Optimization the cutting parameters using PSO and FUZZY method to reduce vibration on cutting tool in production line.

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Abstract: The vibration analysis shows how to find changes in vibration patterns and then follows these changes in the mechanical design of the machine. Vibration levels and vibration patterns inform us about the internal state of the rotating assembly. If the device is unbalanced or aligned, you can tell us to set the vibration. The problems of rollers and coupling can reveal Al. The real work of the project was carried out in the heating system plant. Measure the vibration level of the gas combustion fan. The experimental results show that the vibration depth and operating speed are the main parameters affecting the three controllable factors (vibration depth, running speed and feed rate) of the vibration of the fine production line. Another study can consider more current parameters, tool engineering, different materials for the work materials, and lubrication and cooling strategies in the study to understand how factors affect vibration levels. In this study, an experiment was conducted in a production line to use the comparison function to test vibration tests and machine noise for the horizontal and axial vibration production lines and in the AD-3552 process based on the vibration signals collected by the VEM-controlled MATLAB. The effects of operating parameters such as operating speed, vibration depth, and feed rate are evaluated in machine variants.

Keywords: vibration analysis, vibration patterns, production line, VEM-controlled MATLAB, machine noise

1. Introduction

1.1 Vibration

Vibration is a mechanical phenomenon and oscillation occurs near the equilibrium point. The word comes from the Latin vibem (“shaking, waving”). Vibrations can be cyclical, such as pendulum movement or random motion, such as the movement of tires on gravel road. Vibration analysis (VA) applied in industrial or maintenance environments aims to reduce maintenance costs and equipment failure by detecting equipment failure. A critical component of the CM is often referred to as predictive maintenance .The most common VA is used to detect breakdowns in rotary equipment (fans, motors, pumps, gearboxes, etc.) such as imbalance, non-alignment, rolling failure and resonance conditions. VA can use the offset, speed, and acceleration units that are displayed as Time Waveforms (TWF), but the most common spectrum is derived from TWF's Fourier transform. Vibration range provides important frequency information and can identify faulty components.

1.2 Free vibration without damping

In order to begin the study of the entire spring damper, it is assumed that the damping is negligible and no external force is applied to the mass (ie free vibration). The force exerted by the spring on the mass corresponds to the number of springs "x" (assuming the spring has been compressed by the mass). The proportionality constant, k, is the spring rate and has force/distance units (for example, lbf / in or N / m). Negative signals indicate that the force is always opposite to the motion of its associated mass:

$$F_s = -kx.$$

The mass generated energy corresponds to the mass acceleration specified in Newton's second law:

$$\Sigma F = ma = m\ddot{x} = m\frac{d^2x}{dt^2}.$$

The sum of the forces on the mass then generates this ordinary differential equation:

$$m\ddot{x} + kx = 0.$$

Assuming that the initiation of vibration begins by stretching the spring by the distance of A and releasing, the solution to the above equation that describes the motion of mass is:

$$x(t) = A\cos(2\pi f_n t).$$

This solution says that it will oscillate with simple harmonic motion that has an amplitude of A and a frequency of f_n. The number f_n is called the **undamped natural frequency**. For the simple mass–spring system, f_n is defined as:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}.$$

1.3 Free vibration with damping

When a "sticky" damper is added to the model, it produces a force that is proportional to the mass velocity. This lubrication is called sticky because it can synthesize the effects of the body fluid. The correlation constant is called the damping factor and the power unit is over-speed (lbf s / in or N s / m).[w]

$$F_d = -cv = -c\dot{x} = -c\frac{dx}{dt}.$$

Summing the forces on the mass results in the following ordinary differential equation:

$$m\ddot{x} + c\dot{x} + kx = 0.$$

The solution to this equation depends on the amount of damping. If the damping is small enough, the system will still vibrate but eventually stop vibrating. This condition is called damping, which is very important in vibration analysis. If the damping only increases to the point where the system does not swing, the system reaches the critical damping point. If damping increases after critical damping, the system will become more humid. The value that the damping coefficient must reach for critical damping in the mass spring damper model is:

$$c_c = 2\sqrt{km}.$$

To describe the amount of damping in the system, a percentage called damping ratio (also called damping factor and critical damping percentage) is used.

The damping rate is only the actual damping rate that reaches the required damping for critical damping. The formula for the damping ratio zeta of the mass spring damper model is:

$$\zeta = \frac{c}{2\sqrt{km}}.$$

For example, the metal structure (eg, aircraft fuselage, engine crankshaft) has a damping factor of less than 0.05, and the automatic suspension is between 0.20-0.30. The solution for the spring damper model with less suppression of the system is as follows:

$$x(t) = Xe^{-\zeta\omega_n t}\cos(\sqrt{1-\zeta^2}\omega_n t - \phi), \qquad \omega_n = 2\pi f_n.$$

The value of X, the initial amount and the phase change amount φ are determined by the amount of the spring. The formula for these values can be found in the reference.

2. Production line

A production line is a set of processes established at a factory, where materials are placed through a refining process to produce a final product suitable for future consumption, or components are assembled to form a final product. In general, raw materials such as metal ore or agricultural products such as food or textile factories (cotton, flax) require a series of treatments to make them useful. For metals, business includes cracking, smelting, and further refining. For plants, useful materials should be separated from the shell or contaminants and then processed and sold.

3. Research Investigation

The purpose of this research is to demonstrate the importance of vibration measurement in modern production systems. The purpose of this investigation is to explain how to implement vibration measurements in the field and what type of mechanical diagnosis can be achieved. Effective maintenance services in existing production systems are critical to any company. Vibration measurements provide the user with a clear picture of the state of the machine, making it easier to plan maintenance plans and focus resources on machines that show signs of failure.

Vibration analysis looks around the art of finding changes in vibration patterns and then traces these changes back to the mechanical design of the machine. Vibration levels and vibration patterns tell us about the internal state of the rotor assembly. If the device is unbalanced or aligned, it can tell us the vibration mode. Roller body and coupling problems can detect Al errors. The actual work of the project was carried out at the heating system factory. It measured the vibration level of the flue gas fan. The flue gas fan removes the gas produced in the combustion boiler and then passes through the filter to the atmosphere. The results showed that the smoke fan carried problems and began to develop.

3.1 Maintenance

Maintenance can be described as repairing or replacing damaged items. They are defined as routine procedures that keep the equipment running or prevent any other problems maintenance includes:

- Operation: Process control, use of machines, small component changes
- Keeping machine running: Cleaning, lubrication, monitoring
- Logistics: Selection, procurement and delivery of resources
- Improvement: Without changing the object's original action
- Changes: Changes to the original function
- Factory service: e.g. security, fire protection, sanitation, waste- and snow removal

Scandinavian plants are the most advanced plants in the world today. In addition to permanent environmental aspects, operational reliability is also constantly evolving. Visitors from all over the world have confirmed this fact. Key success factors are first-class maintenance traditions and maintenance skills.

3.2 Failures

When the device does not perform the functions required for the accident, it can be described as a failure. In most cases, failures can be expected through good maintenance plans, but there is always the possibility of accidental severe crashes.

3.2.1 Common reasons for failures

- Equipment is not used in the right way
- Too much focus on repairing instead of checking and analyzing
- The operating conditions are not optimal
- The design does not adequately take into account the actual use or the conditions of use
- Equipment operators detect symptomatic defects, but they don’t take any action or reports.

4. Materials & Methods

In the automation process, vibration is a common problem that affects the performance of operations, especially the machining of surfaces and life tools. Extreme vibration occurs in the operating environment due to the dynamic movement between the production line and the work-piece. In all ongoing processes, such as rotation, boring and grinding, the vibrations are stimulated by the deformation of the work-piece, the machine structure and the operating tools. In the automation process, forced vibration and natural vibration are defined as operating vibrations.

Forced vibration is caused by some periodic forces inside the machine, bad gears such as drive device, centered interference, unbalanced machine tool parts, etc. Self-excited vibration is caused by the interaction of the chip removal process and the structure of the automatic instrument, resulting in interference in the operating area. Natural vibration affects the processing capacity, reliability, and surface quality. Today, the standard procedure for avoiding vibrations during manufacturing is to carefully plan operating parameters and prevent operation tools. The method for reducing vibrations is based on experience as well as trial and error to obtain the appropriate operating parameters for each operation.

Many sensors are used in tool condition monitoring systems, namely: touch sensors, power sensors, vibration sensors, temperature sensors, force sensors, vision sensors, flow sensors, acoustic emission sensors, and the like. Tool wear sensing technology can be roughly divided into two categories: direct and indirect, as shown in Table 1. When the running tool is not in contact with the work-piece, a direct tool wear monitoring method can be applied. However, the direct method of measuring tool wear is not easily applicable to shop floor applications. The indirect tool sensing method uses the relationship between operating conditions and process response, which is a measurable quantity through sensor signal output (such as force, acoustic emission, vibration or current) and can be used to predict the production line (Tata Motors Limited Company production line).

Table 1 Tool wear sensing methods

Direct methods	**Indirect methods**
Electrical resistance	Torque and power
Optical measurements	Temperature
Radio-active	Vibration & acoustic emission
Contact sensing	Vibration ting forces & strain measurements

These indirect methods are widely used by various researchers and have been analyzed in detail over the past two decades. Today, the availability of electronic computing power and reliability helps to develop reliable case control systems through indirect methods. However, there is one problem with the TCM system, which is the choice and location of the appropriate sensor. The sensor should be monitored as close as possible to the target position. It should be noted that the TCM system consists of three steps:

(i) Collection of data in terms of signals from sensors such as running force, vibration, temperature, acoustic emission and/or motor current,
(ii) Extraction of features from the signals,
(iii) Classification or estimation of tool wear using pattern recognition.

The vibration signal is very important for monitoring the state of the tool during drilling. The accelerometer is mounted on the tool, one in the direction of the crossbeam of the tool holder and the other in the axial direction of the tool holder to measure the vibration amplitude in acceleration. The computer code was developed in Mat Labs to acquire data, store and display data and extract vibrations in terms of time and frequency, which will be explained in the software development section.

- **Accelerometers:** Converts the physical acceleration into a voltage signal.
- **Signal conditioning circuit:** Amplifies the voltage signal and improves the resolution.
- **Personal computer:** Runs the program, stores and display at any desired instant of time.

The main purpose of the research work is to monitor the vibration level of the instrument. Therefore, it is assumed that the state and components of the machine are good in all other respects, such as the foundation of the machine, the hardness of the machine components (e.g., bed, spindle, tailstock, etc.). The simplest vibration analysis is performed by collecting the root value of the total vibration value (RMS) and the vibration data layout in the time and frequency range. The "overall" signal represents the total energy content of all vibration sources at all frequencies. Free vibration testing for a given production line without any damping pad. The accelerometer is mounted on the tool holder and connected to the data acquisition card and Mat lab to record the response of the production line over time and frequency.

The response of the tool holder captured in time and frequency domains as shown in **Figure 1.**

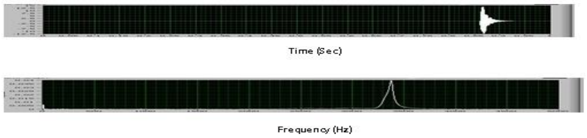

Figure 1 Vibration signal for response of the accelerometer of free vibration test (without damping pad*)*

It can be clearly seen from Fig. 1 that the basic natural frequency of this instrument is approximately 3.4 kHz, with an acceleration of 12.5 g. It takes approximately 0.95 seconds to reach stability. Use the bandwidth method to calculate the damping ratio and obtain a value of 0.0149. Use a neoprene cushion for free vibration testing of the production line. Repeated damping state experimental plastic analysis. Figure 2 shows that the basic natural frequency of the production line is about 2,150 kHz and the stability is about 0.4 seconds. The damping ratio is calculated as 0.06976.

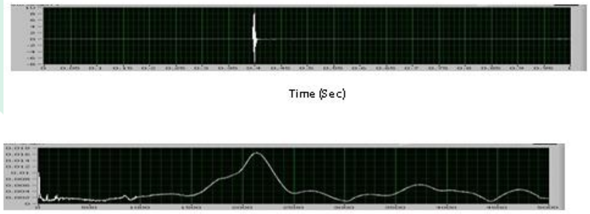

Figure 2 Vibration signals for response of the accelerometer of free vibration test (with damping pad).

4.1.1 Dynamic Analysis - without damping pad

Under actual processing conditions, there is no damping pad for vibration analysis. In this analysis, a series of experiments were performed using the production line in the tool holder. Accelerometer measurements are used to collect vibration signals in both coaxial and axial directions.

MATLAB acquires the vibration signal and continuously stores the signal in the frame at each stage of Internet operation. The vibration data shown in Fig. 3 was obtained at a drilling speed of 250 m/min, a vibration depth of 0.5 mm and a feed rate of 0.1 mm/rev. The dynamic response of the accelerometer without any damping pad is shown in Table 2.

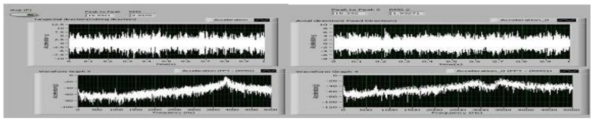

Figure 4. 3 Production Line vibration signals without damping pad

4.1.2 Dynamic Analysis with damping pad

In this set of experiments, the production line was installed by a shock absorber called neoprene made of rubber material. Repeat the same set of experiments given in the previous section and use a suction pad to assemble the vibration signal. The jogging level of the product line vibration signal is 250 m / min, the vibration depth is 0.5 mm and the feed rate is 0.1 mm / cycle, as shown in Figure 2. Table 2 shows the dynamic response of the accelerometer with the damping pad.

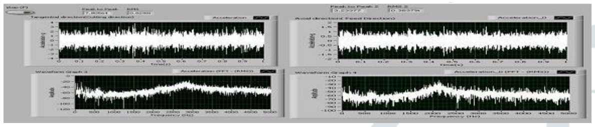

Figure 4 Production Line vibration signals with damping pad

5 Experimental Design

The experimental design approach for investigations is selected in three controllable parameters at three levels, since the effective 3K design is effective for studying the effects of two or more factors. Without loss of the general, three levels of the worker are referred to as low, medium and high. The levels are designed through blocks 0.1 and 2. Each treatment combination in 3K design is denoted by k numbers where the first digit refers to A (vibration) Vibration depth), indicates the level of the second fender and C (feed) indicates a three level. These factors in addition to their specific levels are shown in Table 3.

Table 2 Input parameters and dynamic response of accelerometers (Production Line) with and without damping pad

Expt. No.	CS	DOC	FR	Amplitude of acceleration level of Production Line in g			
				Tangential Direction		Axial Direction	
				RMS		RMS	
				Without damping pad	With damping pad (Neoprene)	Without damping pad	With damping pad (Neoprene)
1	200	0.05	.01	2.46	1.05	1.5	0.56
2	200	0.05	.02	3.1	0.86	2.18	0.75
3	200	0.05	.03	2.76	1.2	1.7	0.59
4	200	0.05	.01	3.45	0.79	2.4	0.79
5	200	0.075	.02	4.04	1.9	2.07	0.68
6	200	0.075	.03	4.08	2.05	2.3	0.70
7	200	0.075	.01	3.74	1.7	1.95	0.60
8	200	0.1	.02	4.64	2.12	2.86	0.95
9	200	0.1	.03	4.44	2.24	2.28	0.75
10	200	0.1	.01	3.07	1.78	2.16	0.70
11	230	0.05	.02	3.6	1.84	3.04	1.01
12	230	0.05	.03	3.9	1.95	3.26	1.08
13	230	0.05	.01	3.75	1.62	2.48	0.80
14	230	0.05	.02	4.45	2.5	2.85	0.90
15	230	0.075	.03	5.05	2.56	3.42	1.14
16	230	0.075	.01	3.77	1.92	2.34	0.75
17	230	0.075	.02	5.04	2.45	3.34	1.10
18	230	0.1	.03	5.15	2.5	2.96	0.97
19	230	0.1	.01	2.85	1.6	1.94	0.68
20	230	0.1	.02	4.04	1.98	3.85	1.28
21	260	0.05	.03	4.84	2.54	3.96	1.30
22	260	0.05	.01	4.54	2.34	3.16	1.5
23	260	0.05	.02	5.0	2.64	3.64	1.20
24	260	0.05	.03	5.25	2.73	3.76	1.25
25	260	0.075	.01	5.85	2.82	3.48	1.15
26	260	0.075	.02	5.55	2.72	2.96	0.97
27	260	0.075	.03	5.95	2.47	3.87	1.28
28	260	0.1	.01	4.84	2.42	3.04	1.01
29	260	0.1	.02	5.65	2.57	3.82	1.25

30	260	0.1	.03	5.60	2.74	3.16	1.05
CS= running Speed in m/min				DOC= Depth of Vibration in mm		FR= Feed Rate mm/rev	

Table 3 Identified control factors and their levels

Variables or parameter	Parameter designation	Level 1	Level 2	Level 3
Vibration ting speed(m/min)	A	200	230	260
Depth of vibration(mm)	B	0.05	0.075	0.1
Feed(mm/rev)	C	0.01	0.02	0.03

6. Results and Discussion

The MATLAB program was used to analyze the vibration under different operating conditions. The test plan aims to evaluate the effect of operating speed, feed rate, and vibration depth on the vibration of the production line. Table 2 shows the experimental results of running and axial vibration. After the vibration analysis, a negative damping pad is provided below the line elements. The same experiment is now performed for different operating conditions and the line vibration is measured and listed in Table 2. Figure 5 shows a comparison of the vibration of the operating tool under different lateral working conditions without the damping pad and damper pad. Figure 4.6 shows the comparison of line vibration under different axial working conditions without the use of damping pads and damping pads.

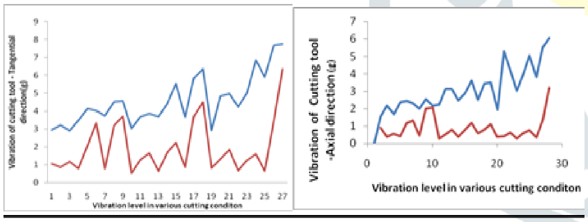

Figure 5 & Figure 6 Displays the comparison of vibration of running

The upper curve shows vibration signal without damping and lower curve is with damping. This passive cushion dissipates energy under different operating conditions. Due to the addition of damping material in this experiment, the vibration level was reduced to 60%. One of the objectives of this study is to find important and comprehensive factors that affect the level of vibration in the production line, and use less performance better. The experimental results were analyzed using MATLAB VIBRATION TOOLS, a tool used to identify factors that significantly affect performance measurements. Use Mat Lab to analyze the results. The results of MATLAB VIBRATION TOOLS analysis show that vibration depth is the most effective factor in vibration. The contribution rate shows that the vibration depth is 38%, the operating speed contributes 35%, and the feed rate is only 27%. Therefore, the vibration depth of the vibrating line is considered to be a more important parameter. According to the MATLAB VABATION TOOLS tool, obtain the best regression equation **(1&2)** to obtain axial and axial vibration of the production line:

(1) Vibration Level (VT) = - 3.50 + 0.0184 x1 + 3.92 x2 + 7.32 x3

(2) Vibration Level (VA) = - 3.34 + 0.0217 x1 + 1.40 x2 + 5.48 x3

Where *x*1 =running Speed , *x*2 = Depth of vibration , *x*3 = Feed rate, *VT* = Vibration level in terms of acceleration, *g* in tangential direction, *VA* = Vibration level in terms of acceleration, *g* in axial direction. To perform the parametric study using these regression models, the relationships have been drawn between the machining conditions and responses like Acceleration vs. running speed, Acceleration vs. Depth of vibration, Acceleration vs. Feed rate.

6.1 Main Effect, Interaction plot and Contour plot–Tangential direction

The relationship between the main effect and the interaction index (vibration depth, running speed, feed rate, and vibration level) is shown in Figure below. Shows the main effects of line vibration levels on different vibration depths, operating speeds, and feed rates, with the operating speed to the left. He pointed out that with the increase of the operating speed, the operating speed of the production line is continuously increased, up to 200 m/min, which produces the lowest vibration capability and 260 m/min produces the highest vibration capability. In fig. below, the right side is the depth of vibration, which shows that as the vibration of the production line continues to increase, the depth of vibration increases. The vibration depth of 0.05 mm produces less vibration and 0.1 mm produces higher vibration capability.

The feed rate at the bottom left shows that the feed rate has increased and the vibratory production line has been increasing. The feed rate of 0.01 mm/cycle produces less vibration and the 0.03 mm/cycle produces higher vibration capability.

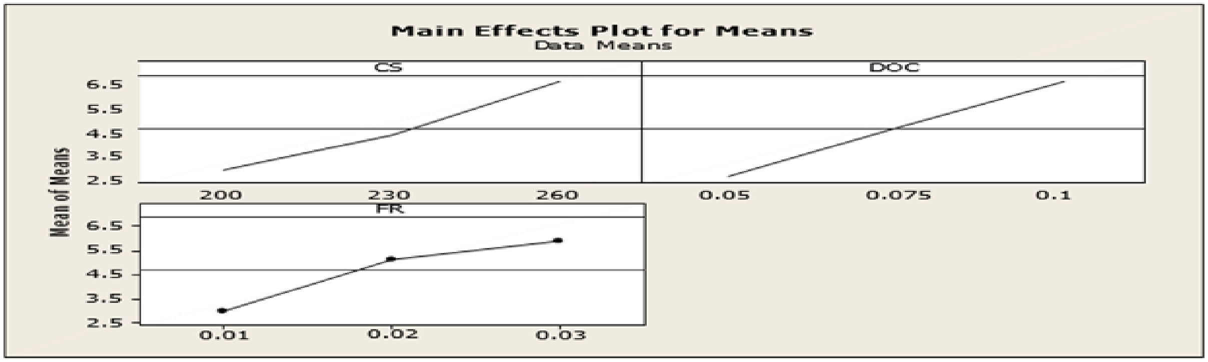

Figure 7 shows the interaction plot for amplitude level at 260 m/min CS, Feed rate 0.03 mm/rev. In this plot, the parallel trends of the lines clearly show very little interaction between the two parameters.

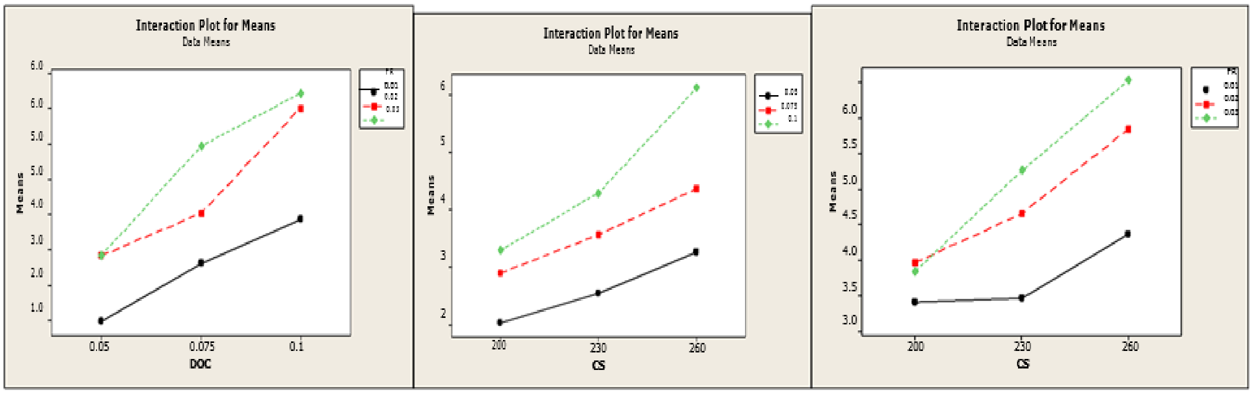

Figure 8 a. Interaction plot between depth of vibration and feed rate for Production Line vibration in tangential direction. **Figure 8 b.** Interaction plot between running speed and depth of vibration for Production Line vibration in tangential direction. **Figure 8 c.** Interaction plot between running speed and feed rate for Production Line vibration in tangential direction.

6. 2 Main Effect, Interaction plot and Contour plot– Axial direction

The graphs of the main effects and reaction patterns (between vibration depth, operating speed, and feeding rate and vibration level) are shown in a pivotal pattern in Figs 10 to 10c. Figure 9 shows the main effect of the vibration level of the production line with different depths of vibration, operating speeds and feeding rates, with the left side of the operating speed. He pointed out that with the speed of implementation, the value of production line vibration continues to increase. The operating speed produces 200 m / min minimum vibration capacity and 260 m / min produces the highest vibration capacity. In Figure 6, the depth of the vibration on the right indicates that the depth of the vibration increases with the continuous vibration of the production line in the increase. Vibration depth 0.05 mm produces less vibration and 0.1 mm produces higher vibration ability. The nutrition rate at the bottom left shows that the feeding rate has increased and the vibration production line is increasing. Feed rate 0.01 mm / mm produces less vibration and 0.03 mm / mm produces the highest vibration ability.

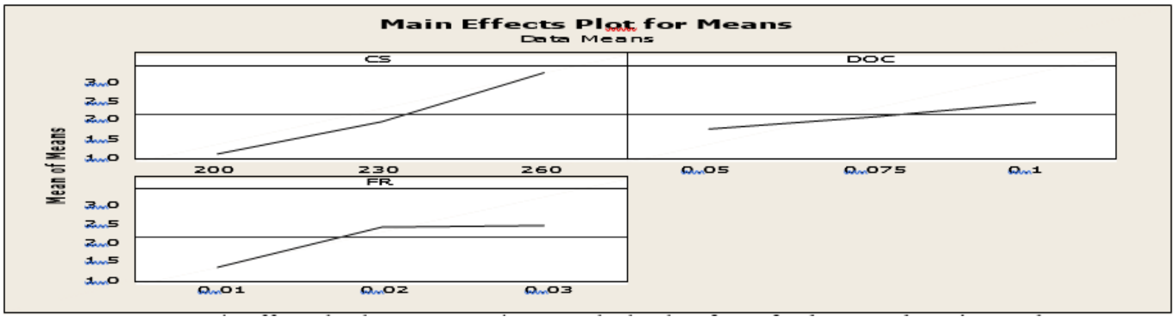

Figure 9 Main effect plot between running speed, depth of vibration, feed rate and Production Line vibration (g) in axial direction.

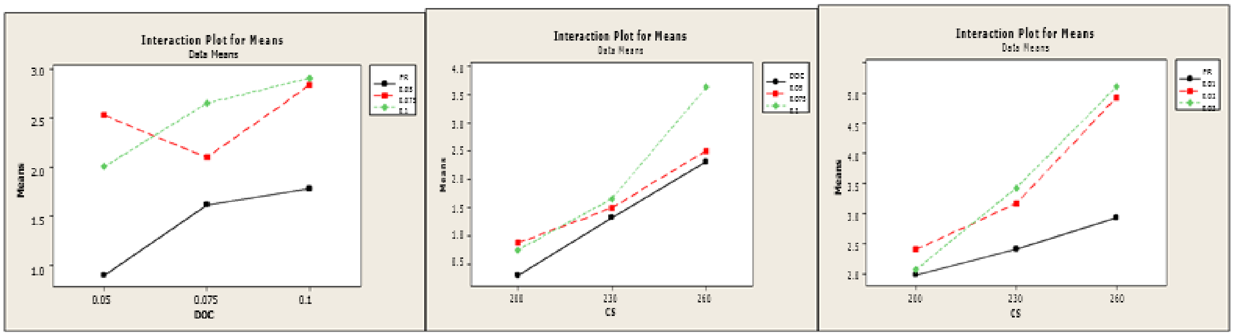

Figure 10 a Interaction plot between depth of vibration and feed rate for Production Line vibration in axial direction. **Figure 10 b.** Interaction plot between running speed and depth of vibration for Production Line vibration in axial direction. **Figure 10 in**teraction plot between running speed and feed rate for Production Line vibration in axial direction.

7. Conclusions & Future Scope

In this study, an experiment was conducted on a production line to use a comparison function to test the machine vibration and noise tests of the horizontal and axial vibration production lines, and in the AD-3552 operation based on the vibration signals collected by MATLAB and controlled by the VEM Measured neoprene. The effects of operating parameters such as operating speed, vibration depth and feed rate are evaluated on the machine variables.

Test results show that the advanced method is successful. Based on the current research, the following conclusions can be drawn:

- The damping rate of the neoprene mat production line increased from 0.0256 to 0.0782, which indicates that the use of production line panels helps to extend the life of the production line.

- Observe that the normal frequency deviates from the operating frequency, thus avoiding the actuator's resonance.

- The neoprene damping pads have axial and axial vibration levels of 65% and 73.5%, respectively.

- Negative damping can provide significant performance advantages in many types of structures and machines, usually without significant weight or cost loss. In all aspects of the research conducted, a significant reduction in tool vibration was achieved during the automated testing of the AD-3552 running test.

- This method effectively measures and monitors the vibration of the production line. The goal of this search has been successfully achieved.

- Multiple regression models have been developed and validated by experimental results.

- The analysis of variance (MATLAB vibration TOOLS) reaches the depth of vibration (38% contribution), the operating speed (35% contribution) and the feed rate (27% contribution) have a greater effect on the vibration of the production line. The experimental results show that the vibration depth and operating speed are the main parameters affecting the three controllable factors (vibration depth, running speed and feed rate) of the vibration of the fine Al-alloy production line. Another study can consider more current parameters, tool engineering, different materials for the work materials, and lubrication and cooling strategies in the study to understand how factors affect vibration levels.

This future scope is to establish the vibration strategy with very sensitive machine so that high control will be established over the various machinery to reduce the failure or damage.

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