Fabrication and Performance Evaluation of a Mechanical Sieve Shaker

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Abstract
This paper presents the details of the fabrication and testing of a mechanical sieve shaker suitable for sand grain size analysis in the foundry industry. It consists of a set of stacked sieves mounted on a shaker unit, which is agitated by means of two bevel gears that produce rotary motion of the sieves. Several fabrication techniques such as welding, machining, etc., are adopted for the fabrication of the machine. Dry clay-free sand sample was tested with the machine for operational effectiveness and particle size distribution. The result shows that the machine is suitable for sieving sand grain size of the order of 0.1 to 1.0mm but cannot sieve larger particles such as gravel. The fabricated mechanical sieve shaker performed well with high sieving efficiency, reliability and durability. The particle sieving efficiency ranges from 92 to 97%.

Keywords: *Sieve shaker, Fabrication, Sand grains, Sand grain distribution, Sieves*

1. Introduction

The quality of product achieved by sand casting is partly a function of the kind of sand used during moulding. Quartz and other silica rock particles are the source of silica sand which is commonly used in moulding (Chipil and Basal, 2014). However, the natural sand does not possess the actual properties needed for moulding. It consists of different shaped and sized particles (particle size distribution), responsible for important physical and mechanical properties of the product (Hagen et al, 1987).

If the particle size distribution changes during manufacturing process, then the quality of the finished product will also change. Hence only a continuous monitoring of the particle size distribution can maintain constant product quality (Ayodeji et al, 2014; Scott and Tim, 2015).

In order to determine the particle size distribution of sand, sieving is employed. Sieving is a unit operation carried out by allowing solid particles of different sizes to pass through the pores of an orderly arranged set of stacked sieves in a manner of the particle sizes and shape (Abubakar et al, 2015).

Numerous studies (Keshun, 2009; Ujam and Enebe, 2013; Christopher and Robinson, 2014; Ayodeji et al, 2014) reveal the fabrication of electrically operated sieving machines, in which agitation and vibration of the sieves are accomplished via electric motor. The sieves are vibrated and rotated about its axis. These designs equally work in similar manner with the Electromagnetic sieve (Ujam and Enebe, 2013; Smith, 1990), in which a combined action of electricity and magnetism is utilized to operate the sieves. The sieving operation is achieved by either rotary or vertical motion, or a combination of these thereof.

In other designs (Simolowo and Adeniji, 2011; Oladeji, 2012; Eccless and Ekwue, 2008), vibrating the sieves may be achieved by means of pulley and belt drives operated by electric motor. The pulley system is supported on a shaft mounted on bearings that facilitate both lateral and vertical oscillation with amplitude of 32mm in each direction. A special type of the sieve shaker is the Pedal driven type (Abubakar et al, 2015; Smith, 1990) wherein, sieving is achieved by driving the set of sieves by a chain – sprocket mechanism using pedals. The sieves vibrate vertically. In all these designs, the sieving method can be vibratory sieving, horizontal sieving, vertical sieving, tap sieving, air jet sieving or a combination of two or more these methods (Jacob et al, 2015; Oladeji, 2012). In the vibratory sieving method, the sample is thrown upwards by the vibrations of the sieve bottom and falls back down due to gravitation forces (Ayodeji et al, 2014). The tap sieve shaker sieves the sample via a horizontal circular movement superimposed by a vertical motion generated by a tapping pulse (Rajput, 2010). Air jet sieving involves the use of only one sieve in which the material on the sieve is moved by a rotating jet of air (Adebayo, 2014).

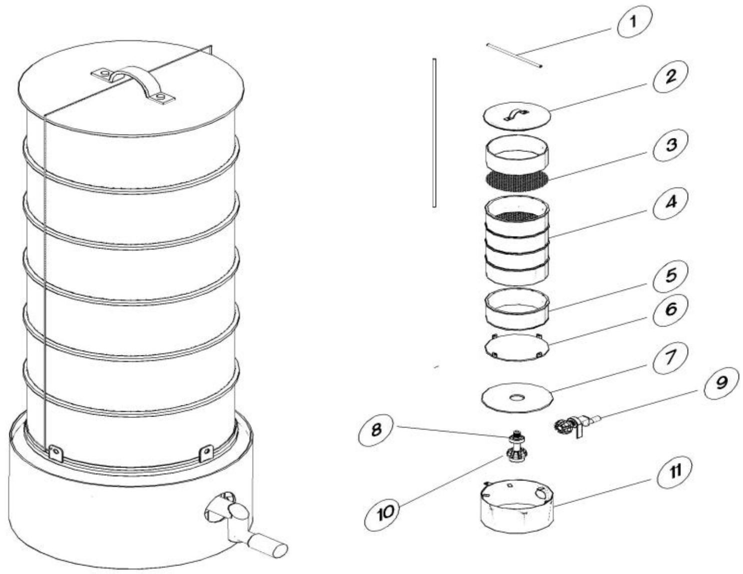
In this work, a mechanical sieving machine that uses bevel gears to sieve sand grains is fabricated and tested for operational effectiveness and sand particle size analysis. The machine does not require any input power source for its operation as it is manually operated. It is proposed to be used for experimental research purposes even in remote areas where power supply is a problem.

2. Materials and Methods

The materials used for the fabrication of the sieve shaker are mild steel sheets, aluminium sheets, mild steel bars, bevel gears and bearings. Other materials used were mild steel wire mesh of different mesh sizes and bolts and nuts. These materials were chosen because of their excellent mechanical and physical properties such strength, ductility, machinability, weldability, availability, corrosion resistance, weight and affordability (Rajput, 2010; Adebayo, 2014).

2.1 Fabrication

The sieving containers (230mm diameter x 70mm high) are fabricated from aluminium sheets (2mm thick) with the cover also of aluminium sheet (2mm thick). At the end of each container is attached a sieving mesh achieved by folding and use of adhesive bond. The sieving container has an average volume of 2908.7cm^3. The component by component description of the sieving machine is given in Figure 1.



Part No.	Part name	Quantity
1	Sieve guide	1
2	Cover	1
3	Mesh	5
4	Sieves	5
5	Receiver pan	1
6	Sieve carrier	1
7	Driving system cover	1
8	Bearings	3
9	Handle	1
10	Bevel gears	2
11	System housing	1

Figure 1 Isometric and exploded views of the mechanical sieve shaker

The sieve guide is made of mild steel rod of 5mm diameter and threaded at one end to a length of 210mm. The bevel gears are mounted on mild steel shafts machined on the centre lathe machine and supported on two roller bearings. These gears are set at right angles to each other. The system housing is also fabricated from mild steel sheet (3mm thick). Figure 2 shows the pictorial views of the fabricated sieve shaker. The sieve carrier and system container are fabricated from 3mm thick mild steel sheet. The system housing is formed by folding a 3mm thick rectangular mild steel sheet into an open cylinder. Then one end is closed with a circular mild steel sheet of diameter 290mm, by arc welding. The sieve cover is fabricated from 3mm thick aluminium by folding, cutting and trimming processes.

Figure 2 Pictorial views of the sieve shaker

2.2 Experimentation and Performance Analysis

The performance analysis of the newly designed sieving machine was carried out by comparing grain size distribution (cumulative grading curve) obtained with the machine for a sand sample with that obtained using manual process of sieving. Clay-free sand grains were obtained from the Ken Saro-Wiwa Polytechnic campus. The sand was sun dried for 2 days to ensure that it is completely free of moisture. 200g of the dried sand was placed in the top sieve of the fabricated sieving machine and covered, with the other sieves stacked in the order of decreasing mesh size from the top to the pan. The sieve shaker is then rotated properly by turning the machine handle for about 10 minutes. The various sieves are then taken apart and its content weighed, including the pan. The experimental procedure for the manual sieving entailed shaking the six set of sieves unstacked in the machine with hand with equal amount of sand sample on the top sieve for the same duration as with machine sieving. The content in each sieve is also weighed, including the pan.

On the basis of the total weight of sample taken and the weight of sand retained on each sieve, the percentage of the total weight of soil passing through each sieve is as calculated below (Oladeji, 2012):

$$P = \frac{W_r}{W_t} \times 100\% \quad (1)$$

where P = percentage of soil retained on a particular sieve
W_r = retained weight (g), on each sieve
W_t = total weight of sand taken (g)

The cumulative percent of sand retained is obtained as

$$CP = (PL + P) \quad (2)$$

Where PL = percent on all sieves of larger sizes

The sieving efficiency is obtained as

$$\varepsilon = \frac{W_{rm}}{W_{rmc}} \times 100\% \quad (3)$$

where W_{rm} = retained weight (g), on each sieve for manual sieving
W_{rmc} = retained weight (g), on each sieve for machine sieving

3. Results and Discussion

The result of sand grain size distribution and sieving efficiencies as obtained with the fabricated sieving machine and manual process is given in Tables 1 & 2 and graphically represented with Figures 3 & 4.

Table 1 Sand grain analysis

S/N	Sieve No.	Retained mass [g]		Retained percentage [%]		Cumulative percentage [%]	
		Machine	Manual	Machine	Manual	Machine	Manual
1	1	15	15	7.5	7.5	7.5	7.5
2	2	32	31	16.0	15.5	23.5	23.0
3	3	20	20	10.0	10.0	33.5	33.0
4	4	29	31	14.5	15.5	48.0	48.5
5	5	25	30	12.5	15.0	60.5	63.5

6	Pan	79	73	39.5	36.5	100.0	100.0

Table 2 Machine sieving efficiency

S/N	Sieve No.	Retained mass [g]		Efficiency [%]
		Machine	Manual	
1	1	15	15	100
2	2	32	31	97
3	3	20	20	100
4	4	29	31	155
5	5	25	30	120
6	Pan	79	73	92

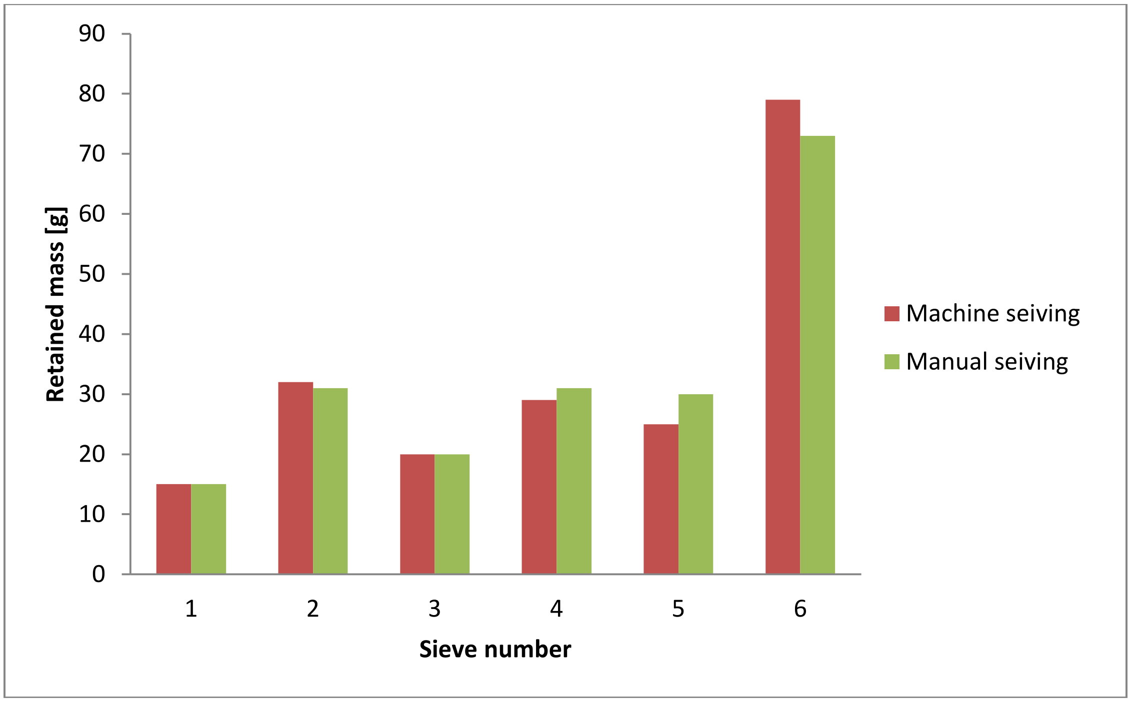


Figure 3 Variation of retained mass with sieve number as obtained with manual and machine sieving

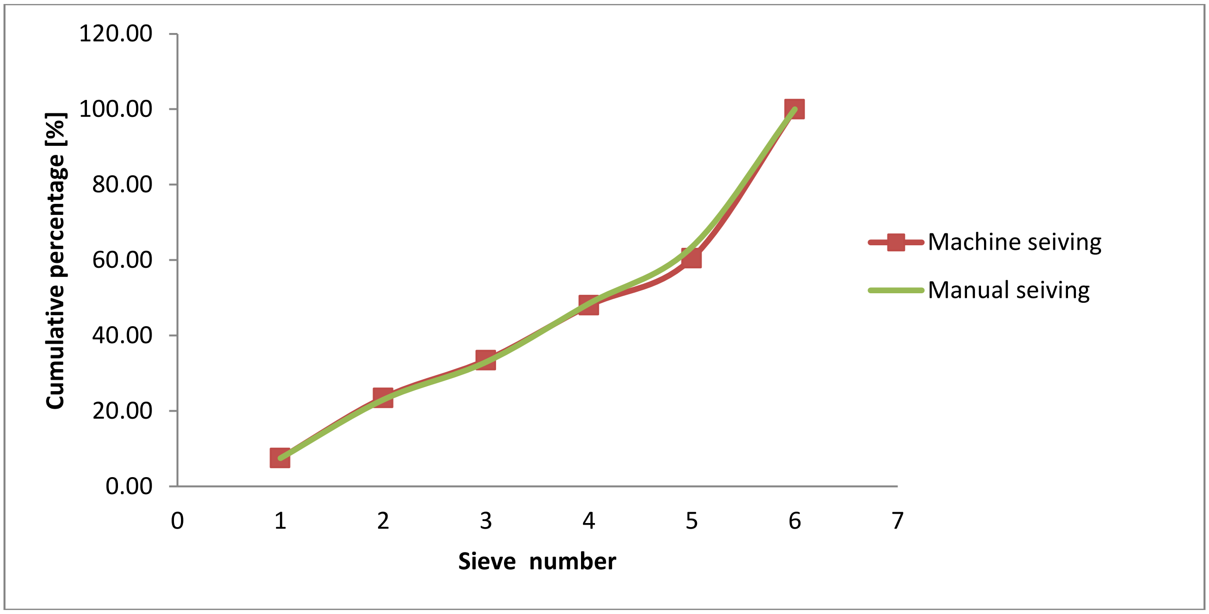


Figure 4 Cumulative grading curves for sand sample as obtained with manual and machine sieving

Figure 4 shows that the cumulative amount of the grain retained on the sieves increases with the sieve number. The increasing order of the sieve number, represents decreasing mesh size. For instance, sieve number 1 is of higher mesh size than sieve number 2. Similarly, sieve number 2 is of higher mesh size than sieve number 3 and so on in that order. The graph thus indicate that the machine cannot sieve effectively larger sand particles such as gravel but can sieve effectively sand grain size of the order of 0.1 to 1.0 mm, considering the cumulative amount retained with sieves of smaller meshes. This result compares with those of Abubakar et al (2015), in which a pedal driven pulverizing and sieving machine was designed for dewatered grated cassava, implying that the fabricated machine in this report can effectively be used for similar purpose. Table 2 indicates that the fabricated machine has relatively very high sieving efficiency when compared with manual sieving. This contrasts with the specifications of ASTM that the mechanical shaker must agitate the material until it meets the 10% or 50% particle passing when compared to a hand sieved sample (Christopher and Robinson, 2014). The deviation might be caused by human factors in sieving such as inconsistent and non-uniform sieving, etc. However, the high efficiency, calculated indicates that the machine's durability is high. The exceptional high efficiencies calculated are actually not feasible as no machine can be 100% efficient, but they merely represent the excesses of theoretical evaluations.

4. Conclusion

The fabricated mechanical sieve shaker performed well with high sieving efficiency, reliability and durability. The particle sieving efficiency ranges from 92 to 97%. Though in most cases, it exceeds 100% which is not feasible with any practical system and is thus attributable to human factors and disparity between theoretical evaluations and real practice. The results show that the machine cannot sieve effectively larger sand particles such as gravel but can sieve effectively sand grain size of the order of 0.1 to 1.0 mm.

References

Abubakar, M., Abdulkadir, B. H., Katsina, C. B., Abdulkarim N., Olawale, J. O. and Dele, S. J. (2015) Fabrication and Performance Evaluation of a Pedal Driven Pulverizing and Sieving Machine for Dewatered Grated Cassava, American J. Eng. Research, 4(2), 146 152.

Adebayo, E.O. (2014) Corrosion Control of Petroleum Pipelines, B. Eng. Project, Department of Mechanical Engineering, University of Illorin, Illorin.

Ayodeji, S. P, Olabanji, O. M. and Akinnuli, B. O. (2014) Development and Performance Evaluation of a Sieving Machine for Poundo Yam Process Plant, J. Emerging Trends in Eng. and Appl. Sc. 5(4), 229-236.

Chipil, W. S. and Basal, F. (2014) A rotary sieve method for determining the size distribution of Soil particles, Soil Sci. 56, 95 – 100.

Christopher, J. and Robinson, P.E. (2014) Mechanical Shaker: Time and Sieving Efficiency Determinations, Retrieved, https://www.cmec-accreditation.com/wp-content (Retrieved 10/01/2017).

Eccless, C. and Ekwue, E. I. (2008) A mechanical sieve shaker for dry sand samples, W. Indian J. Eng., 30(6), 13 – 23.

Hagen, L. J., Skidmore, E. L. and Fryrear, D. W. (1987) Using two sieves to characterize dry soil aggregate size distribution, Transactions of the ASAE, 30, 162 – 165.

Jacob, L., Ngabea, S. and Wilfred, I.O. (2015) Design, Fabrication and Performance Evaluatio of a Magnetic Sieve Grinding Machine, Global J. Eng. Sci., 2(8), 65 – 72.

Keshun, L. (2009) Some factors affecting sieving performance and efficiency, American J. Powder Tech. 193, 208 – 213.

Oladeji, A. O. (2012) Design, construction and testing of a dry sand sieving machine, J. Appl. Sci. and Environ. Mgt., 16(3), 241 - 243.

Rajput, R. K. (2010) Material Science in Engineering, Kataria & Sons Publishing Co. Ltd. New Delhi.

Scott, B. and Tim, H. (2015) Evaluating particle size, www.citeseerx.ist.psu.edu, (Retrieved 18/11/2016).

Smith, G. N. (1990) Elements of Mechanics, 6th Edition, Blackwell Series, London.

Simolowo, O. E. and Adeniji, O. O. (2011) Prototype design and performance analysis of a sieving machine for improved food-slurry processing in Nigeria, Indian J. Sci. and Tech., 4(12), 1639 – 1643.

Ujam, A. J. and Enebe, K. O. (2013) Experimental analysis of particle size distribution using electromagnetic sieve, American J. Eng. Research, 2(10), 77 – 85.