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TOOL MONITORING SIMULATION USING MAT LAB

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Abstract: Vibration plays an important role in order to recognize or predict the phenomenon of chatter. Vibrations are produced during any machining process. For drilling operation, analysis of these vibrations plays an important role in order to predict phenomenon of 'chatter'. The project's main aim is to monitor vibration in drill bit. This project emphasizes the analysis of vibration during drilling operation.

While monitoring drill bit there are three types of vibrations comes in picture transverse vibration, longitudinal vibration, and torsional vibration. Longitudinal vibration effects on depth of cut. Torsional vibration leads to the removal of material from the work piece, but doesn't effect on dimension of work piece. Transverse vibration may lead to enlargement of hole, which effects on assembly of parts.

Project serves the purpose of simulating the scenario of transverse vibration to maintain appropriate speed which may reduce vibration. The output results of analysis are useful to find out amplitude of vibrations produced with respect to drill bit, drill size, and spindle speed for standard rate of recommended feed/min.

***Index Terms* – Vibration Analysis, Tool Monitoring.**

I INTRODUCTION:

Vibration is an undesirable phenomenon in machining processes. It results in the reduction of material removal rate (MRR), poor surface finish and increased tool wear. Tool chatter is a primary component of machine vibration and affects the process directly. It causes instability to machining process leading to loss of control over the process. Hence, many researchers have attempted to study and suppress the tool chatter problems. The techniques used for chatter suppression can be broadly classified as active damping and passive damping. Both techniques have their own pros and cons. Hence it becomes necessary to study both techniques and compare the performance of them to know the best chatter suppression method. This forms the basic motivation for choosing chatter suppression problem and taking up this study. In recent years, many works have been reported for turning operation. The dynamics and governing phenomenon may vary from operation to operation. Hence, one has to study the individual process characteristics in order to handle the tool chatter problem in an effective way. Drilling is an operation that is widely used in industries. Studying the chatter suppression of drilling operation will add value to the literature and useful to many industries. Hence, chatter detection and suppression of drilling tool was chosen for this research work. In active damping techniques, the tool chatter has to be predicted in advance and the control signal is to be given to damper in order to suppress the chatter in on-line basis. Prediction and identification of chatter frequencies is a challenge.

Need of vibration analysis during drilling operation

Phenomenon of „chatter" is widely observed during drilling operation. Vibration Analysis is the best solution to predict this complex phenomenon. Due to vibrations produced by drill dimensional accuracy of the hole gets affected. E.g. Transverse Vibration of 0.3 mm amplitude can result into enlarged hole of 0.6 mm excessive diameter. Vibration during drilling operation affects the surface finish of the hole produced. Assembly problems can be raised if the improper surface finished or enlarged holed work piece is required to assemble with other. Operational Problems can be raised if such part is installed on site e.g. tube and shell heat

Exchanger if the size of holes on baffles is enlarged then loosening of it may happen when fluid is flowing above them.

Sources of vibration during drilling operation

In Drilling Operation two types of vibrations are observed:

External Vibrations

In drilling operation spindle of drill may vibrate because of the vibration developed by machine due to malfunctioning. These vibrations can be categorized as vibrations due to external parameters. Sources of external vibrations are as follows:

- Shaft Misalignment in spindle, motor, nut-bolts and transmitting elements viz., pulley or gear drives.
- Improper Foundation of machine
- Loosen fasteners such as nut-bolts, clamps etc.

Internal Vibrations

Internal Vibrations in the drilling operation are produced due to „drilling process itself ‟. Internal vibrations are unavoidable as they occur because of internal characteristics of the system. Sources of Internal Vibrations are as follows:

- Spindle Speed
- Force exerted by work piece in opposite direction to the drill motion.
- Resistive torque by induced by work piece during material cutting.
- High feed rate.
- High Overhung of drill.

Theoretical considerations

Chatter starts as a self-excited phenomenon in the closed loop of dynamically flexible machining structure and the machining process (Figure 1.5(a)) where vibrations change the cutting forces and oscillatory cutting forces create vibrations between the tool and the work piece. Vibrations between the tool and the work piece damages the surface finish (Figure 1.5(b)), increase cutting forces dramatically and ultimately lead to tool breakage and damages to the machine tool. The phase difference between the vibration marks left on a freshly cut surface, which is reflected on the outside of chips, and vibration at the moment of cutting, that makes the inner side of a chips (swarf), produces an oscillating cutting force at the frequency of the vibration and contributes to the existing vibration, leading to the possibility growing vibration amplitude and vibration regeneration.

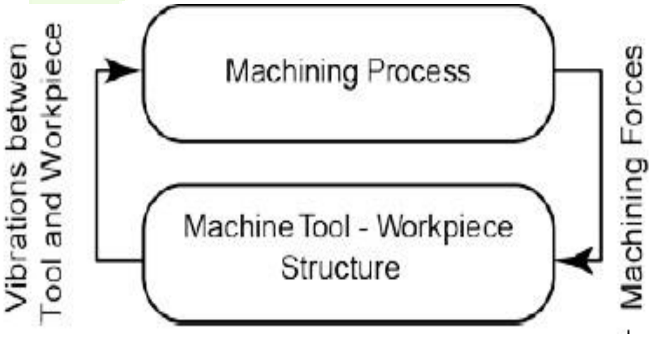

Figure 2 : The closed loop between machining process and machining structure

II Literature survey:

Amit S. Wani, at el in their paper on "vibration analysis of drilling operation" proposed that in the analysis of vibration during drilling operation, the output results of analysis are useful to find out amplitude of vibrations produced with respect to drill size and spindle speed for standard rate of recommended feed/min. They used the straight and simplified approach in the analysis of the vibrations produced during drilling operation on "Thakur pelter drilling machine". We arrived to the conclusion that the "chatter" phenomenon is produced due to the transverse vibrations of the drill, which adversely affect the assembly problem. Longitudinal vibration only changes the length of blunt hole and does not affect the though hole. Torsional vibration leads to the removal of the material from the work piece with the help of chisel edge and flanks on drill, but does not affect the dimensions of the hole. This report is the best example to show that how the theory knowledge gained in the academic curriculum can be effectively applied to the practical scenario.

Anthony S White published paper outlines a strategy for the active control of the self- excited vibration of machine tools which arises when metal is turned, ground or milled. The requisite sensor and actuators for successful operation of such a scheme are outlined. Examples of the results of typical sensors are illustrated in a brief review of previous work. A simple single degree of freedom model of chatter is simulated, although a higher order system could be included to model the chatter process for control purposes. The effect of using different sensors feedback is also considered. Several control strategies are demonstrated. These show that the vibration can be reduced to less than 10% of its' original value in less than 10 cycles. The implications regarding problems of implementation are discussed several control algorithms would appear to be suitable. These include conventional servo practice such as Lead/lag, PID, PI, and PDF. Modern LQG state space control has been used, and LQR control with sensor input which has been investigated here.

C. Sanjay in their paper comparative quality and performance analysis of the twist drills at different cutting condition as per the model, designed according to the factorial design method. Experiments were performed by using two twist drills of different make, possessing the same specifications. Drilling experiments with 14 mm drill size were performed at two cutting speeds and feeds. Selected values of controlling parameters (cutting speed, viscosity of lubricant, feed and number of holes) at each set of experiment shows their significant effect after regression analysis and is concluded along with the response parameters. Hardness values were measured for the drills at different locations and the conclusions are drawn by the frequency response analysis and surface roughness. Based on the statistical analysis and nature of graphs the better quality and performance of the tool is decided. The tool Y is better in design as no natural frequency is getting excited in operating conditions, which is better in quality and performance than tool X, within the range of experimental values and the parameters studied for the work.

III.METHOD AND METHODOLOGY

(Mathematical Analysis)

Assumptions

1) Only the vibrations produced because of machining are considered. Effect of external vibrations is neglected as these vibrations can be controlled with various techniques. On the other hand internal vibrations which we are analysing can be controlled only by adopting safe machining parameters.
2) During analysing of particular type of vibration, only that type is assumed to be taking place. Effect of the other types is neglected for that analysis
3) We have considered cylindrical drill bit for the analysis as our scope is to find out the vibrations that are going to take place not the cutting operation which is being carried out.
4) During our analysis our main focus is concentrated on the transverse vibrations. This is because of the fact that the transverse vibrations produced during drilling operation are the main cause of the enlargement of the diameter of hole being produced beyond tolerance limit.

Types of vibrations

For the drilling operation following three types are observed:

a) Longitudinal Vibrations
b) Torsional Vibrations
c) Transverse Vibrations

a) Longitudinal Vibrations: When the particles of a bar or disc move parallel to the axis of the shaft, then the vibrations are known as longitudinal vibrations. Right hand corner of figure 3.1(a) shows the longitudinal vibration in a drilling machine.

b) Torsional Vibrations: When the particles of the bar or disc get alternately twisted and untwisted on account of vibratory motion of suspended body, it is said to be undergoing torsional vibrations. The second figure in figure 3.1(a) shows the torsional vibration in a drilling machine.

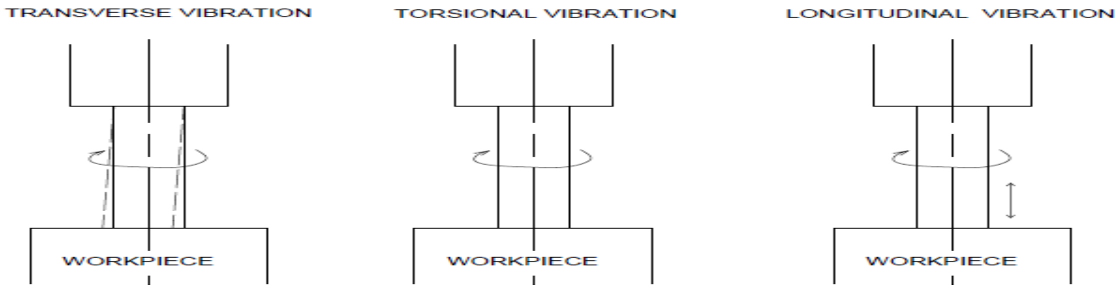

Figure 3: Types of vibrations

Following procedure essential for Vibration Analysis of the drilling operation:

- Identification of the type of vibrations produced during machining operation.
- Determination of the factors affecting these vibrations.
- Applying concepts of the equilibrium to solve the problem.
- Finding out the forces that are exerted on the tool under various conditions.

LIST OF SYMBOLS:

d = Diameter of drilll = Length of drill
E = Young's Modulusσ = Tensile Strength
τ = Shear strength

ω = Frequency of vibration

ωn= Natural Frequency

ωt = Frequency with which spindle is rotatingV = Tangential velocity of drill
r = Radius of drillF = Force
ξ = Damping ratio
A = Amplitude of excitationB

Amplitude of support

Transverse vibration is the major cause for the enlargement of holes which is the area of concern; hence transverse vibration is considered the point of interest for the project.

c) Transverse Vibration: There are two types of transverse vibration

1. Free Transverse vibration
2. Forced Transverse vibration

1. Free Transverse vibration Analysis: Free vibration of the system helps to determine natural frequency of the system (wn). The vibration in the drill is Free State i.e., w/o rotation can be assumed as free transverse vibration.

2. Forced Transverse Vibration AnalysisCases:

1) When the drill is rotating and approaching towards work piece:

When the drill approaches towards the work piece, the no external force on the drill exceptthe force of vibration developed by the motor torque. And thus these vibrations can be neglected because there is no restricting force acting on the drill bit in the direction of the transverse vibration of the drill.

2) When the drill is rotating and drilling a hole into the work piece:

When drill enters into the work piece, the force is exerted by the workpiece material on the drill bit in the direction of the transverse motion of the drill. i.e. perpendicular to the axis of the drill.

The drill and work piece are considered to be attached with the help of the spring whosestiffness is„k‟.Under equilibrium conditions,

$$k = \sigma * v$$

This is because of the fact when the drill transverses with the linear velocity „v‟, the force is exerted on the drill in the direction of the transverse motion due to the stress induced in the material. Force is the resistive force applied by the work piece in the direction perpendicular to the axis of the drill.

$$F=\sigma\ (\text{work piece}) * \frac{\square}{4} * d^2\ (\text{feed/sec})$$

$$\square\, t\, \square\, \frac{2\square\ N}{4}$$

The forced frequency of transverse vibration can be computed with the help of followingprocedure: N= rpm of the spindle

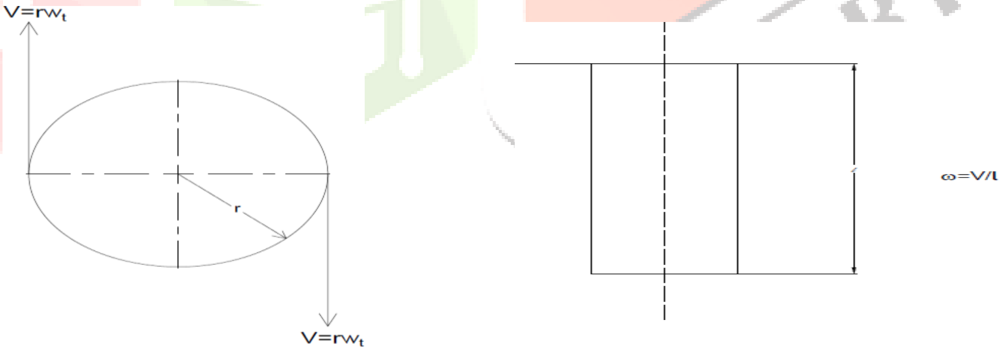

Figure 4: Free transverse vibrations in any body

The relation between angular velocity and linear velocity of the drill cross section inthe transverse direction can be given in the following manner

$$v = \frac{\omega t * d}{2}$$

Now consider, the length of the drill oscillating at forced transverse frequency of 'ω'in the following manner:

$$\omega = \frac{v}{l}$$

Now the amplitude of the transverse forced vibration when the drill enters into theworkpiece can be computed by using the following formula:

$$A = \frac{\frac{F}{K}}{\sqrt{(1-(\frac{\omega}{\omega n})^2)^2 + (2\xi\frac{\omega}{\omega n})^2}}$$

For our drilling machine we have considered no damping condition (since we want toconsider the worst possible case)

e. $\xi = 0$

The project considers the analysis of the vibration caused in the system. In the graph given it can be clearly observed that at initial values of speed and feed the vibration increases exponentially until the parameters reach a critical value. After this point it can be observed that the vibration of the system tends to decrease and as the values of the parameters continues to increase the vibration tend to remain constant. The graph practically suggest that at the point tool touches the surface of the work piece the vibration starts and until some point the vibration increases exponentially. But once the feed given to the drill bit increases with the increase in speed the vibrations decrease. the project focuses at the point where the vibration reach optimum value, if measures are taken to reduce this initial increase in vibration and get the minimize the vibration to about 6.5mm then there can be consistent reduction in the tool wear. Also by the reduction of vibration the surface roughness of the work piece can be minimized thereby facilitating proper assembly of the parts.

Practical Approach

Following sample of calculations represent practical approach of forced transversevibration and given input data are as follows:

Given,

Length of drill bit = 0.15 m = 150 mm

Drill bit diameter d = 3.175 mm

Stress σ = 420 * 10^6 N/m^2

Spindle speed N Feed Rate = 92 Rpm

(mm/min) Transverse Frequency = 4.6736

(wt) = 2 * pi * N/60

Natural Frequency (wn) = $\sqrt{\frac{mgh}{I}}$ = 2 * pi * 92/60 = 9.63 Rad/Sec.

wn	=	$\frac{3.835}{l} = \frac{3.835}{0.15}$ = 9.901 Rad/Sec.
Forced (Resistive)	F	= pi * d * (feed/sec) * stress
Feed / Sec		= (Fed/Rev) * N/60
		= 4.6736/92 * 0.001 * 92/60
		= 7.789 * 10^-5 m/s.
F		= pi * 0.00317 * 7.789 * 10^-5 * 420 * 10^6 = 329.84 N/Sec.
Velocity (V)		= wt * r
		= 9.63*0.00317/2 = 0.015 m/s.
Stiffness (K)		= σ * V
		= 420 * 10^6 * 0.015

= 63*10^5 N/m.

Forced frequency (w) = V/l
= 0.015/0.15
= 0.1 Rad/Sec.

2 nd Iteration

Length of drill bit l = 0.15 m

Drill bit diameter d = 3.175 * 10^-3 m

Stress σ = 420 * 10^6 N/m^2

Spindle speed N = 165 rpm

Feed rate = 14.0208 mm/min

Transverse vibration $=\frac{2wN}{60}$

Table: 1 Manual iteration of forced transverse vibration

Speed(Rpm)	Feed(mm/min)	Amplitude(mm)
92	4.6737	0.051
165	14.0208	0.083
285	23.368	0.082
504	35.052	0.07
600	42.863	0.071
700	50	0.072

Analyzing the existing problem

Chatter is a self-excited vibration caused by the interaction of the chip removal process and the structure of the machine tool and it is a major concern today when trying to achieve high product quality. The vibrations can be of quite large amplitude and result in the following:

- Poor surface finish
- Dimensional inaccuracy of the work
- Premature wear, damage and ultimately failure of the cutting tool. This is particularlyimportant in the case of ceramic tipped tools.
- Damage to machine components from vibration.
- Loud objectionable noise.

Regenerative chatter is the most important type of self-excited vibration. This is when the tool cuts a surface which has roughness or disturbances from the previous cuts. Chatter can exist in lathes, milling machines, grinding machines and in a drilling process. The theory of chatter in grinding machines is similar to that of regenerative chatter in lathes except that both work-piece and the grinding wheel will develop irregular surfaces and in consequence results in two separate finite time delays. In drilling machines, the results will have a sinusoidal motion superimposed on its axis, and the depth of cut taken by one flute depends on the cut taken by one before it. The number of flutes therefore alters the time delay involved in the regenerative chatter process.

Acquire vibration input data

Vibration Produced during drilling operation will cause chattering effect. If vibrations produced by external parameters, it can be controlled by various methods. But, vibration produced because of spindle speed and feed cannot be controlled completely. These vibrations depend upon the various machining input parameters and calculation of vibration can be done under different input parameters.

While monitoring drill bit there are three types of vibrations comes in picture transverse vibration, longitudinal vibration, and torsional vibration. Longitudinal vibration effects on depth of cut. Torsional vibration leads to the removal of material from the work piece, but doesn‟t effect on dimension of work piece. Transverse vibration may lead to enlargement of hole, which effects on assembly of parts.

We are doing this project in order to simulate the scenario of transverse vibration to maintain appropriate speed which may reduce vibration. The output results of analysis are useful to find out amplitude of vibrations produced with respect to drill bit, drill size, and spindle speed for standard rate of recommended feed/min.

IV. RESULT AND DISCUSSION

The program helps to get amplitude of forced transverse vibration. In this program the input parameters such as length of dril bit l, diameter of dril bit d, and stress σ are kept constant. But spindle speed N along with feed rate will be varied in order to achieve the project goal.

Result and graph

Following graph shows the output of the simulated program:

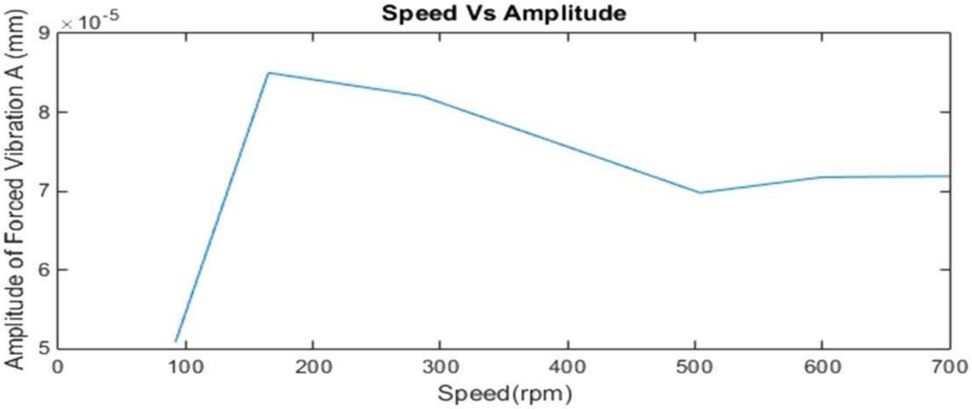

Fig. 4: Speed vs. Amplitude

Above graph shows comparison between Speed and Amplitude. Where the speed is considered from 0 rpm to 92 rpm has zero amplitude because of free vibration which is neglected

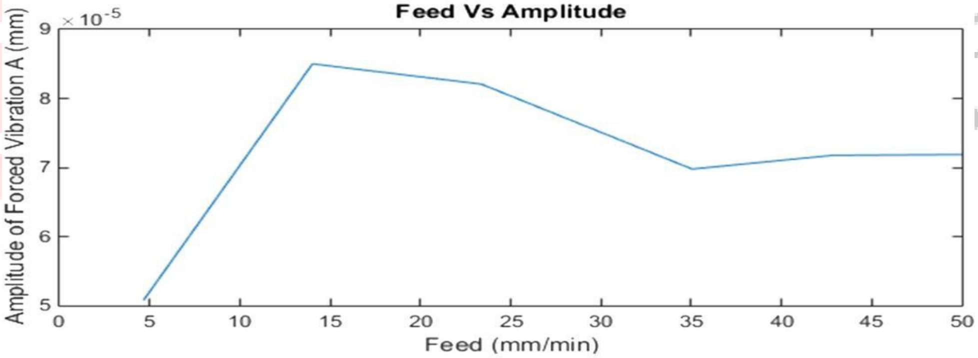

Fig. 5 Feed vs. Amplitude

Above graph shows comparison between Feed and Amplitude. The Feed is considered from 0 rpm to 92 rpm has zero amplitude because of free vibration which is neglected.

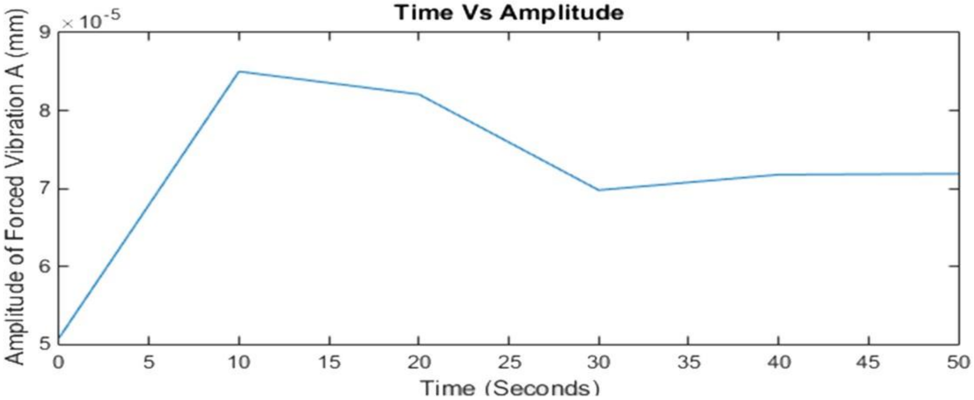

Fig. 6 Time vs. Amplitude

Above graph shows comparison between Feed and Amplitude. The vibration occursfrom 0th sec to 50th sec.

Comparison of analytical and practical values

Table 2. Comparison of analytical and practical values

Speed (Rpm)	Feed (mm/min)	Analytical Amplitude (mm)	Simulated Amplitude (mm)
92	4.6737	0.051	0.05081
165	14.0208	0.083	0.085
285	23.368	0.082	0.08208
504	35.052	0.07	0.06977
600	42.863	0.071	0.07176
700	50	0.072	0.07187

V.CONCLUSION

We used the straight and simplified approach in the analysis of the vibrations produced during drilling operation. We arrived to the conclusion that the “chatter” phenomenon is produced due to the transverse vibrations of the drill, which adversely affect the assembly problem. Longitudinal vibration only changes the length of blunt hole and does not affect the though hole. Torsional vibration leads to the removal of the material from the workpiece with the help of chisel edge and flanks on drill, but does not affect the dimensions of the hole. This report is the best example to show that how the theory knowledge gained in the academic curriculum can be effectively applied to the practical scenario.

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