ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VIII [2015] Fascicule 4 [October – December]
ISSN: 2067 – 3809

[1.] S. UDHAYAKUMAR, [2.] P. PRABAKARAN,
[3.] S. SIVASUBRAMANIAM, [4.] S. GANESAN

FACTORS INFLUENCING CONVEYING VELOCITY OF PRISMATIC PARTS ON A VIBRATORY FEEDER

[1-4.] Department of Mechanical Engineering, PSG College of Technology, Coimbatore, INDIA

Abstract: Vibratory feeders are commonly used in industries for part feeding. There are several factors that affect the conveying velocity of parts on the vibratory feeder. Among these, the critical factors such as excitation frequency, amplitude of vibration, mass of part, co-efficient of friction and Length-to-width (L/W) ratio of the part were considered for experimental studies. The percentage of influence of each factor on conveying velocity was determined through ANOVA. Regression and Artificial Neural Network (ANN) models were developed to predict the velocity of prismatic parts on vibratory feeder. Comparison of results with experimental results revealed that ANN was able to predict closer than the regression model.
Keywords: Vibratory feeder, conveying velocity, regression, Artificial Neural Network

INTRODUCTION

Vibratory part feeders are commonly used in industries such as food processing, plastic component manufacturing, automobiles etc. Several literature focus on part motion in a vibratory feeder. Lim [1] performed a theoretical analysis of feeding on a track vibrating with simple harmonic motion. He considered excitation frequency, amplitude of vibration, co-efficient of friction and track angle as the factors affecting the conveying velocity of part on a vibratory feeder. He also developed a model to predict the conveying velocity based on the above said factors. Reznik et al [2] analyzed the part motion on a planar part feeder which had a longitudinally vibrating flat plate. They developed analytical expressions for feed rate. Ramalingam and Samuel [3] discussed the behavior of a linear vibratory feeder, used for conveying small parts. They considered barrel dimension, amplitude and angle of vibration, coefficient of friction and the operating frequency as the factors affecting the feed rate and conveying velocity of part the effect of these factors was determined experimentally. Udhayakumar et al [4] discussed the effect of excitation frequency, amplitude of vibration and trap inclination angle on conveying velocity of brakeliners on a vibratory feeder. The literature reported discussed the effect of factors individually on conveying velocity. Further, the literature on effect of Length-to-width (L/W) ratio of part on conveying velocity is very limited. In this paper, an attempt is made to determine the percentage of effect of factors such as excitation frequency, amplitude of vibration, mass of part, co-efficient of friction and Length-to-width (L/W) ratio of the part on conveying velocity on a vibratory feeder. Models to predict the conveying velocity of part was developed using Regression and Artificial Neural Network (ANN). The results predicted by the model were compared with the experimental results.

PARTS CONSIDERED

The factors considered were L/W ratio (Figure 1), mass (m), co-efficient of friction (μ), excitation frequency (f) and amplitude of vibration (A). The levels chosen for each factor is shown in Table 1. To vary the co-efficient of friction between the part and the feeder, four different materials made of steel, aluminium, brass and copper were chosen. The parts were fabricated according to the different L/W Ratio having different mass leading to 16 different parts as shown in Figure 2.

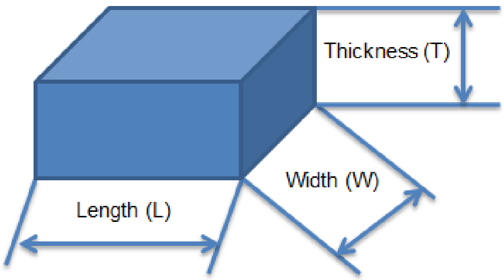


Figure 1. Prismatic part indicating the Length (L) and Width (W)

Table 1. Factors and levels chosen

S. No	Factors	Level-1	Level-2	Level-3	Level-4
1	L/W Ratio	1	1.5	2	2.5
2	Mass, M (g)	25	50	75	100
3	Co-efficient of friction, μ	0.37	0.39	0.41	0.45
4	Excitation Frequency, f(Hz)	28	30	32	34
5	Amplitude of vibration, A (mm)	0.5	0.6	0.7	0.8

Figure 2. Parts of different material with different L/W Ratio and mass: a) copper; b) steel; c) aluminum; d) brass

EXPERIMENTAL SET-UP

A feeder tray made of acrylic material is fabricated and mounted on electro-dynamic shaker table, as shown in Figure 3. The specification of the electro-dynamic shaker system is shown in Table 2. The control unit of the shaker system has provisions for adjusting the frequency and amplitude of vibration of the shaker. When a part is put on the feeder tray and the shaker system is switched on, the part moves forward due to the vibratory motion caused by the shaker.

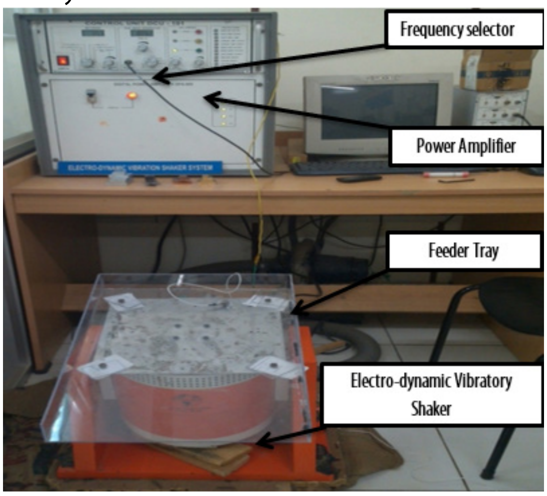


Figure 3. Experimental set-up

Table 2. Specification of electro-dynamic shaker

Armature diameter	100 mm
Mass of the armature	0.8 kg
Frequency range	Up to 4 KHz
Maximum displacement	12 mm (peak to peak)
Velocity	1.5 m/s
Shaker rotation	(±900)
Cooling	Air cooling

TAGUCHI'S DESIGN OF EXPERIMENTS

Robust design of experiments could be achieved by Taguchi method, wherein variation in a process is reduced. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. He developed a method for designing experiments to investigate how different factors affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design involves using orthogonal arrays to organize the factors affecting the process and the levels at which they should be varied. Instead of full factorial design, the Taguchi method tests only certain combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Since 5 factors were chosen at four levels, Taguchi's L16 (Table 3) orthogonal array was chosen for the experimentation.

Table 3. Taguchi's L16 Array

Experiment	P1	P2	P3	P4	P5
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	2	1	2	3	4
6	2	2	1	4	3
7	2	3	4	1	2
8	2	4	3	2	1
9	3	1	3	4	2
10	3	2	4	3	1
11	3	3	1	2	4
12	3	4	2	1	3
13	4	1	4	2	3
14	4	2	3	1	4
15	4	3	2	4	1
16	4	4	1	3	2

Based on the L16 orthogonal array, the experiments were conducted to determine the conveying velocity as the response. Each experiment was conducted five times and the mean conveying velocity was considered for further calculations.

ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA), developed by R.A.Fisher, is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups). In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal. The experimental data was fed as input to Minitab 17 software and based on ANOVA, the influence of each factor on response was determined. The percentage of influence of each factor on conveying velocity of part on a vibratory feeder is given in Table 4.

Table 4. Percentage of influence of each factor on conveying velocity

Input parameter	% of influence
L/W Ratio	0.989
M (g)	26.02
μ	6.33
f (Hz)	42.39
A (mm)	24.25

From Table 4, it can be observed that the frequency of vibration is the most influencing parameter followed by amplitude of vibration, mass of part and co-efficient of friction. The L/W ratio has no significant effect on conveying velocity.

REGRESSION ANALYSIS

Regression is another statistical tool for measuring relationship between variables [5]. Regression is used to predict the output values with the set of input parameters. It creates an equation in terms of input variables to find the desired output. In this paper, the dependent variable is conveying velocity (V) and the independent variables are L/W Ratio, Mass (M), co-efficient of friction (μ), excitation frequency (f) and amplitude of vibration (A), With the help of the experiment results the regression model was generated using the Minitab 17 Statistical software, which is given by Equation (1).

$$v = -26.9155 - 1.99932\,L/W - 0.205103\,M - 95.6271\,\mu + 3.2722\,f + 49.5078\,A \qquad (1)$$

where: v is Conveying Velocity (mm/s); L/W is Length/Thickness Ratio; M is Mass (g) ; μ is Co-efficient of friction between feeder tray and part; f is Excitation frequency (Hz); A is Amplitude of vibration (mm)

ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANN) have been used for the structure and functionality of biological natural of human brain [6].Therefore, ANN is found to be more flexible and suitable than other modelling methods. Neural network is an information processing system in which the process is carried out by means of elements called neurons that are interconnected by link. The concept is based on ideal neuron which is assumed to be responding optimally to applied inputs. ANN model was developed using MATLAB 2013 based on the experimental results. The parameters chosen for developing the model is shown in Table 5.

Table 5. *Parameters for developing ANN Model*

Structure	Feed Forward
Algorithm	Back propagation
Type of Training	Trainlm
Network structure	15,h and l
Transfer function	TANSIG
Number of iterations	1000(max epoch)
Performance function	MSE = 0.00001
Data division	Random
Learning rate	0.01
Momentum	0.95

To determine the number of neurons in the hidden layer, trial and error method was employed [7]. 'R' value represented the correlation between outputs and targets. The hidden neurons were initially varied from 10 in increments of 100(i.e., 10, 20, 30 . . . etc.) From that maximum R value is chosen which means the input values are closer to fit the line. The overall 'R' value obtained by varying the hidden neurons is shown in Figure 4.

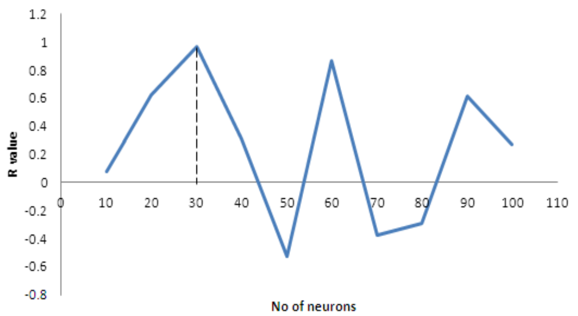
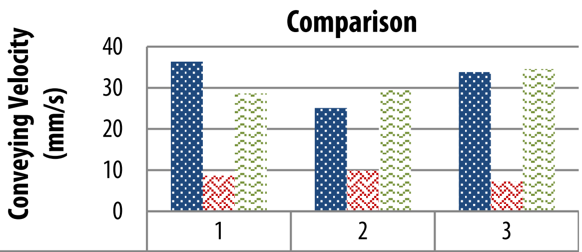


Figure 4. *Overall 'R' Vs no. of neurons in hidden layer*

From Figure 4, it could be inferred that hidden neuron size of 30 had the maximum 'R' value (shown in dashed line) and hence 30 was chosen as the appropriate number of hidden neuron. On increasing the neurons in hidden layer beyond 30, the 'R' value was found to decrease and hence the test was stopped at neuron size of 100.Using this, the ANN network was again created and trained. An ANN model capable of predicting the conveying velocity based on input parameters is available now.

COMPARISON OF RESULTS

Three different prismatic parts were chosen for validating the above two models. The comparison of regression and ANN model results with the experimental results is shown in Figure 5. From the results, it could be observed that ANN model was able to predict the results much closer to the experimental values than the regression model. This is in agreement with Abounoori and Bagherpour [8], who also concluded that ANN could predict results much better than regression models. ANN could make rules without any implicit formula and hence were able to predict the results much accurately than the regression equations. These models will help the industries to predict the conveying velocity of parts on a vibratory feeder based on their input parameters.



	1	2	3
Experimental value	36.4	25.1	33.8
Regression value	8.64	9.89	7.23
ANN value	28.63	29.503	34.56

Figure 5. *Comparison of Regression & ANN with Experimental results*

CONCLUSIONS

An attempt was made to determine the influence of factors such as excitation frequency, amplitude of vibration, mass of part, co-efficient of friction and Length-to-width (L/W) ratio of the part, on conveying velocity of part on a vibratory feeder. Based on experimental results and ANOVA, the excitation frequency was found to be the most influencing factor followed by amplitude of vibration. The L/W ratio has no significant effect on conveying velocity. Regression and ANN models were developed to predict the conveying velocity of part on vibratory feeder. On comparing the results predicted by the models with the experimental results, it was observed that ANN model was much accurate than regression model. This model will aid the industries in predicting the conveying velocity of part on a vibratory feeder.

REFERENCES

[1] Lim, G.H : On the conveying velocity of a vibratory feeder, Computers & Structures, 62(1),197-203, 1997

[2] Reznik, D., Canny, J. and Goldberg, K : Analysis of part motion on longitudinally vibrating plate, Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), vol. 1, 421-427, 1997

[3] Ramalingam, M. and Samuel, G.L : Investigation on the conveying velocity of a linear vibratory feeder while handling bulk-sized small parts, Int J Adv Manuf Technol, vol. 44, 372-382, 2009.

[4] Udhayakumar, S., Mohanram, P.V., Keerthi Anand, P and Srinivasan, R : Trap based part feeding system for stacking sector shaped parts, Journal of the Brazilian Society of Mechanical Sciences and Engineering, 36 (2), 421-431, 2014.

[5] Al-Khatib, I.A., Abu-Hassan, H.M and Abaza, K.A: Development of empirical regression-based models for predicting mean velocities in asymmetric compound channels, Flow Measurement and Instrumentation, vol. 33, 77-87, 2013.

[6] Arulmozhi, K.T and Sheelarani, R : Application of artificial neural network technique to predict ultrasonic velocities in binary oxide glasses, Advances in Applied Science Research, 2(4), 147-155, 2011

[7] Ricca, R.N., Jami, M.S and Alam, M.Z : The potential of artificial neural network (ANN) in optimizing media constituents of citric acid production by solid state bioconversion, International Food Research Journal, 19 (2), 491-497, 2012.

[8] Abounoori, E and Bagherpour, M: Estimation of industrial production costs, using regression analysis, neural networks or hybrid neural-regression method, Journal of Interdisciplinary Mathematics, 10(2), 59-167, 2007.

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN:2067-3809