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Performance Evaluation of a Miniature Pulse Machine Energized by Human Powered Flywheel motor

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Abstract. The most pulses are exported from India than any other country in the globe (eaten legumes). The Indian cuisine relies heavily on pulses as a primary source of protein and other nutrients. In point of fact, pulses are the richest source of plant-based proteins in the world. Pigeon pea, also known as Tur (Cajanuscajan), is the second most valuable type of pulse that India produces. This type of pulse is most commonly processed into a product known as "Tur dhal/pulse." The pulse processing business has a significant amount of untapped potential for both value addition and the creation of new jobs. A high processing efficiency will be beneficial not only to the dal miller but also to the revenue of the producer. The primary emphasis of the present inquiry was an analysis of the performance of a miniature pulse machine that was powered by a human-powered flywheel motor (HPFM). To accomplish the same goal, a mathematical formulation was developed utilizing a dimensional analytical approach to determine the production rate in a small pulse machine that was powered by HPFM. This was done in order to obtain the same result. The production rate is related to a number of independent variables, including the feed rate, angle of feeding, air flow rate, speed, mean diameter of roller, and bulk density. The relationship between these three factors has been established. The production rate of the machine can range from as low as 30 kg/hr to as high as 80 kg/hr, depending on the setting. The conclusions drawn from quantitative analysis and empirical research are not that dissimilar to one another. This demonstrates that the model that was proposed is quite accurate in forecasting the result of the situation.

Keywords-*pigeon pea, miniature pulse machine, Human powered flywheel motor, production rate.*

INTRODUCTION

Pulses are an imperative protein source in the diets of India's enormous vegetarian populace[1]. The nation scored first in worldwide consumption and production of pulses, accounting for 22 percent of total world production and 33 percent of total world area[2]. However, due to rising population, pulse availability (32-35 g/day/capita) has fallen significantly below the Indian council of Medical Research (ICMR) suggested amount of 47 g/day/capita, even when additional protein sources are taken into account[3]. This might be related to the country's nearly flat pulse output (about 13-15 mt) during the previous two decades[4]. An approximate 75% of pulse output is processed into dal in commercial mills, the majority of which are situated in metropolitan areas [5]. Producers produce their raw grain immediately after harvesting at quite a cheap cost (now about Rs. 55.00 per kg for pigeon pea) and buy dal for roughly Rs. 100.00 per kg. As a result, there is indeed a significant price difference among raw resources and produced dal [6]. The middlemen and processors collect the lion's share of this earnings. This imbalance can be remedied if small-scale dal mills (Mini Dal Mills) are made available in rural areas and growers are motivated into becoming processors of their own product [7]. There's around 15,000 dhal mills throughout India[3], with approximately 2000 dhal mills having a normal output of 10–20 Tons/day [8]. Pulse dehulling is a time-honored technique in which numerous procedures and devices have been created via trial - and - error. In pulse processing, dehulling is an essential unit operation. As a result, the procedures used for dehulling and the machinery used for dehulling are not consistent around the globe [9]. The presence of a film of gum seen between hulls as well as the cotyledons of the pulses affects the hull removing effectiveness. To remove the link between the hull and the cotyledons, many pre-milling treatments procedures were devised. Attempts have also been made to create reliable techniques and pulse dehulling equipment in order to reduce dehulling wastage and increase quality of the product [10].

Pulses dehulling is often accomplished by use of coarse forces [11]. Vertical stone mills were widely employed in India for dehulling pulses in the early 1970s. Because of grain breakage of upto 20 to 45 percent and lower quality of product, stone mills are no longer utilized [3]. As a result, numerous devices for dehulling pulses have been created [12]. The emery-coated cylinder-concave system is the most typical commercial equipment for pulse dehulling [13,14]. In dehulling machines, emery grits ranging from 14/16 to 36/40 mesh are employed [15]. Carborandum is crystalline aluminium oxide with chromium, titanium, and iron traces, whereas emery is finer-grained contaminated carborandum containing Aluminium oxide (Al2O3)[16]. Finer-mesh emery roller is occasionally utilized for polishing and pitting, while big grit emery are utilized in dehulling machinery rolling[17]. Roller's rotational speed ranges from 600 to 1000 rpm, with a greater speed suggested for pigeon pea. Depending on the type of pulse being treated, mild Steel sheet with round holes is often utilized as concave. Emery-coated rollers with lengths of 600–900mm and diameters of 200–350 mm are positioned at a 140-degree angle from horizontal[12].

Machines for pulse dehulling created by several Indian research institutes were personalizing diversion of dehulling machines utilized in commercial pulse milling companies. All of the machines were worked upon the principle of abrasion, and can dehulled 80 to 88 percent of the pigeon pea within 3 to 4 passes using different pretreatments. For untreated pigeon pea grains, the dehulling efficiencies of the CIAE (Central Institute of Agricultural Engineering) dhal mill, the IIPR (Indian Institute of Pulses Research) dhal chakki, and the CFTRI (Central Food Technological Research Institute) dhal mill were 40.35 percent, 49.53 percent, and 45.35 percent, respectively[18]. Some researchers[19] also found 43.3 percent efficiency for with the CFTRI small dhal mill. As a result, pretreatment of pulses significantly increases the performance of dehulling devices. Excluding the study published for wet dehulling of guar seeds[20], no organized independent research to pulses dehulling at greater moisture contents were documented. The seeds are next dehulled with an abrasive grinder. According to author[20], following pretreatment, the guar seed has moisture content (d.b.) of 72–78%.After pretreatment with new dehulling equipment, the seeds are dehulled at the same moisture content within a set time frame. This method produced in the dehulling of around 92 percent and less than 3 percent fractured formation. More research work is desirable to determine that whether technology created by Vishwakarma[20] can also be employed for pulse dehulling.

The dehulling of pulses is affected by a number of variables. These factors are shown in the Figure 1.

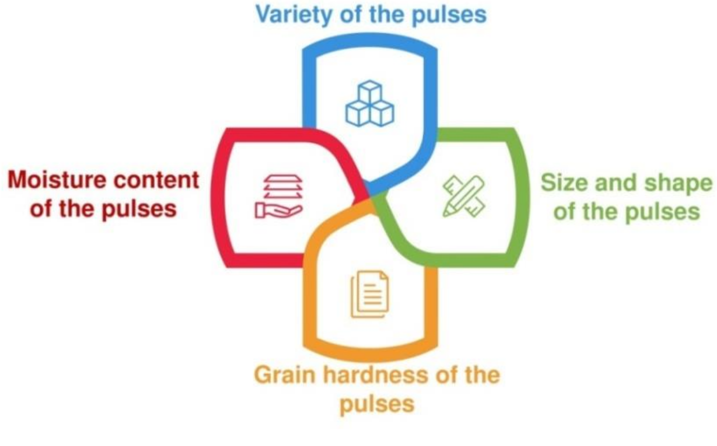

FIGURE 1. Several elements that influence pulse dehulling

According to the aforementioned literature analysis, several flaws are: 1. limited market availability as farmers sell raw materials, 2. a labour scarcity and high labour costs. 3. Brokerage and transformation costs, loading and unloading costs, and 4. Existing pod separation systems are time consuming and costly. Aside from that, the different machines' claimed output rates are fairly modest. As a result, the current project was undertaken to assess the performance of the Miniature Pulse Machine. To accomplish this, a semi-automatic Miniature Pulse Machine powered by a human-powered flywheel motor was constructed. The Miniature Pulse Machine's performance was also assessed in terms of production rate and other independent factors. Miniature Pulse Machine may earn a significant income while working flexible hours to meet the demands of housewives. This designed equipment is also capable of creating jobs for rural residents.

METHODS

Mathematical Modeling of the Miniature Pulse Machine

Production rate involves all action from the feed through the hopper to the collection in bin. The physical quantity affecting the production rate includes both physical properties and machine parameters. A mathematical model formulation was done using a dimensional analytical approach to determine the production rate in miniature pulse machine energized by human powered flywheel motor. Buckingham's pi theorem is suggested as a way to establish non-dimensional parameters that may be used to describe the links between the physical variables involved in the process under investigation and the basic dimensions. Buckingham's pi theorem method was successfully utilized by the different researchers in agricultural[21-31] and industrial[32-44] applications. The relationship is established between the production rate and independent variables which comprise; feed rate, angle of feeding, air flow rate, speed, mean diameter of roller, and bulk density. The behavior of dependent and independent variables consisting of multiple operation environments may be predicted using formulating the mathematical associations.

The model developed by Buckingham's pi theorem for the Miniature pulse machine is shown in equation 1.

$$Pr = 0.089355\ X\pi_1^{0.248774} X\pi_2^{0.065095} X\pi_3^{0.051511} \tag{1}$$

Experimentation of Miniature Pulse Machine

The Schematic sketch of Miniature pulse machine energized by HPFM is indicated in figure 2.

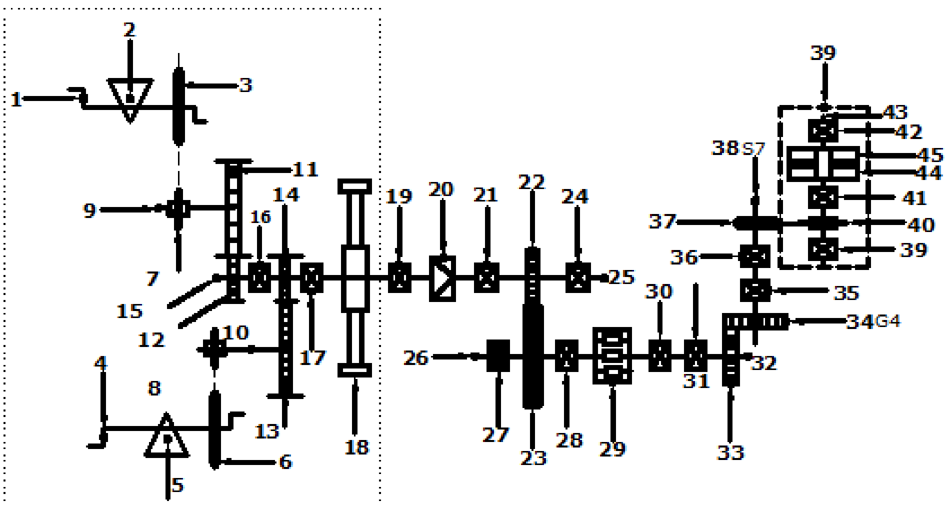

FIGURE 2. Schematic sketch of Miniature pulse machine energized by HPFM

1. Pedal, Pe1; 2. Seat, Se1; 3. Big chain sprocket, BCs1; 4. Pedal, Pe2; 5. Seat, Se2; 6. Big chain sprocket, BCs2: 7. Small chain sprocket, SCs2; 8. Small chain sprocket, SCc1; 9. Shaft, S1; 10. Shaft, S2; 11.Gear G1; 12 Pinion P1; 13. Gear G2; 14 Pinion P2; 15. Shaft S3; 16.Bearing, B1; 17.Bearing B2; 18.Flywheel, FW; 19.Bearing, B3; 20.TFC (Torsional frictional clutch); 21.Bearing, B4; 22.Pinion, P3; 23.Gear, G3; 24.Bearing,

B5; 25.Shaft, S4; 26. Shaft, S5: 27.Bearing, B6; 28. Bearing, B7; 29, Coupling C, 30.Bearing, B8; 31. Bearing, B9; 32. Shaft S6; 33. Pinion 4 (Bevel), 34. Gear G4 (Bevel), 35. Bearing B10; 36. Bearing B11; 37. Bigger Pulley PL1: 38. Shaft S7; 39. Miniature Pulse Machine (MPM); 40.Smaller Pulley PL2; 41. Bearing, B12; 42. Bearing, B13; 43. Shaft S8; 44.Rotating Emery wheel Esw; 45.Stationary Emery wheel, Erw; Free wheel,Fr1;Free wheel,Fr2; Bottom bearing,Bb1; Bottom bearing,Bb2;

The schematic of Miniature pulse machine energized by HPFM is depicted through Figure 2. The tandem driven HPFM process unit is depicted in the figure by dot line. A tandem drive bicycle unit is fond of to drive the flywheel shaft with appropriate speed amplification device. The human energy is used to store in the form of kinetic energy in a flywheel after certain pedaling progression and the obtainable energy of a flywheel is then utilized for the appropriate work.

FIGURE 3. Developed experimental set-up of Miniature pulse machine energized by HPFM

Developed experimental set-up of Miniature pulse machine energized by HPFM as indicated figure 3 were chosen for the present study was developed by using the locally available materials. The developed machine is capable to cater the needs of small entrepreneurs and farmers for dehusking and splitting of pulse crops. The capacity of the mill ranges from 50 to 100 kg/ h for different pulse crops. The mill basically comprises of a feeding hopper, milling section, positive feed auger, and a cyclone separator. The full factorial method of design of experimentation was chosen to perform the experimentation. The various independent variables feed rate (50-75-100 kg/hr), angle of feeding (5-10-15 degrees), air flow rate (5-10-15 m/sec), speed (200-300-400 rpm), mean diameter of roller (0.135 m), and bulk density (810 kg/m^3) were varied to find the production rate. The material i.e. sun dried tur dhal/pulse is cleaned to avoid any foreign contamination. The material i.e. sun dried tur dhal is fed into grinding wheels through positive feed auger. The feed rate of the materials is controlled by the sliding gate which is provided at the base of the hopper. The clearance between the disks can be adjusted according to grain size for different pulse crops.

The wheel rotates at about 200 rpm, 300 rpm, and 400 rpm. After entry of the seeds into the wheels, dehulling and splitting takes place due to friction between seeds and grinding wheels. Eventually dhal will come out of wheels and flow downward via bottom hopper. The dhal along with outer shells, crushed seeds and flour is collected in a container. The dhal is then separated from other material by winnowing and crushed grains and flour along with outer shell is collected in separate bin.

RESULTS AND DISCUSSIONS

Effect of the Feed Rate on the Performance of Production Rate

The figure 4 shows the comparative analysis of the effect of the feed rate on the performance of production rate. From figure 4, it can be seen that maximum production rate obtained at the feed rate of 60 kg/ hr, 90 kg/ hr, &120 kg/ hr, is 62kg/ hr, 68kg/ hr, &79kg/ hr respectively. Whereas, minimum production rate obtained at the feed rate of 60 kg/hr, 90 kg/hr, &120 kg/hr, is 30kg/hr, 34.5kg/hr, &39kg/hr respectively.

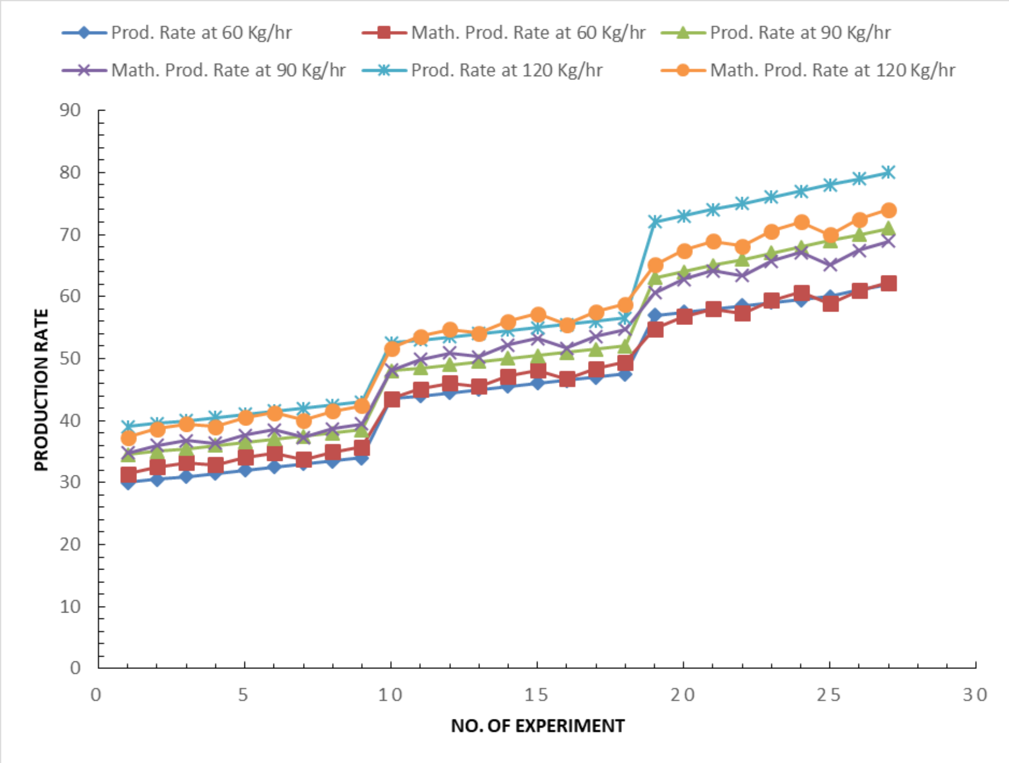

FIGURE 4. Effect of the feed rate on the performance of production rate

The average production rate obtained at the feed rate of 60 kg/hr, 90 kg/hr, & 120 kg/hr, is 45.55 kg/hr, 51.17kg/hr, &57.17kg/hr respectively. The average % error between the actual results and mathematical model results are 4.38%, 6.25%, & 4.23% for the feed rate of 60 kg/hr, 90 kg/hr, & 120 kg/hr respectively. The result obtained by mathematical data & experimental data is very close to each other. In fact, at some points they are overlapping each other. This reflects, the developed model is very much reliable to predict the output.

Effect of the Feed Angle on the Performance of Production Rate

Figure 5 presents a comparative examination of the different effects that different feed angles have on the performance of the production rate. Figure 4 shows that the maximum production rate that can be attained at the Feed angle of 5 degrees, 10 degrees, and 15 degrees, respectively, is 74 kilograms per hour, 77 kilograms per hour, and 80 kilograms per hour. In contrast, the least output rate that may be achieved when the feed angle is 5, 10, or 15 degrees is 30, 31.5, or 33 kg per hour, respectively. At a feed angle of 5 degrees, 10 degrees, and 15 degrees, the average production rate is 49.44 kilograms per hour, 51.28 kilograms per day, and 53.17 kilograms per day, respectively. 4.16 percent, 5.36 percent, and 5.35 percent are the respective average percentages of inaccuracy when comparing the actual results to the results of the mathematical model when the Feed angle was 5, 10, and 15 degrees, respectively.

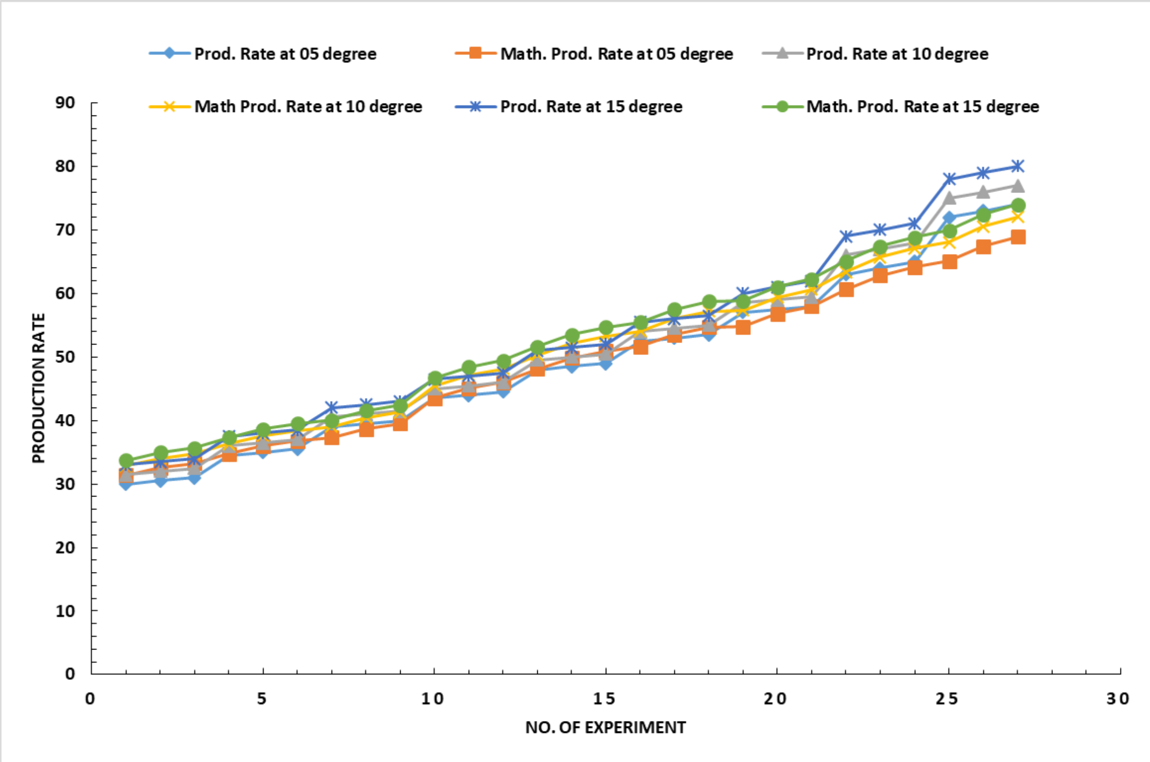

FIGURE 5. Effect of the Feed angle on the performance of production rate

The conclusions drawn from quantitative analysis and empirical research are not that dissimilar to one another. In point of fact, their movements occasionally overlap one another. This demonstrates that the model that was proposed is quite accurate in forecasting the result of the situation.

Effect of the Air Flow Rate on the Performance of Production Rate

The figure 6 shows the comparative analysis of the effect of the Air flow rate on the performance of production rate. From figure 6, it can be seen that maximum production rate obtained at the Air flow rate of 5 m/sec, 10 m/sec, & 15 m/sec, is 78Kg/hr, 79Kg/hr, &80Kg/hr respectively. Whereas, minimum production rate obtained at the Air flow rate of 5, 10, & 15 m/sec, is 30 Kg/hr, 30.5Kg/hr, &31Kg/hr respectively. The average production rate obtained at the Feed angle of 5, 10, & 15 degrees, is 50.67Kg/hr, 51.29 Kg/hr, &51.95 Kg/hr respectively. The average % error between the actual results and mathematical model results are 2.80%, 6.95%, & 5.11% for the Feed angle of 5, 10, & 15 degrees, respectively. The result obtained by mathematical data & experimental data is very close to each other. In fact, at some points they are overlapping each other. This reflects, the developed model is very much reliable to predict the output.

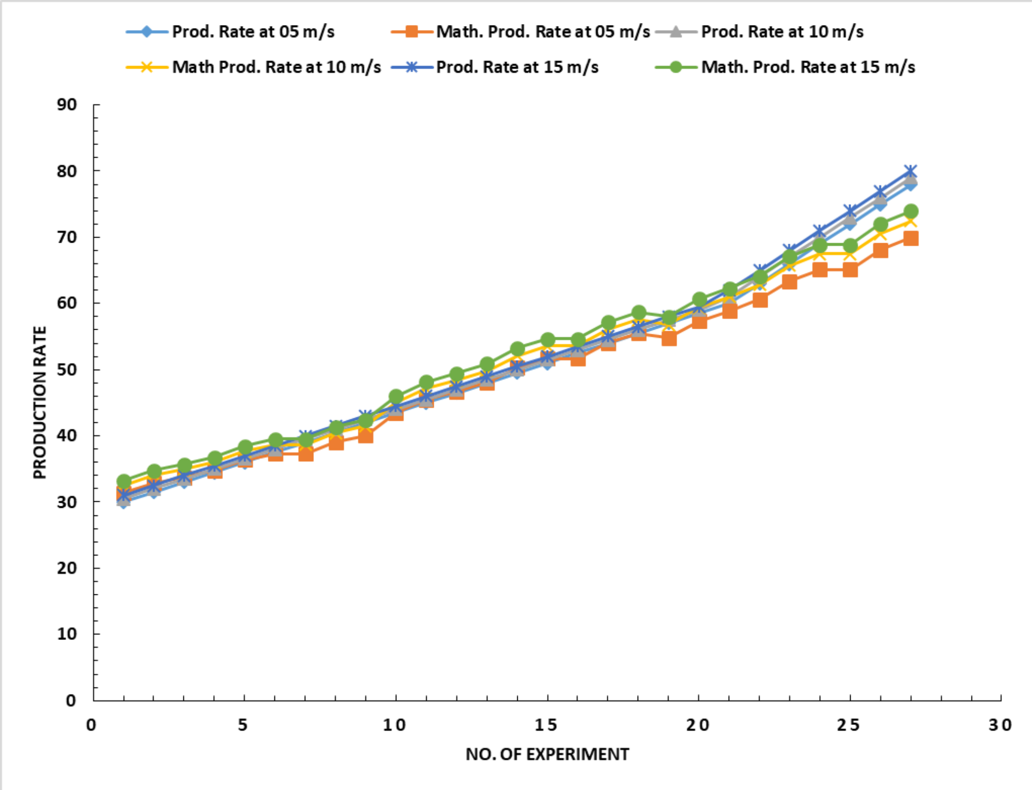

FIGURE 6. Effect of the Air flow rate on the performance of production rate

Effect of the Speed on the Performance of Production Rate

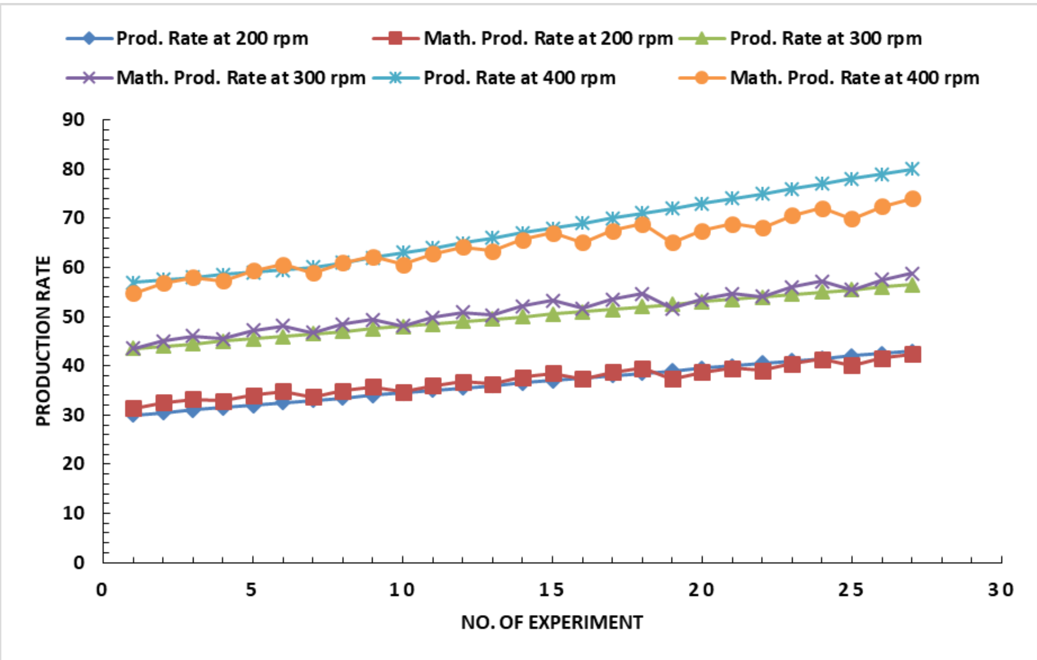

FIGURE 7. Effect of the Air flow rate on the performance of production rate

The figure 7 shows the comparative analysis of the effect of the speed on the performance of production rate.

From figure 7, it can be seen that maximum production rate obtained at the speed of 200 rpm, 300 rpm &400 rpm, is 109 Kg/hr, 56.5 Kg/hr, & 80 Kg/hr respectively. Whereas, minimum production rate obtained at the speed of 200 rpm, 300 rpm &400 rpm is 30Kg/hr, 43.5Kg/hr &57Kg/hr respectively.

The average production rate obtained at the speed of 200 rpm, 300 rpm, &400 rpm, is36.5 Kg/hr, 50.00 Kg/hr, &37.39 Kg/hr respectively. The average % error between the actual results and mathematical model results are 2.59%, 6.66%, & 5.61% for the Feed angle of speed of 200 rpm, 300 rpm, &400 rpm, respectively. The results produced from mathematical data and experimental data are quite close. In fact, they are overlapping at several locations. This demonstrates that the established model is quite trustworthy in predicting the result.

CONCLUSION

The data acquired from the Miniature Pulse Machine Powered by Human Powered Flywheel Motor are encouraging due to the fact that they show that it generates more than a typical emery roller would. The machine has a production rate that is variable and may produce anywhere from 30 kilograms per hour down to a minimum of 30 kilograms per hour. With the equipment that we have right now, it is feasible to attain the maximum output rate that is conceivable, which is up to 80 kilograms per day. The feed rate (60-90-120 kg/hr), angle of feeding (five-ten-fifteen degrees), air flow rate (five-ten-fifteen metres per second), and speed are all factors that contribute to the significant increase in production that takes place when these variables are raised (200-300-400 rpm). The results that are determined by mathematical data and the outcomes that are determined by experimental data are remarkably comparable to one another. [Case in point:] In addition, the percentage of inaccuracy that can be found between the mathematical data and the experimental data is significantly less than 10%. This demonstrates that the model that is currently being utilized has a high degree of reliability when attempting to predict the result of the situation that is being modelled.

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