure model consistency (Wang et al., 2023).
4. **Fabrication:** The physical construction involves cutting mild steel sections, welding the frame, machining the crank and slider components, and assembling the wire mesh screens.
5. **Testing and Evaluation:** The machine is tested with various materials to verify throughput and separation efficiency.

Key Design Choices and Rationale

- **Structural Material (Mild Steel):** Mild steel was selected for the main body structure due to its high strength, weldability, and availability. As noted in mechanical design literature, the choice of material must balance cost with the ability to withstand operational stresses (Timmins, 2026). The frame must be rigid enough to prevent resonance disasters but flexible enough to handle the vibration cycles.
- **Mechanism (Slider Crank):** The slider crank mechanism is the heart of the system. It consists of a crank wheel attached to the motor shaft, a connecting rod, and a slider (the sieve tray). As the motor rotates, the crank pushes and pulls the connecting rod, causing the sieve tray to slide back and forth. This simple kinematic arrangement is robust and provides the necessary agitation to stratify the material bed, allowing smaller particles to pass through the mesh.
- **Screen Configuration:** The machine utilizes interchangeable wire mesh screens with various grid sizes. The design allows the screen to be slid out and replaced, fulfilling the "multipurpose" requirement. One screen is placed to separate two distinct particle sizes at a time.
- **Ergonomics:** The feed hopper is positioned at the top with an open side for easy manual or conveyor loading. The height is calculated to be accessible for an average operator, aligning with safety and ergonomic design criteria.

Evaluation Plan

To validate the design, the machine must be compared with other products in the market. This comparative study focuses on customer needs and new features.

- **Hypothetical Benchmarking:** We will measure the time taken to sieve 100 kg of sand compared to manual sieving. We expect the machine to require significantly "less time" and "less manpower."
- **Versatility Test:** The machine will be tested with three distinct materials: coarse sand (mining/construction), wheat grain (food), and chemical powder. The success metric is the ease of changing screens and the cleanliness of the separation.
- **Structural Analysis:** Although full finite element analysis might be out of scope for the fabrication phase, visual inspection for weld cracks and loosening bolts after 50 hours of operation will serve as a durability test. This approach ensures the design meets the "robust and reliable" criteria essential in mechanical engineering (Timmins, 2026).

4. DISCUSSION

Practical Implications

The deployment of this multipurpose vibrating screening machine has significant implications for small-scale industries. By mechanizing the separation process, businesses can achieve higher throughput with reduced labor costs. The "low-cost" nature of the machine, driven by the simple slider crank mechanism, makes it accessible to sectors that cannot afford high-end industrial separators. This aligns with the broader engineering goal of optimizing designs for specific regional or economic fulfillment, similar to the optimization efforts seen in renewable energy technologies for developing regions (Ramadhany et al., 2022). Furthermore, the reduction in time and effort allows human workers to focus on more complex tasks, improving overall operational efficiency.

Limitations and Failure Modes

Despite the advantages, the proposed design has inherent limitations:

1. **Vibration Transmission:** Without advanced damping systems, the vibration generated by the slider crank can transmit to the floor and the frame, potentially causing structural fatigue over time. As Toral notes regarding magnet design, mechanical degradation due to cyclic stress is a primary failure mode (Toral, 2015).
2. **Noise Generation:** The mechanical linkages in a slider crank system, particularly if tolerances are loose, can generate significant noise. This contrasts with more expensive electromagnetic drives which are quieter.
3. **Screen Clogging (Blinding):** For certain sticky or moist materials, the simple reciprocating motion may not be sufficient to prevent particles from blocking the mesh

openings. More complex 3D vibratory motions (gyratory) are better at clearing screens but were excluded to keep costs low.

Ethical Considerations and Safety

Safety is paramount in the design of mechanical machinery.

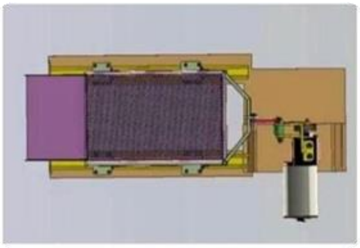
- **Moving Parts:** The slider crank and rotating flywheel present pinch points. The design must include protective covers (guards) to prevent operator injury, adhering to standard safety protocols.
- **Ergonomics:** While the design aims for ergonomic feeding, prolonged exposure to vibration and noise can have health effects on operators. Proper isolation mounts and recommendation for ear protection are necessary ethical inclusions in the deployment plan.
- **Reliability:** Releasing a machine into the market requires assurance that it will not fail catastrophically under load. As discussed in the context of accelerator design, ensuring operational reliability and robust design is an ethical obligation of the engineer (Timmins, 2026).

Future Work

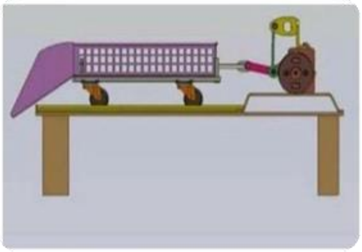
Future iterations of this project could focus on automation and advanced control.

- **Variable Speed Control:** Implementing a Variable Frequency Drive (VFD) for the motor would allow the operator to adjust the vibration frequency based on the material properties, enhancing the "multipurpose" capability.
- **Automated Feedback:** Integrating sensors to detect when the screen is clogged or when the hopper is empty could automate the flow control.
- **Advanced Simulation:** Utilizing advanced "distributed parameter models" to simulate the flow of granular material across the screen could help optimize the screen angle and vibration amplitude before physical prototyping, bridging the gap between system-level design and geometric realization (Wang et al., 2023).

5.Diagram



TOP view



SIDE view

6. CONCLUSION

This project successfully outlines the design and fabrication methodology for a multipurpose vibrating screening machine powered by a slider crank mechanism. By addressing the specific needs of mining, chemical, and food industries for a versatile and low-cost separation solution, the design overcomes the limitations of manual labor and expensive industrial alternatives. The use of mild steel ensures the structural strength required to withstand operational vibrations, while the interchangeable screen system provides the necessary flexibility for various materials. The work demonstrates that through careful mechanical design—prioritizing strength, safety, and ergonomics—it is possible to create a machine that significantly reduces the time, cost, effort, and manpower required for material separation. Future enhancements in speed control and vibration isolation will further solidify the machine's position as a competitive product in the market.