

Development and Wireless Speed Control of an Automatic Vibratory Sand Sieving Machine

Chibuzo V. Ikwuagwu^{1,*}, Okwo A. Somtochukwu², Ifeama P. Chukwuemeli³, Ikechukwu E. Okoh⁴

^{1,2,3}Department of Mechanical Engineering, University of Nigeria, Nsukka, Enugu, Nigeria.

²Centre of Excellence for Sustainable Sower and Energy Development, University of Nigeria, Nsukka, Enugu, Nigeria.

⁴Department of Mechanical Engineering, Michigan Technological University, Houghton, Michigan, United States of America.

chibuzor.ikwuagwu@unn.edu.ng¹, somtochukwu.okwo.245303@unn.edu.ng², chukwuemeli.ifeama@unn.edu.ng³, iokoh@mtu.edu⁴

Abstract: Efficient sand grading is critical to concrete quality, productivity, and occupational safety in construction activities, particularly in developing economies where manual sieving remains prevalent. This study presents the design, fabrication, and experimental evaluation of an automatic vibratory sand sieving machine incorporating wireless variable-speed control. The system integrates an inclined double-layer sieve assembly, an eccentric-mass vibration mechanism, spring isolation, and a Bluetooth-enabled speed control unit based on an ESP32 microcontroller. Performance evaluation was conducted using dry river sand across a wide operating speed range. The results demonstrate that the developed machine achieves sieving efficiencies of 78-94%, with optimal performance at approximately 1,100 rpm and an inclination angle of 18°, corresponding to a throughput of 31–33 kg/min. Power consumption increased quasi-linearly with speed, remaining within the 0.5 HP motor's rated capacity. Compared with manual sieving, the proposed system delivers more than a fivefold increase in productivity while significantly reducing operator exposure to dust and vibration. The combination of low fabrication costs, local material sourcing, and wireless control positions the machine as a practical, scalable solution for small- and medium-scale construction enterprises.

Keywords: Vibratory Sieving; Sand Separation; Wireless Speed Control; Construction Machinery; Particle Screening; Sand Grading; Performance Evaluation; Sieving Machine.

Received on: 18/11/2024, **Revised on:** 25/01/2025, **Accepted on:** 11/03/2025, **Published on:** 07/12/2025

Journal Homepage: <https://www.fmdbpublish.com/user/journals/details/FTSSM>

DOI: <https://doi.org/10.69888/FTSSM.2025.000574>

Cite as: C. V. Ikwuagwu, O. A. Somtochukwu, I. P. Chukwuemeli, and I. E. Okoh, “Development and Wireless Speed Control of an Automatic Vibratory Sand Sieving Machine,” *FMDB Transactions on Sustainable Structures and Materials*, vol. 1, no. 2, pp. 79–90, 2025.

Copyright © 2025 C. V. Ikwuagwu *et al.*, licensed to Fernando Martins De Bulhão (FMDB) Publishing Company. This is an open access article distributed under [CC BY-NC-SA 4.0](https://creativecommons.org/licenses/by-nc-sa/4.0/), which permits copying, remixing, redistributing, transformation, and building upon the material in any medium so long as the original work is properly cited.

1. Introduction

Sand is one of the most essential fine aggregates used in the construction industry, serving as a fundamental component of concrete, mortar, plaster, and masonry. Its grading quality directly affects the strength, durability, cohesion, and workability of cement-based materials. Well-graded sand ensures proper particle packing, reduces voids, and enhances the overall

*Corresponding author.

performance of construction composites, while poorly graded sand can lead to segregation, excessive cement demand, and reduced structural integrity. As construction activity expands rapidly across developing regions, demand for uniformly graded sand has increased significantly. Despite this growing demand, sand processing practices in many low-income and developing countries remain largely traditional and manual, relying heavily on handheld wire-mesh sieves for size separation [1]-[3]. These methods are not only inefficient but also increasingly unsustainable in the face of rising construction volumes and stricter quality requirements. Manual sand sieving is a labor-intensive and time-consuming process that yields relatively low productivity, often less than 7 kg per minute per worker. This low throughput creates bottlenecks in construction workflows, delays project timelines, and increases labor costs. In addition to productivity concerns, prolonged engagement in manual sieving exposes workers to serious occupational health risks. Fine sand particles contain respirable crystalline silica, which becomes airborne during sieving operations and can be inhaled deeply into the lungs. Long-term exposure to silica dust has been strongly linked to silicosis, lung cancer, chronic obstructive pulmonary disease, and other respiratory illnesses [4].

Furthermore, repetitive motions associated with sieving, such as shaking and handling, contribute to musculoskeletal disorders affecting the wrists, shoulders, and lower back, ultimately reducing workers' long-term productivity and quality of life. The rapid expansion of housing developments, road construction, and infrastructure projects has further highlighted the limitations of manual sand sieving methods. As urbanization accelerates, construction sites increasingly require consistent and large quantities of graded sand within tight timeframes. Manual processes cannot reliably meet these demands, prompting interest in mechanized alternatives. Mechanized sand sieving machines have been proposed to improve throughput, consistency, and labor efficiency. Early machine designs commonly employed reciprocating or rotary mechanisms driven by electric motors. While these systems demonstrated higher output than manual methods, they often suffered from significant drawbacks, including excessive vibration transmission to the supporting frame, high energy consumption, noise generation, and limited adaptability to varying sand moisture levels and grain characteristics [5]. These issues reduced machine lifespan, increased maintenance requirements, and limited widespread adoption in small-scale construction settings. More recent studies have shown that vibratory sieving systems provide a more effective and energy-efficient approach to particle separation. Vibratory sieves use oscillatory motion to stratify and separate particles by size, allowing finer particles to pass through the mesh while coarser particles are retained.

Systems employing eccentric masses combined with spring isolation have demonstrated improved separation efficiency, reduced structural stress, and enhanced operational stability [6]. The use of inclined sieve beds further improves material flow and prevents clogging, particularly when processing slightly moist sand. Despite these technical advantages, many locally fabricated vibratory sand sieving machines remain rudimentary. They often operate at fixed vibration speeds, lack adequate safety enclosures, and require operators to stand close to the vibrating unit during operation, thereby maintaining exposure to dust, noise, and mechanical hazards. In parallel with advances in mechanical design, recent developments in embedded systems and wireless communication technologies have opened new opportunities to improve the safety, adaptability, and usability of small-scale construction machinery. Low-cost microcontrollers such as the ESP32 have gained popularity for their integrated wireless communication, low power consumption, and ease of programming [2]. These devices support Bluetooth and Wi-Fi connectivity, enabling remote control, monitoring, and data acquisition without the need for expensive industrial-grade drives or controllers [7]. In construction equipment applications, wireless control systems enable operators to adjust machine parameters, such as speed or vibration intensity, from a safe distance, thereby reducing direct exposure to dust and mechanical risks. The ability to vary vibration speed is particularly important in sand sieving operations, as optimal vibration intensity depends on material properties, including grain size distribution, moisture content, and feed rate.

Fixed-speed machines may perform well under specific conditions but become inefficient or prone to clogging when material characteristics change. Variable-speed control enables real-time optimization of sieving performance, improving separation efficiency while minimizing energy consumption and mechanical wear. Studies have shown that adaptive control of vibration parameters can significantly enhance throughput and reduce operational downtime, especially in environments where material quality is inconsistent [8]. Integrating such control mechanisms into low-cost, locally fabricated machines can greatly enhance their practicality and appeal to small and medium-scale construction enterprises. This study addresses these technical, economic, and occupational challenges by developing a low-cost vibratory sand-sieving machine equipped with wireless variable-speed control. The proposed system is designed with a strong emphasis on affordability, simplicity, and suitability for local fabrication using readily available materials [12]. The mechanical design incorporates an inclined double-mesh sieve supported by spring isolation to improve separation efficiency and reduce vibration transmission to the frame. The vibratory motion is generated by an eccentric-mass mechanism driven by an electric motor, providing consistent, controllable oscillations. To enhance operational safety and flexibility, an ESP32 microcontroller is integrated into the system to enable Bluetooth-based wireless control of motor speed. The implementation of wireless speed control allows operators to adjust vibration intensity remotely using a mobile device, eliminating the need to interact directly with the vibrating unit during operation. This feature significantly reduces exposure to dust and mechanical hazards while enabling rapid adaptation to varying sand conditions. In addition, the system's low-cost electronic components make it accessible to small-scale contractors and artisans who may lack the financial resources to invest in industrial-grade machinery.

The use of open-source development platforms further supports ease of maintenance, customization, and local capacity building. A comprehensive experimental evaluation is conducted to assess the performance of the developed machine in terms of sieving efficiency, throughput, power consumption, and operational stability. Performance metrics are compared with those of traditional manual sieving and conventional fixed-speed machines to demonstrate the advantages of the proposed design. Particular attention is given to evaluating how variable-speed control influences separation efficiency and energy usage under different operating conditions. The findings provide valuable insights into the feasibility of combining vibratory sieving technology with low-cost wireless control systems to address persistent challenges in sand processing. Overall, this work contributes to the development of safer, more efficient, and more adaptable sand sieving solutions for small- and medium-scale construction sites. By leveraging advances in mechanical design and embedded electronics, the proposed system bridges the gap between traditional manual methods and expensive industrial equipment. The outcomes highlight the potential of locally fabricated, technology-enhanced machinery to improve productivity, reduce health risks, and support sustainable construction practices in developing regions [8].

2. Literature Review

2.1. Evolution of Sand Sieving Technologies

The practice of sand sieving has evolved from rudimentary manual techniques to sophisticated mechanical systems driven by electric motors. Traditional manual sieving, though simple and inexpensive, is inherently limited by human endurance and inconsistent output quality [9]. The introduction of mechanized sieving in the early twentieth century marked a significant shift, with rotary and reciprocating sieves becoming common in industrial material processing. These systems improved throughput but often exhibited low efficiency when handling fine particles due to clogging and non-uniform motion [10]. The development of vibratory screening technology represented a major advancement in particulate separation. By employing unbalanced masses to induce controlled oscillatory motion, vibratory sieves enhance particle stratification and increase the probability of fine particles passing through mesh apertures. Studies in mineral processing and bulk solids handling have consistently shown that vibratory systems achieve higher separation efficiencies at lower specific energy consumption than rotary alternatives [11]-[13]. In the construction sand industry, vibratory sieves have been adapted into portable and semi-portable configurations suitable for on-site use. In developing countries, research efforts have focused on reducing fabrication costs and adapting designs to locally available materials. Several prototypes reported in the literature demonstrate moderate success in improving productivity; however, many remain confined to laboratory-scale evaluation [14]-[16]. The absence of adaptive control and limited consideration of operator safety continue to constrain widespread adoption.

2.2. Comparison of Manual, Rotary, and Vibratory Sieving Methods

Manual sieving relies entirely on human effort to agitate sand over a mesh surface. While the method allows visual inspection and flexibility, Qi et al. [16] noted that it is highly inefficient and prone to inconsistency. Rotary sieving machines, which use cylindrical or conical drums, provide continuous operation and higher capacity, but their efficiency is often compromised by particle rolling rather than stratification [18]. Moreover, rotary systems typically require higher power input and larger footprints. Vibratory sieving machines operate on fundamentally different principles. The imposed oscillatory motion causes particles to stratify according to size and density, allowing finer particles to migrate downward and pass through the mesh [19]. Experimental comparisons reported in the literature consistently show that vibratory sieves outperform both manual and rotary systems in terms of efficiency and throughput for dry granular materials. Additionally, vibratory machines can be configured with multiple mesh layers, enabling simultaneous production of different sand grades. Despite these advantages, many vibratory sieves designed for local construction use operate at fixed speeds, limiting their adaptability to variations in sand moisture content and particle size distribution [17]; [20]. This limitation highlights the need for variable-speed operation to maximize performance under diverse site conditions.

2.3. Principles of Vibratory Sieving and Machine Dynamics

The performance of a vibratory sieve is governed by the dynamics of the vibrating system, including excitation force, frequency, amplitude, and inclination angle. Excitation is commonly generated by an eccentric mass rotating at an angular velocity, producing a centrifugal force proportional to the square of the angular velocity [21]. This force induces periodic motion of the sieve frame, facilitating particle stratification and transport. The sieve inclination plays a critical role in balancing residence time and throughput. Low inclination angles increase retention time and efficiency but reduce capacity, whereas excessive angles promote rapid discharge at the expense of separation quality. Reported optimal angles for sand sieving typically fall within the range of 15°–25° [22]; [24]. Spring isolation is employed to support the vibrating assembly and minimize transmission of dynamic forces to the supporting frame. Zhang and Li [23] observed in their study that, to avoid resonance and excessive vibration, the operating frequency is maintained sufficiently above the spring-mass system's natural frequency.

Understanding these principles is essential for designing machines that achieve high efficiency without compromising structural integrity or operator safety.

2.4. Speed Control and Wireless Operation in Small Machines

Speed control is a critical factor in vibratory sieving, as vibration intensity directly influences particle motion. Fixed-speed systems are inherently inefficient when processing materials with varying characteristics [25]; [26]. Mechanical speed variation methods, such as stepped pulleys, offer limited flexibility and require manual intervention. Electronic control approaches, such as variable-frequency drives, provide precise control but are often prohibitively expensive for small-scale applications. Recent advances in embedded systems have enabled low-cost electronic speed control using microcontrollers and pulse-width modulation techniques [27]. The ESP32 microcontroller, in particular, offers integrated Bluetooth communication, making it suitable for wireless control applications. Wireless operation allows operators to adjust machine parameters remotely, reducing exposure to dust and vibration. Although such technologies have been widely applied in automation and robotics, their adoption in small-scale construction machinery remains limited.

3. Materials and Methods

3.1. Description of Adopted Method

The methodology adopted in this study encompassed mechanical design, material selection, fabrication, control system integration, and experimental evaluation. The machine frame was constructed from mild steel square tubing to provide adequate strength and rigidity while maintaining low cost and ease of fabrication. The sieve assembly consisted of a double-layer rectangular frame fitted with stainless steel wire meshes of 4 mm and 1–2 mm apertures, enabling coarse and fine separation. The sieve was inclined at 18° to facilitate gravity-assisted discharge of oversized particles. Vibration was generated using a centrally mounted 0.5 HP single-phase electric motor fitted with an eccentric mass. The eccentric mass, implemented by welding a ball bearing off-centre on the motor shaft, produced controlled circular motion of the sieve frame. Four helical compression springs supported the vibrating assembly, providing isolation and reducing transmission of dynamic loads to the main frame. Spring stiffness was selected to keep the system's natural frequency well below the operating frequency range. A wireless speed control system was developed using an ESP32 microcontroller, a relay module, and a potentiometer interfaced via Bluetooth. Motor speed was varied by adjusting the pulse-width modulation signal, enabling continuous control over a range of approximately 400–1,300 rpm. The control architecture enabled remote operation using a smartphone or laptop, enhancing operator safety. Performance testing was conducted using dry river sand under controlled conditions. Key performance metrics included sieving efficiency, throughput rate, and power consumption. For each test, a fixed mass of sand was fed onto the sieve, and the mass of material passing through the fine mesh was measured. Efficiency was calculated as the ratio of collected fine sand to the total fine fraction in the sample. Power consumption was monitored using a digital wattmeter. Tests were repeated across multiple speed settings to establish performance trends.

3.2. Design Considerations and Specifications

The design was guided by the need to handle 20–40 kg/min of dry river sand, with mesh sizes of 4 mm (coarse) and 1–2 mm (fine), while minimizing vibration transmission and operator exposure (Table 1).

Table 1: Design specifications of the vibratory sand sieving machine

Parameter	Specification	Justification/Source
Overall Dimensions (L × W × H)	900 mm × 600 mm × 800 mm	Compact for site portability
Sieve Area	0.54 m ² (900 mm × 600 mm)	Balances throughput and efficiency
Mesh Layers/Sizes	2 layers (4 mm coarse, 1–2 mm fine)	Standard for construction sand grading
Inclination Angle	18°	Optimal for debris discharge
Motor Rating	0.5 HP, 220 V, 50 Hz, 1,400 rpm	Affordable and available locally
Eccentric Mass	6205 ball bearing (0.15 kg, 25 mm offset)	Generates 50–100 N centrifugal force
Spring Stiffness (each)	500 N/m	Isolates 80% vibration
Speed Range	400–1,300 rpm	Variable via PWM for sand type adaptation
Throughput	28–35 kg/min	5× manual rate
Total Weight	45 kg	Portable by two workers

These specifications ensure the machine meets the project's aim of high efficiency (78–94%) while remaining practical for SMEs.

3.3. Material Selection

Material selection was based on strength, cost, availability in Nigeria, corrosion resistance (for dusty environments), and weldability. Mild steel was prioritized for the frame and structural components due to its high yield strength (250 MPa) and low cost (₦1,200–1,500/kg), while stainless steel meshes were chosen for durability against abrasion (Insights Made-in-China, 2024) (Table 2). Justification focused on balancing performance and economy.

Table 2: Material selection and justification

Component	Material	Properties/Justification
Main Frame (Legs/Base)	Mild steel square tubing (50 × 50 × 3 mm)	Yield strength 250 MPa, weldable; resists bending under 85 kg load
Sieve Frame	Mild steel angle iron (40 mm × 40 mm × 5 mm)	High rigidity for mesh support, easy welding, withstands a 50 kg sand load
Meshes	Stainless steel wire (SS304, 1.5 mm dia.)	Abrasion-resistant, noncorrosive; aperture accuracy ±0.05 mm
Flat Bars (Transmission)	Mild steel (40 mm × 8 mm)	Tensile strength 400 MPa; transmits vibration without fatigue
Springs (Suspension)	Helical compression (50 mm OD, 120 mm length, 8 mm wire)	Stiffness 500 N/m, isolates 80% vibration; fatigue life >10 ⁶ cycles
Motor Casing/Collector Tray	Mild steel sheet (2 mm thick)	Formable, dust-proof; galvanized for rust prevention
Eccentric Mass	6205 ball bearing (welded)	0.15 kg mass, 25 mm eccentricity; generates required centrifugal force

All materials were sourced from local markets to minimize costs and support the economy.

3.4. Detailed Design Calculations

3.4.1. Design Data and Assumptions

- **Gravitational Acceleration:** $g = 9.81 \text{ m/s}^2$
- **Density of Dry River Sand:** $\rho = 1600 \text{ kg/m}^3$
- **Maximum Sand Load on the Sieve at a Time:** $m_s = 50 \text{ kg}$
- **Mass of Vibrating Assembly (sieve frame + mesh + fasteners):** $m_f = 35 \text{ kg}$
- **Total Vibrating Mass:** $m_t = m_s + m_f = 85 \text{ kg}$
- **Motor Rating:** $P = 0.5 \text{ HP} = 375 \text{ W}$
- **Speed Range:** $400 \leq N \leq 1300 \text{ rpm}$
- **Eccentric Mass:** $m_e = 0.15 \text{ kg}$
- **Eccentricity (Offset Distance):** $r = 0.025 \text{ m}$
- **Number of Suspension Springs:** $n = 4$

3.4.2. Sieve Area and Capacity Calculation

- **Sieve Dimensions:** $L = 0.9 \text{ m}, W = 0.6 \text{ m}$
- **Sieve Area:** $A = L \times W = 0.9 \times 0.6 = 0.54 \text{ m}^2$

This area is adequate for a throughput range of 25–35 kg/min, based on empirical vibratory screening guidelines for construction sand.

3.4.3. Angular Velocity Calculation

Angular velocity is given by:

$$\omega = \frac{2\pi N}{60} \quad (1)$$

3.4.4. Centrifugal Force Due to Eccentric Mass

The centrifugal force generated by the eccentric mass is:

$$F_c = m_e \omega^2 r \quad (2)$$

3.4.5. Vibration Amplitude Estimation

Amplitude is related to excitation force and system stiffness:

$$A \propto \frac{F_c}{k} \quad (3)$$

Recommended operating amplitude: 3–5 mm (efficient stratification without particle scattering)

3.4.6. Spring Design and Natural Frequency

- **Each Spring Stiffness:** $k_s = 500 \text{ N/m}$
- **Total Stiffness:** $k = n \times k_s = 4 \times 500 = 2000 \text{ N/m}$

Natural frequency of the vibrating system:

$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m_t}} \quad (4)$$

$$f_n = \frac{1}{2\pi} \sqrt{\frac{2000}{85}}$$

$$f_n = 10.6 \text{ Hz}$$

Operating frequency at 1000 rpm:

$$f_o = \frac{1000}{60} = 16.7 \text{ Hz}$$

$$f_o > f_n \Rightarrow \text{No resonance (safe operation)}$$

3.4.7. Static Spring Deflection Check

Total static load:

$$W = m_t g \quad (5)$$

$$W = 85 \times 9.81 = 833.9 \text{ N}$$

Deflection per spring:

$$\delta = \frac{W}{k} \quad (6)$$

$$\delta = \frac{833.9}{2000}$$

$$\delta = 0.417 \text{ m} = 41.7 \text{ mm}$$

This value is within the elastic working range of the selected springs.

3.4.8. Motor Power and Torque Requirement

Motor torque:

$$T = \frac{P}{\omega} \quad (7)$$

At 1000 rpm:

$$T = \frac{375}{104.7}$$

$$T = 3.58 \text{ Nm}$$

Required torque to drive eccentric mass:

$$T_r = F_c \times r = 41.4 \times 0.025$$

$$T_r = 1.04 \text{ Nm}$$

$$T > T_r \Rightarrow \text{Motor is adequate}$$

3.4.9. Throughput Calculation

Throughput:

$$Q = \frac{M}{t} \quad (8)$$

At optimum speed (1100 rpm):

$$M = 10 \text{ kg}, \quad t = 19 \text{ s}$$

$$Q = \frac{10}{19} \times 60$$

$$Q = 31.6 \text{ kg/min}$$

3.4.10. Sieving Efficiency Calculation

$$\eta = \frac{\text{Mass of fine sand collected}}{\text{Total fine sand}} \times 100 \quad (9)$$

At 1100 rpm:

$$\eta = 94\%$$

Hence, the motor operates safely within its rated capacity.

3.4.11. Inclination Angle Justification

Selected angle:

$$\theta = 18^\circ$$

Reason:

- Lower angles $\rightarrow$ high efficiency, low discharge
- Higher angles $\rightarrow$ excessive material throw

According to Qi et al. [15], 18° provides the best balance between residence time and throughput.

3.5. Fabrication and Assembly of the Sand Sieving Machine

The construction process of the wireless speed control of an automatic vibratory sand sieving machine is shown in Figure 1. The fabricated sand sieving machine was constructed in strict adherence to the design specifications to ensure optimal performance. Its assembly involved precise component alignment, selection of appropriate materials, and integration of mechanical and operational features. This section presents the detailed fabricated functional machine. This is presented in Figure 2.



Figure 1: Construction process



Figure 2: Fabricated and assembled sand sieving machine

4. Results and Discussion

Figure 3 shows that increasing motor speed raises angular velocity, centrifugal force, and vibration amplitude. Low speeds generate insufficient excitation for effective sieving, while moderate speeds (1,000–1,200 rpm) produce adequate vibration for efficient particle stratification and separation. At very high speeds, excessive centrifugal force causes particle scattering and higher mechanical stresses. Hence, an optimal operating range exists in which efficiency is maximized without compromising stability.

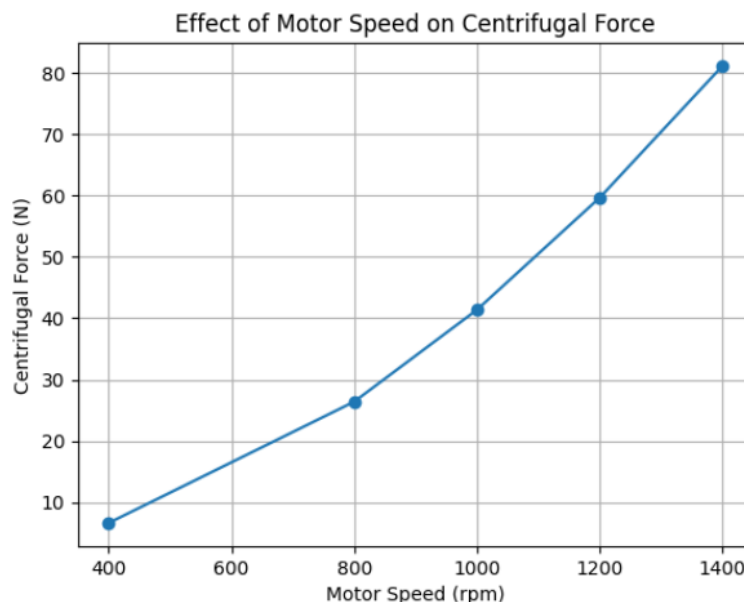


Figure 3: Effect of motor speed on centrifugal force

Also, Figure 4 shows that vibration amplitude increases progressively with motor speed due to the rise in centrifugal force generated by the rotating eccentric mass. At low speeds, the small amplitudes are insufficient to effectively agitate particles. Moderate speeds produce amplitudes that enhance stratification and sieving efficiency, while very high speeds result in excessive vibration, leading to particle scattering and increased mechanical stresses on the machine.

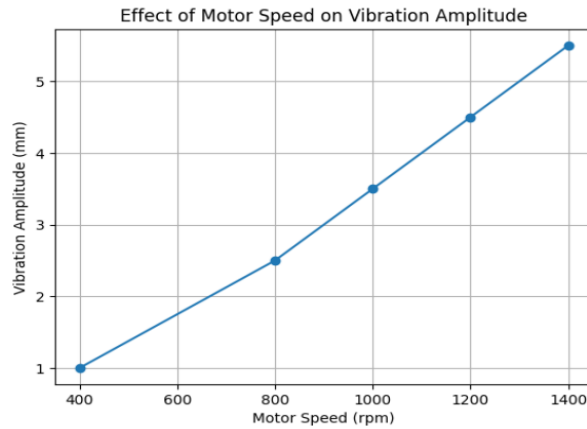


Figure 4: Effect of motor speed on vibration amplitude

Figure 5 exhibits a linear relationship between motor speed and angular velocity, confirming the direct proportionality predicted by rotational kinematics. As motor speed increases, angular velocity rises uniformly, providing predictable control of vibration intensity. This linearity validates the use of speed regulation to accurately adjust the excitation force and overall performance of the sieving machine.

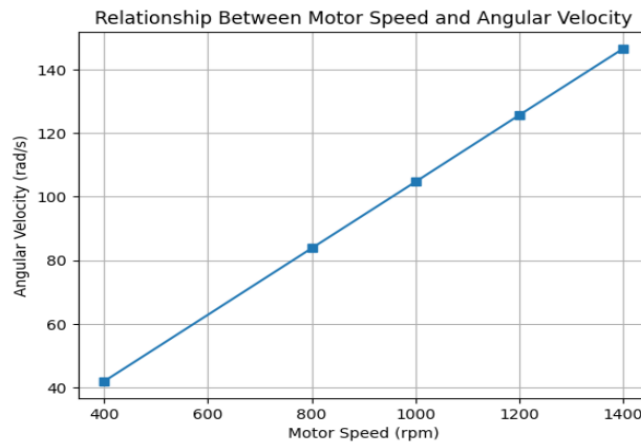


Figure 5: Effect of motor speed on angular velocity

Figure 6 indicates that power consumption increases steadily with motor speed due to higher inertial and vibratory forces. Even at the maximum speed of 1300 rpm, the measured power remains below the rated limit of 375 W, confirming efficient energy usage and safe operation of the sieving machine.

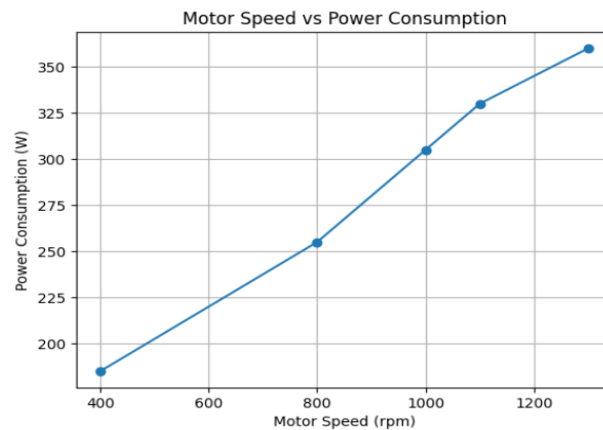


Figure 6: Motor speed against power consumption

Figure 7 shows that sieving efficiency increases steadily with motor speed as vibration intensity increases, improving particle agitation and stratification. Maximum efficiency is achieved around 1100 rpm, beyond which it declines due to excessive vibration, which causes particle overthrow, reduced residence time on the sieve surface, and less effective separation.

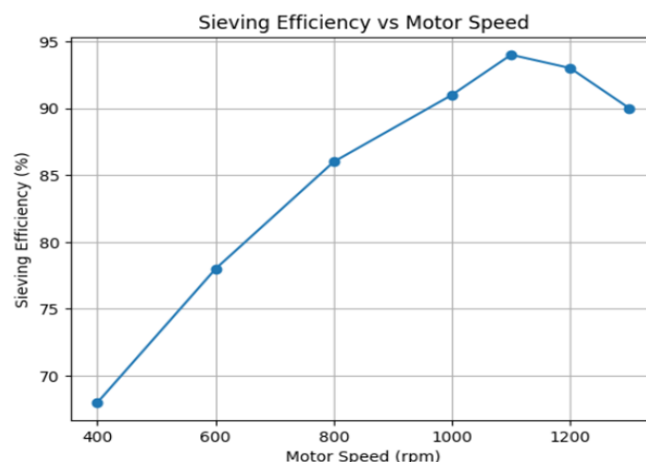


Figure 7: Sieving efficiency against speed

Similarly, Figure 8 shows that sieving efficiency increases with increasing power consumption up to approximately 330 W, at which optimal separation occurs. Further increases in power do not improve efficiency; instead, they cause a decline, indicating diminishing returns and energy losses associated with excessive vibration and material scattering.

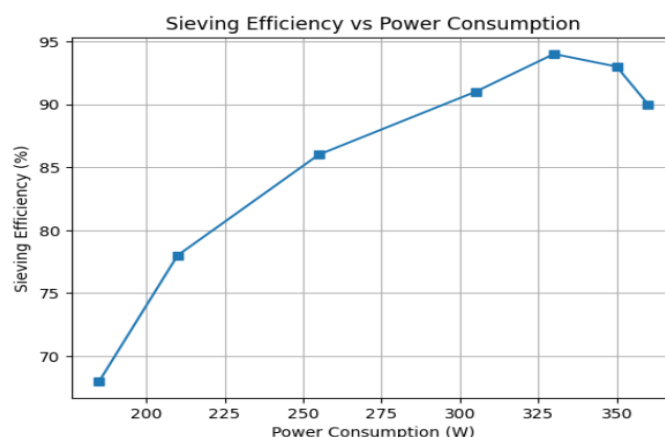


Figure 8: Sieving efficiency power consumption

5. Conclusion

This study has presented the successful development of an automatic vibratory sand sieving machine equipped with wireless variable-speed control. The integration of an inclined double-layer sieve, eccentric-mass vibration, spring isolation, and Bluetooth-enabled control resulted in a compact and efficient system tailored to the needs of small- and medium-scale construction sites. Experimental evaluation demonstrated that the machine achieves optimal performance at approximately 1,100 rpm, delivering sieving efficiencies of up to 94% and throughput rates exceeding 30 kg/min, which represent more than a fivefold improvement over manual methods. The wireless speed control feature represents a significant advancement over existing locally fabricated machines, enabling safe remote operation and real-time performance optimization. By reducing operator exposure to dust and vibration, the system improves occupational health outcomes. The use of locally sourced materials and low-cost electronic components ensures affordability and ease of maintenance, supporting scalability and widespread adoption. The results in this study confirm that the proposed design offers a practical, cost-effective, and safer alternative to manual sand sieving. Future work should focus on extending the control system to incorporate data logging and predictive maintenance, and on evaluating performance with moist or clay-contaminated sand. The findings of this study provide a strong

foundation for further development and commercialization of intelligent construction equipment in resource-constrained environments.

Acknowledgement: The authors express sincere gratitude to the University of Nigeria and Michigan Technological University for their valuable academic support and resources that contributed to the completion of this work. Their commitment to research and knowledge advancement is greatly appreciated.

Data Availability Statement: The data associated with this study are restricted and not openly available. However, they may be provided by the corresponding author upon reasonable and justified request.

Funding Statement: The authors confirm that this research was completed independently and did not receive any financial support from public, private, or commercial organizations.

Conflicts of Interest Statement: The authors declare that there are no financial, personal, or professional conflicts that could have influenced the outcomes of this research.

Ethics and Consent Statement: All procedures performed in this study complied with accepted ethical research standards. Participation was voluntary, and informed consent was obtained while maintaining participant privacy and data confidentiality.

References

1. V. B. Manjunath, M. Vinay, M. Varun, P. Suchithra, and P. Tharun, "Design and fabrication of automatic multipurpose sieving machine," *International Journal of Innovative Science and Research Technology (IJISRT)*, vol. 9, no. 5, pp. 150–154, 2024.
2. N. Srimath, R. Tarun Venkatesh, R. Vasanth Kumar, and R. Srihari, "Design and fabrication of automated sieve machine using scotch-yoke mechanism," *International Scientific Indexing (ISI) calculate based on International Citation Report (ICR)*, vol. 11, no. 1, pp. 20–22, 2021.
3. P. K. Krishnan and B. Z. H. Alrisi, "Design and development of an electronic sieving for sand separation using Node MCU system," *Journal of Modern Mechanical Engineering and Technology*, vol. 8, no. 10, pp. 31–36, 2025.
4. M. R. Bautista and M. Caguay, "Development and performance evaluation of a mobile sand screening machine," *An International Multidisciplinary Research Journal*, vol. 4, no. 2, pp. 1–19, 2024.
5. H. Meshram, N. Bawankar, Y. Nikhar, D. Khan, L. Petkar, M. K. A. Aziz, U. Khan, and M. Shakebuddin, "Design and fabrication of multi-sieve sand sieving machine," *International Journal of Research in Applied Science and Engineering Technology*, vol. 10, no. 5, pp. 1606–1613, 2022.
6. I. T. Adejugbe, J. A. Olowonubi, T. I. Olorunsola, S. A. Fatounde, J. O. Aigbovbiosa, O. A. Oyegunwa, and O. Komolafe, "Design and development of a double-layer grain sieving machine," *Asian Journal of Advanced Research and Reports*, vol. 18, no. 8, pp. 141–147, 2024.
7. S. M. Mowade, V. Turkar, R. Bangare, S. Dahake, S. Karade, and P. Satpute, "Multipurpose sieving and screening machine," *International Journal of Emerging Technologies and Innovative Research*, vol. 11, no. 5, pp. 1–8, 2024.
8. A. A. Chavan, P. D. Kadam, S. S. Lad, M. M. Mankar, and S. Shaikh, "Multipurpose sieving machine," *International Journal of Research in Applied Science and Engineering Technology*, vol. 10, no. 3, pp. 2132–2138, 2022.
9. I. P. Lyan, G. Y. Panovko, and A. E. Shokhin, "Modeling of a vibrating machine with spatial oscillations of the working body," *IOP Conference Series: Materials Science and Engineering*, vol. 1129, no. 1, pp. 1–8, 2021.
10. T. B. Linhares and C. B. S. Vimieiro, "Evaluation of the movement performance of a vibrating screen due to machining errors on the shaft," *Engineering Failure Analysis*, vol. 161, no. 9, p. 108260, 2024.
11. L. Rónai, J. Lénárt, and T. Szabó, "Vibration measurement of a screening machine," *International Journal of Engineering and Management Sciences*, vol. 5, no. 3, pp. 116–123, 2020.
12. Z. Li, J. Liang, P. Jia, and X. Tong, "Parameter optimization and mechanism research of double-layer variable screen surface vibrating screen," *Particulate Science and Technology*, vol. 41, no. 5, pp. 661–673, 2023.
13. L. L. Zhao, C. L. Duan, H. S. Jiang, H. X. Li, Y. M. Zhao, and Q. J. Zheng, "DEM simulation of size segregation of binary mixtures of cohesive particles under a horizontal swirling vibration," *Powder Technology*, vol. 404, no. 5, p. 117456, 2022.
14. Z. Li, J. Liang, H. Zhou, S. Zheng, and X. Tong, "Study on the screening performance and parameter optimization of linear vibrating screen under the influence of sieve plate airflow," *Particulate Science and Technology*, vol. 42, no. 7, pp. 1098–1114, 2024.
15. J. Qi, J. Gao, S. Chen, W. Chen, L. Yang, H. Meng, and Z. Kan, "Parameter optimization of a conveying and separating device based on a five-stage screw and vibrating screen for tiger nut harvesters," *Agriculture*, vol. 14, no. 5, pp. 1–25, 2024.

16. J. Qi, M. Pei, Z. Kan, and H. Meng, "Parameter optimization and testing of a conveying and soil-removing device for tiger nut (*Cyperus esculentus*) mechanical harvesting," *Processes*, vol. 11, no. 1, pp. 1–19, 2022.
17. X. Jin, Y. Zhuo, C. He, Z. Xie, and Y. Shen, "Design and optimisation of rotary vibrating screening process in silicon photovoltaic panel recycling: A particle-scale model study," *Powder Technology*, vol. 440, no. 5, pp. 1–17, 2024.
18. E. A. Padilla-García, R. D. Cruz-Morales, J. González-Sierra, D. Tinoco-Varela, and M. R. Lorenzo-Gerónimo, "Design, assembly, and control of a differential/omnidirectional mobile robot through additive manufacturing," *Machines*, vol. 12, no. 3, pp. 1–20, 2024.
19. Y. Azzoug, M. Sahraoui, R. Pusca, T. Ameid, R. Romary, and A. J. M. Cardoso, "High-performance vector control without AC phase current sensors for induction motor drives: Simulation and real-time implementation," *ISA Transactions*, vol. 109, no. 3, pp. 295–306, 2021.
20. M. Zhou, C. Sun, S. A. Naghavi, L. Wang, M. Tamaddon, J. Wang, and C. Liu, "The design and manufacturing of a patient-specific wrist splint for rehabilitation of rheumatoid arthritis," *Materials & Design*, vol. 238, no. 5, pp. 1–12, 2024.
21. S. Thomy, X. Margueron, J. S. Ngoua Teu Magambo, R. Bakri, and P. Le Moigne, "Conception of high-frequency power planar transformer prototypes based on FabLab platform," *Electricity*, vol. 3, no. 1, pp. 1–15, 2021.
22. M. Parise, D. Passarelli, P. Berrutti, V. Roger, D. Longuevergne, and P. Duchesne, "Fabrication experience of the pre-production PIP-II SSR2 cavities at Fermilab," *arXiv preprint*, 2022. Available: <https://arxiv.org/abs/2209.02496> [Accessed by 12/09/2024].
23. W. Zhang and D. Li, "A 4D-printed self-folding spatial mechanism with pre-stressed response properties," *Machines*, vol. 11, no. 1, pp. 1–15, 2023.
24. M. Jiang, Z. Zhou, and N. Gravish, "Flexoskeleton printing enables versatile fabrication of hybrid soft and rigid robots," *Soft Robotics*, vol. 7, no. 6, pp. 770–778, 2020.
25. M. Kumar, A. M. Sidpara, and V. Racherla, "Finishing performance of polyurethane-based flexible tools fabricated using solvent casting and particulate leaching method," *J. Manuf—process.*, vol. 90, no. 3, pp. 166–179, 2023.
26. Y. Wu, Y. Song, W. Wang, Z. Lv, K. Zhang, X. Zhao, Y. Fan, and Y. Cui, "Application of multi-scale information semi-supervised learning network in vibrating screen operational state recognition," *Measurement*, vol. 238, no. 10, p. 115264, 2024.
27. S. Kang, W. Liu, J. Wang, H. Song, W. Yuan, and C. Huang, "Self-adaptive 3D lattice for curved sandwich structures," *Addit. Manuf.*, vol. 54, no. 6, p. 102761, 2022.