The Effect of Tool Dimension, Tool Overhang and Cutting Parameters Towards Tool Vibration and Surface Roughness on Turning Process

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***Abstract*— Turning process is the removal of metal from the outer diameter of a rotating cylindrical workpiece. Turning is used to reduce the diameter of the workpiece, usually to a specified dimension, and to produce a smooth finish on the metal. This research investigates the effect of feed rate, spindle speed, tool overhang and tool dimensions toward vibration amplitude and surface roughness on turning process. This study uses both statistical and graphical analysis of the data collected. The experimentation was carried out on conventional lathe machine with straight turning operation. Material used as workpiece was St.60 carbon steel which was turned with HSS tool bit with the dimension of 3/8 Inches and ½ Inches. Cutting parameters varied by spindle speed, feed rate, and tool overhang, while the depth of cut is maintained at a depth of 0.5 mm. The vibration data of cutting tool obtained from a transducer (vibrometer) mounted at a distance of 10 mm from the tip of the cutting tool during the cutting process takes place, whereas the surface roughness data obtained from measurements of surface roughness apparatus after turning process. The results showed that, The effect of feed rate, spindle speed, tool overhang, and tool dimension simultaneously towards vibration amplitude and surface roughness has a grater effects on the use of 3/8 inches cutting tool than ½ inches cutting tool. With the use of the same tool dimensions obtained that, The most influential parameters on the vibration amplitude is tool overhang while the most influential parameter on surface roughness value is feed rate.**

***Key words*— Turning, vibration, surface roughness, cutting tool**

I. Introduction

Challenges faced by today's modern machining industry primarily focused on achieving a high quality product. One of them are the quality of surface roughness. Surface roughness of a product of machining process can affect some functions of these products such as surface friction, heat transfer, spreading capabilities of lubrication, coating, and others. Thus, in practical field,the desired of surface roughnes value will be the reference of cutting parameters selection [1]. Turning is one of the main machining processes used in the process of cutting a rotating cylindrical workpiece. Lots of machinery components made through turning process. Problems are often encountered in all of the machining process especially on turning, is the vibration during the material cutting process. This vibration will affect the quality of the products, one of them is the surface roughness [1].

Nowadays, a standard procedure used to avoid vibration during turning is planning the selection of cutting speed, feed rate, and depth of cut carefully. A method applied is usually based on an operator’s experience and also trial and error method to gain a proper cutting parameters in the machining process.

Vibration in machining process occurs throughout the cutting process takes place which is derived from some sources, such as frame structure of the machine, cutting tool type, types of material that are cutting, etc. Vibration on machining process is very complicated because it involves lots of variables. Nevertheless, at least two kinds of vibrations occurred on machining process, this covers both force vibration and self-excited Vibration. Force vibration is usually gained from components in the machine itself, for example because there are damaged gear components, imbalances on machine components, misalignment of the shaft, the electrical motor rotation, and etc. Self-excited vibration which is so-called *Chatter* caused by the interaction between the release of chips and cutting tool which causes interference with the cutting area. *Chatter* or self-excited always affects on the surface roughness of machining product. Therefore a vibration which is caused by self excited vibration related to the surface roughness as the result of machining [2]

Some previous research, both descriptive and experiment have studied how vibration affects surface roughness towards surface roughness as a product of machining process [1][2][3][4][5]. One of those researches is the effect of spindle speed, feed rate, and depth of cut towards tool vibration amplitude and surface roughness of the workpiece on the lathe machine, in which concludes that spindle speed is the most influential towards vibration and so does the surface roughness, then followed by the feed rate and the last is the depth of cut. Based on that research, the writer conducted a further research towards some variables which has not been experimented before, it is the effect of tool overhang and cutting tool dimension in which involving the same variation of cutting conditions that that have been studied before.

II. THEORITICAL BACKGROUND

A. Vibration in metal cutting process

Vibration is a back and forth motion about its fixed equilibrium position. The equilibrium position means a condition in which an object is on motionless position if there is no force acting on the object. Vibration has similar amplitude (distance deviation furthest to the midpoint) [6]. All objects that have mass and elasticity are able to vibrate.

In the machining process, there are three mechanical vibrations caused by insufficiency of dynamic stiffness in machinery equiptment. The vibrations are free vibration, force vibration, and self-excited vibration. A tool holder, workpiece and the machine itself are parts of machinery which causes vibration. The free vibration is usually caused by shocks effect, such as, the presence of impulse waves that are transferred to the cutting tool or at the time between the beginning of the cutting tool with the workpiece. Force vibration is caused by periodic force which occurred in the system, for example due to the imbalance of machine components for instance, gears system, spindle or bearing. Self-excited vibration usually occurs as a result of dynamic instability that occurs during metal cutting processes. As it shows, the self-excited vibration is the most uncontrolled vibration while two other vibrations can be controlled through arranging cutting parameters on the machine [7].

B. Surface roughness

Surface roughness is a measurable characteristic based on the roughness deviations as defined in the preceding. Surface finish is a more subjective term denoting smoothness and general quality of a surface. In popular usage,surface finish is often used as a synonym for surface roughness.

The most commonly used measure of surface texture is surface roughness. Withrespect to Figure 1, surface roughness can be defined as the average of the vertical deviations from the nominal surface over a specified surface length. An arithmetic average (AA) is generally used, based on the absolute values of the deviations, and this roughness value is referred to by the name average roughness. In equation form

$$R_a = \int^{Lm} \frac{|y|}{L_m} \, dx \quad (1)$$

where R_a = arithmetic mean value of roughness, m (in); y = the vertical deviation from nominal surface (converted to absolute value), m(in); and L_m = the specified distance over which the surface deviations are measured.

The AA method is the most widely used averaging method for surface roughness today. Analternative, sometimes used in the United States, is the root-mean-square (RMS) average, which is the square root of the mean of the squared deviations over the measuring length. RMS surface roughness values will almost always be greater than the AA values because the larger deviations will figure more prominently in the calculation of the RMS value.

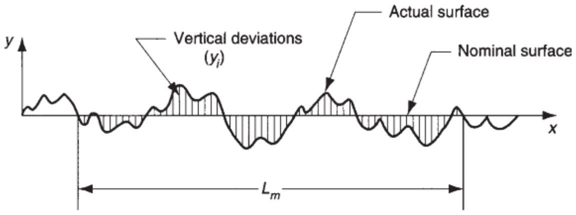

Figure 1. Deviations from nominal surface used in the two definitions of surface roughness.

C. General overview of turning process

Turning process is the removal of metal from the outer diameter of a rotating cylindrical workpiece. Turning is used to reduce the diameter of the workpiece, usually to a specified dimension, and to produce a smooth finish on the metal.

Three main parameters in turning operation are cutting speed, feed rate, and depth of cut. Other factors such as workpiece material and type of cutting tool actually has a considerable influence. However, the three parameters mentioned above are parts that can be set by the operator directly on the lathe machine.

Cutting speed (also called *surface speed* or simply *speed*) may be defined as the rate (or speed) that the material moves past the cutting edge of the tool, irrespective of the machining operation used. The equation of cutting speed can be determine from the equation below

$$C_s = \frac{\pi D N}{1000} \quad (1)$$

Where C_s = cutting speed; m/minute, D = workpiece diameter /mm, N= spindle speed, revolution / minute. The spindle speed (N) in eq.(1) is a measure of the frequency of a rotation. It annotates the number of turns completed in one minute around a fixed axis. The preferred speed is determined by working backward from the desired surface speed (sfm or m/min) and incorporating the diameter (of workpiece or cutter).

Feed rate, V_f , refers to how fast a lathe-tool should move through the material being cut. This is calculated using the Feed per Revolution for the particular material. It is expressed in units of distance per revolution. Feed rate is determined based on machine power, material properties of workpiece, tool material, tool shape, and the most important is the expected surface roughness.

Depth of Cut, the thickness of the material that is removed by one pass of the cutting tool over the workpiece. [8]

D. Regression Analysis

Regression Analysis is applied to study and measure the scatistical relationship among two or more variables. In simple regression analysis two variables are analyzed, whereas in the multiple regression analysis more than two variables are analyzed. In regression analysis, a regression equation was about to set and used to describe a pattern or a function of the relationship between variables. Variables to be called the dependent variable is usually plotted on y-axis. While the independent variable is the variable that is assumed to give effect to the variation in the dependent variable and it is usually plotted on x-axis.

Multiple linear regression, On this multiple linear regression, there are several independent variables (X_1,X_2,X_3...X_n) which are connected to one dependent variable (Y), those are parts of multivariate analysis to estimate the regression coefficient to describe the effect of independent variable towards dependent variable. In a multiple regression test, all of the predictor variables are included in the regression calculation simultaneously.

If there are two independent variables (X_1) and (X_2) and the dependent variable (Y), then the coefficients of the multiple regression equation is determined by the following equation:

$$Y = a + b_1X_1 + b_2X_2 + ... b_nX_n \quad (2)$$

E. Correlation Analysis

Analysis of correlation is an inferential analysis used to determine the degrees of freedom or strength of the relationship, shape or causal and correlation among research variables. Type of statistical hypothesis testing correlations includes simple correlations (bivariate), multiple correlation and partial correlation.

Pearson's Product Moment Correlation, this correlation is used for interval/ratio data in which must meet the following requirements:

- The sample is taken randomly
- Each variable of data is normally-distributed
- A linear regression equation
- Equation :

$$r_{xy} = \frac{n.\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 (\sum y)^2]}} \quad (3)$$

Coefficient of Determination, The Coefficient of Determination is denoted as r^2. This value states the proportion of the overall variation in the value of the dependent variable that can be explained or caused by a linear relationship with the independent variables, the rest is explained by other variables (errors or other variables). Coefficient of determination expressed as the square of the correlation coefficient r^2 x 100% = n% meaning that the value of the dependent variable can be explained by the independent variables of n%, while the residual value of (100 - n)% explained by an error (error) or the influence of other variables.. Meanwhile, for correlation analysis with more dependent variables, there is a correlation coefficient which is significantly sensitive with amount of variables. Usually for multiple correlation analysis, adjustment coefficients of determination are often used.

Multiple Correlation, multiple correlation is the correlation between two or more independent variables together with the dependent variable. Value which shows directions and strength of the relationship between two or more independent variables on the dependent variable is called multiple correlations and denoted as R.

The Equation of multiple correlation of two independent variable X_1 and X_2 with one dependent variable (Y) as [9] :

$$R_{y.12} = \sqrt{\frac{r_{y1}^2 + r_{y2}^2 - 2r_{y1}.r_{y2}.r_{12}}{1 - r_{12}^2}} \quad (4)$$

Where $R_{y.12}$ = coefficient of multiple correlation among X_1, X_2 and Y, r_{y1} = correlation coefficient between X_1 and Y, r_{y2} = correlation coefficient between X_2 and Y, r_{y12} = correlation coefficient between X_1 with X_2

The tested hypothesis is two tailed test:

H_0 : $\rho_{y.12} = 0$

H_1 : $\rho_{y.12} \neq 0$

Hypothesis test of multiple correlation using F- test with degrees of freedom (df) consists of:

df_1 = df numerator = k (k = total of independent variable)

df_2 = df denominator = n – k – 1 (n = numbers of pairs of data or sample)

Value conversion of correlation coefficient R to F_{count} uses the following equation :

$$F_b = \frac{R^2 / k}{(1 - R^2)/(n - k - 1)} \quad (5)$$

Hypothesis testing criteria, namely:

Accept H_0 if $F_{count} < F_{table}$, dan reject H_0 if $F_{count} > F_{table}$

III. RESEARCH METHODOLOGY

A. Experimental set up

Material used as workpiece was St.60 carbon steel which was turned with HSS tool bit (The *Bohler Super Mo Rapid Extra 1200 Brand)* with the dimension of 3/8 Inches and ½ Inches. The cutting tool angles used were Side Relief = 11°, Front Relief = 8°, Side Rake = 12°, Back Rake = 8° [10]. The experimentation was carried out on conventional lathe machine and the method of cutting is shown in Fig. 1, referring to the experimental set up that has been conducted by previous researchers [11].

Figure 2, shows that workpiece which will be turned then divided into four segments separated by grooves. The purpose of this segmental separation is to minimize the affects of tool wear which can effects surface quality towards the effectiveness of measurement. Thus, in collected data measurement, tool bit cuts four times before being substituted by a sharpened cutting tool.

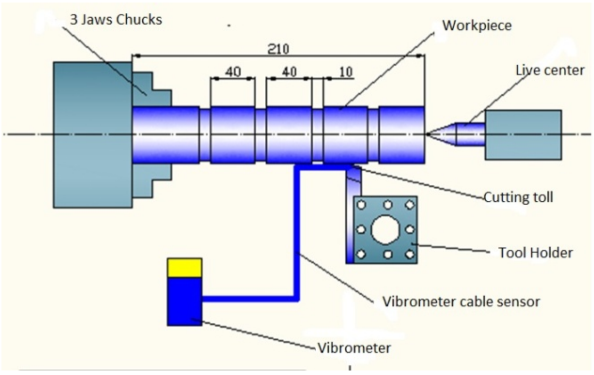

Figure 2. Schematic of experimental set-up for turning

B. Method of Collecting data

Measurement of datas is undertaken by a well-trained and experienced lathe operator in the using of vibration measurement instrument and surface roughness devices. Collecting of measurement datas was arranged as factorial designed so that the interactions between independent variables can be observed more effectively. The independent variables in the study are *feed rate*(V_f), spindle speed, tool overhang, and the tool dimension. While dependent variables is the result of cutting tool vibration (V_{rms}) and the surface roughness (R_a) of workpiece. The details of cutting condition and the groups of experimental testing are shown in Table 1.

Table 1 Groups of Experimental testing variables

Spindle Speed (N) Rpm	Feed rate (Vf) mm/rev	Depth of cut (a) mm	Tool Overhang mm	Tool Dimensions inches
170	0,05	0,5	25;30;35;40	3/8' ; 1/2'
170	0,08	0,5	25;30;35;40	3/8' ; 1/2'
170	0,13	0,5	25;30;35;40	3/8' ; 1/2'
170	0,17	0,5	25;30;35;40	3/8' ; 1/2'
170	0,24	0,5	25;30;35,40	3/8' ; 1/2'
235	0,05	0,5	25;30;35,40	3/8' ; 1/2'
235	0,08	0,5	25;30;35,40	3/8' ; 1/2'
235	0,13	0,5	25;30;35,40	3/8' ; 1/2'
235	0,17	0,5	25;30;35,40	3/8' ; 1/2'
235	0,24	0,5	25;30;35,40	3/8' ; 1/2'
355	0,05	0,5	25;30;35,40	3/8' ; 1/2'
355	0,08	0,5	25;30;35,40	3/8' ; 1/2'
355	0,13	0,5	25;30;35,40	3/8' ; 1/2'
355	0,17	0,5	25;30;35,40	3/8' ; 1/2'
355	0,24	0,5	25;30;35,40	3/8' ; 1/2'
530	0,05	0,5	25;30;35,40	3/8' ; 1/2'
530	0,08	0,5	25;30;35,40	3/8' ; 1/2'
530	0,13	0,5	25;30;35,40	3/8' ; 1/2'
530	0,17	0,5	25;30;35,40	3/8' ; 1/2'
530	0,24	0,5	25;30;35,40	3/8' ; 1/2'
880	0,05	0,5	25;30;35,40	3/8' ; 1/2'
880	0,08	0,5	25;30;35,40	3/8' ; 1/2'
880	0,13	0,5	25;30;35,40	3/8' ; 1/2'
880	0,17	0,5	25;30;35,40	3/8' ; 1/2'
880	0,24	0,5	25;30;35,40	3/8' ; 1/2'

C. Method of Data Analysis

As gained from cutting process on the lathe, measuring data for vibration amplitude (V_{rms}) and surface roughness (R_a) is calculated graphically and statistically. The data were attained through being plotted in graph. Further analysis is undertaken by using both manual calculation [12] and *Statistical Package for Social Sciences* (SPSS) by regression and correlation methods to determine how influential the relationship among the variables (tool dimension, spindle speed, feed rate, and tool overhang) to the value of the vibration amplitude and surface roughness of workpiece[13].

IV. MODEL ANALYSIS AND DISCUSSION

A. Result

The result of cutting tool vibration towards feed rate and variation of spindle speed and tool overhang can be seen in Figure 3, where it appears that the use of ½ inches cutting tool at the same length of tool overhang, addition of feed rate on the turning process will increase cutting tool vibration, where the highest vibration value occurs in 0,24 mm/rev feed rate.

Moreover, conditions where feed rate is maintained at a fixed speed and spindle speed varied at different value, the tool vibration will be higher if spindle speed is increased. However, the magnitude of vibration is smaller with a vibration caused by variations in the parameters of feeding. On the use of 3/8 inches cutting tool as shown in Figure 4 , vibration value is higher compared to vibration value generated by the use of ½ inches cutting tool. On the use of ½ inches cutting tool obtained the highest vibration on cutting tool, that is V_{rms}= 0.65 cms/s while the vibration of 3/8 inches cutting tool is V_{rms}= 0.78 cms/s at spindle speed 880 rpm, feeding 0.24 mm/rev, and cutting tool overhang 40 mm.

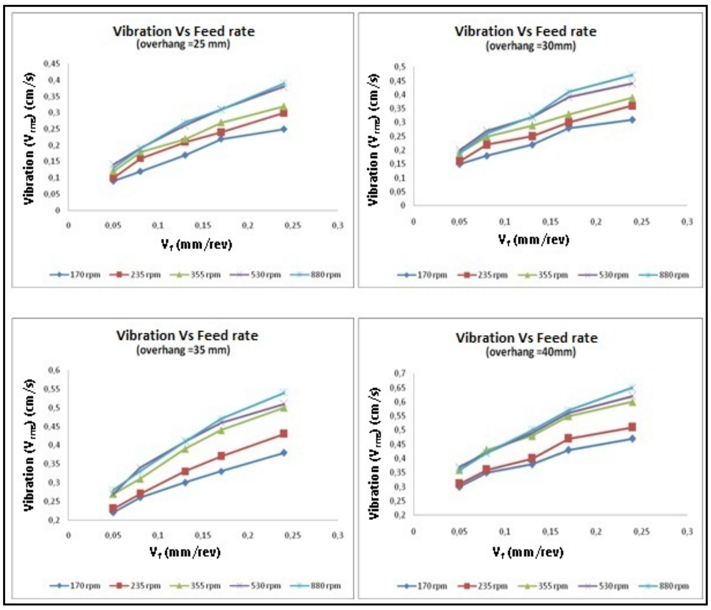

Figure 3. Comparison plot between vibration and feed rate on variation of spindle speed and tool overhang by using ½ inches cutting tool dimension.

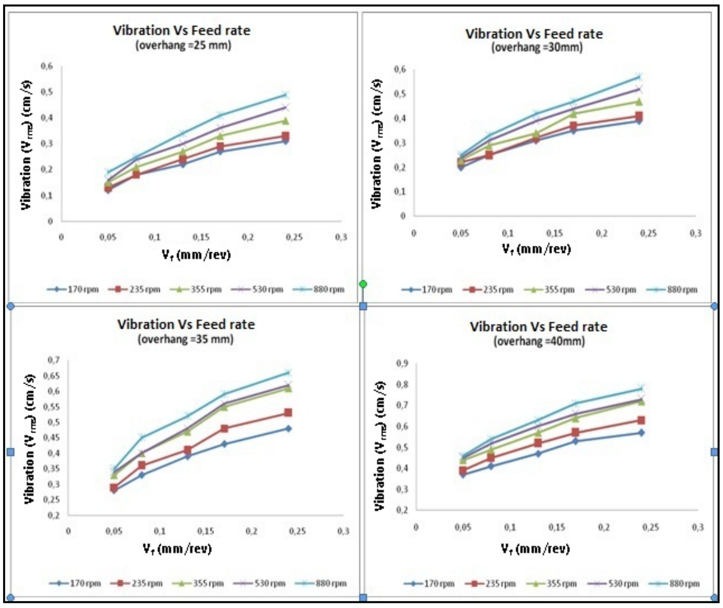

Figure 4. Comparison plot between vibration and feed rate on variation of spindle speed and tool overhang by using 3/8 inches cutting tool dimension

The effects of variation on feed rate towards surface roughness using ½ inches cutting tool as shown in Figure 5, indicates that increasing the feed rate will increase surface roughness on workpiece where the highest value obtained on feeding 0.24 mm/rev. On the variation of cutting tool overhang, the longer the tool bit the higher the surface roughness value where 40 mm tool overhang has the highest roughness value.

By using 3/8 inches tool bit as shown in Figure 6, the surface roughness value will be greater than the roughness values obtained in the use of ½ inches in every similar cutting parameter condition used. On the use of ½ inches tool bit the highest surface roughness value is R_a= 8.54 µm while on 3/8 inches tool bit reaches R_a= 10.34 µm at a spindle speed of 170 rpm, feeding 0.24 mm/rev, and tool overhang 40 mm.

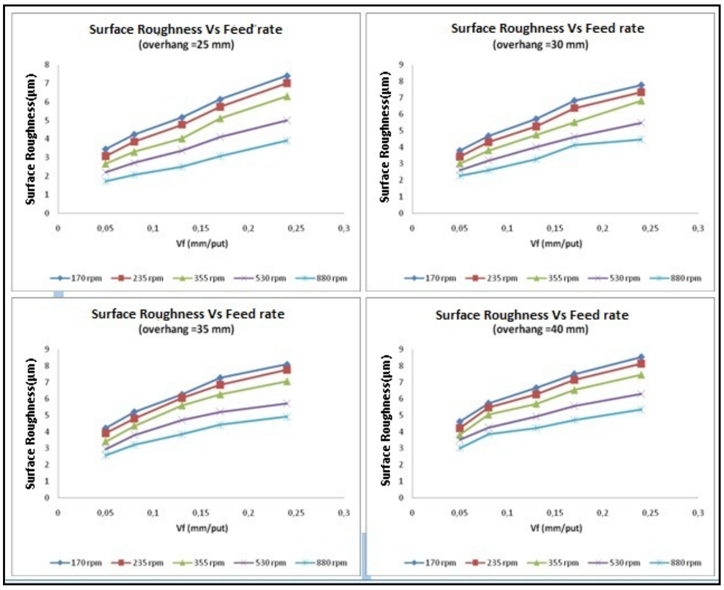

Figure 5. Comparison plot between surface roughness and feed rate on variation of spindle speed and tool overhang by using 1/2 inches cutting tool dimension

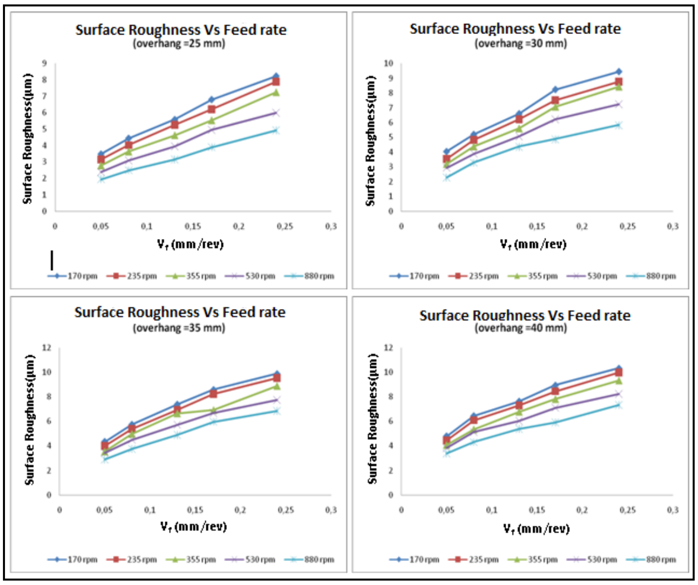

Figure 6. Comparison plot between surface roughness and feed rate on variation of spindle speed and tool overhang by using 3/8 inches cutting tool dimension

To determine a detailed characteristics effect between dependent and independent variables, the data processing is done with statistical methods to determine the correlation and regression equation of each variables as shown in Table 2 and Table 3.

Table 2. The result of correlation statistical analysis and tool vibration regression dan ½ incheses and 3/8 inches.

	½ INCHES CUTTING TOOL	3/8 INCHES CUTTING TOOL
$R^2_{y.123}$	94.40%	96.30%
Regression Equations	$\hat{Y} = -0.3844 + 1.351.10^{-4}X_1 + 0.015488X_2 + 1.14454X_3$	$\hat{Y} = -0.4604 + 1.703.10^{-4}X_1 + 0.01896X_2 + 1.3246X_3$
r_{y1}	0.277	0.293
r_{y2}	0.697	0.718
r_{y3}	0.618	0.602

Table 3. The result of correlation statistical analysis and turning result of surface roughness regression by using ½ inches tool and 3/8 inches

	½ INCHES CUTTING TOOL	3/8 INCHES CUTTING TOOL
$R^2_{y.123}$	95.10%	95.90%
Regression Equations	$\hat{Y} = 0.9367 - 0.00345X_1 + 0.095464X_2 + 17.303X_3$	$\hat{Y} = -0.2846 - 0.00333X_1 + 0.12909X_2 + 24.336X_3$
r_{y1}	-0.552	-0.42
r_{y2}	0.336	0.358
r_{y3}	0.73	0.809

B. Discussion

This study shows that there is an effect of feed rate, spindle speed, tool overhang, and tool dimension toward vibration amplitude and surface roughness on turning process where the most influential parameter towards vibration amplitude is tool overhang, while the most affective parameter towards surface roughness is feed rate.

The experimental result of the effect of independent variables (spindle speed, feed rate, tool overhang) towards vibration amplitude found that, the addition of feed rate on turning process will increase the tool vibration because the more feeding given the faster cutting tool cut of the workpiece, as the result, the frictional forces that occur will be greater due to the magnitude of compressive force on the tip of the cutting tool and workpiece. Moreover, a condition where feeding keeps being constant and the spindle speed varied on different values resulting the increasing of tool vibration if spindle speed is increased. However, vibration obtained will not be as higher as vibration by feeding parameter variation. This vibration is caused by radial cutting force that occurs as a result of interraction between the tip of cutting tool and the rotating workpiece.

The effect of vibration on the cutting tool overhang variation shows that, the more the tools overhang from the tool holder, the greater the vibration results. The length of cutting tool overhang contributes to the deflection which is caused by cutting force that lead to vibration on cutting tool. At the same conditions of cutting parameters, the vibration that occurs in the use of ½ inches tool bit larger than 3/8 inches. This is caused by the stiffness of the ½ inch tool bit larger than 3/8 inches. Material stiffness is determined by volume and elasticity modulus of material, while the magnitude of the deflection is inversely proportional to the value of the rigidity, while the vibration tends to be even greater if the value of deflection increases [14].

Statistically, the coefficient of determination ($R^2_{y.123}$) for ½ inches cutting tool is 0.9442. This shows that, 94.42% of the variation of the amplitude of vibration is the result of the influence of spindle speed, feed rate and tool overhang simultaneously. While the rest 5,6% is caused by other factors. Because the R-square value close to 1, then this indicates the strength of the relationship between the independent and dependent variables in this case. On the use of 3/8 inches cutting tool shows that R *square* is 0,963. This clearly reveals that the effect of spindle speed, feed rate, and tool overhang variables all at once toward tool vibration amplitude is greater than the use of ½ inches tool. On the regression equation of turning vibration amplitude on ½ inches tool, the Constants of -0.3844 states that, if the independent variables like spindle speed, feed rate and tool overhang equals to zero, then the vibration amplitude is -0.3844 µm. Regression coefficient (X_1) of $1.351.10^{-4}$ states that, the addition of spindle speed of 1 rpm will decrease the vibration amplitude of -1.351.10-4 cm/s. Regression coefficient (X_2) of 0.015488 states that, every 1mm addition of tool overhang, will increase vibration amplitude 0.015488 cm/s. Regression coefficient (X_3) of 1.14454 states that, addition of every 1 mm/rev feed rates will increase vibration amplitude 1.14454 cm/s. From the two equations of regression above, it can be seen that coefficient of X_1, X_2 and X_3 on the use of 3/8 inches cutting tool is higher than independent variables coefficient on ½ inches, on the other words, response of independent variable towards vibration amplitude for the use of 3/8 inches tool is greater than the use of ½ inches tool.

To determine the most influential independent variables on the magnitude of the vibration amplitude, the correlation analysis tests is conducted. From the calculation of the correlation coefficient on ½ inches tool shows that the most influential factor on lathe vibration amplitude is tool overhang with correlation value 0.6968 at 99% convidence level, the next is feed rate 0.6182 and the last is spindle speed 0.2767.

In addition, correlation analysis on the use of 3/8 inches cutting tool**,** shows that the most influential factor on the tool vibration amplitude is tool overhang on the correlation value of 0,718, then the feed rate 0,602 and the last is spindle speed which reaches 0.293. as all correlation coefficients are positive, it means that, by increasing the amount of spindle speed, tool overhang, and feed rate will increase tool vibration amplitude. Nevertheless, value of correlation coefficient on the use of tool is 3/8 inches which has a higher correlation value than the use of ½ inches for its all independent variables.

The test result of independent variable effect (spindle speed, feed rate, and tool overhang) towards roughness value found that, addition of feed rate on turning process will increase the value of surface roughness, this is due to the construction of the pointed end (very small nose radius) of the cutting tool, thus, if feeding is slowed down then the distance between the grooves cut by a cutting tool tip at one revolution of workpiece will be even greater. This distance will stimulate such serration effect which is distantly spaced and if measured with surface tester, so, the distance among these serrations is a representation of surface roughness of a turning object. On the variation of tool overhang and tool dimension is seen that surface roughness depends on vibration, thus, the more vibrations the roughness value is greater.

From the results of statistical data processing, for ½ inches tool bit, shows that 95.1% of the variation in surface roughness value is a result of the influence of variable spindle speed, feed rate and cutting tool overhang simultaneously. While the remained of 4.9% is the result of other factors. On the use of 3/8 inches tool bit found that the effect is greater than ½ inches usage ie 95.9%. From the regression equation generated by the use of both types of cutting tool seen that the coefficient of X_1, X_2 and X_3 on the use of 3/8 inches tool bit is greater than the coefficient of the independent variable on the use of 1/2 inches tool bit, in other words, the response to the independent variable of vibration amplitude at the use of 3/8 inch tool bit is much greater than the use of ½ inches tool bit.

The most influential independent variable towards surface roughness value based on correlation analysis test among variables, both for ½ inches and 3/8 inches tools are feed rate , then spindle speed, and the last is tool overhang. Minus sign on the correlation coefficient on the influence of spindle speed states that, the greater the spindle speed is, the smaller the value of surface roughness (R_a) to be generated. where the smaller the value of R_a, the smoother is the surface [15].

C. Conclusion

The effect of feed rate, spindle speed, tool overhang, and tool dimension simultaneously towards vibration amplitude by using ½ inches tool bit is 94.4 %, while the use of 3/8 inches tool bit is 96.3%. The effect of feed rate, spindle speed, tool overhang and tool dimension all at once towards surface roughness by using ½ inches tool bit is 95.1%, while the use of 3/8 inches tool bit is 95.9%. Amplitude correlation of tool vibration by using ½ inches tool towards tool overhang 69.68%, towards feed rate 61.82% and spindle speed 27.67%. On the use of 3/8 inches tool bit, amplitude correlation of tool vibration towards tool overhang 71.8% towards feed rate 60.2% , spindle speed 29.3%. Surface roughness correlation by using 1/2 inches tool bit towards feed rate 73.0% , spindle speed -55.2% , and tool overhang 33.6%. On the use of 3/8 inches tool bit, correlation of surface roughness towards feed rate 80.9%, spindle speed -42.0% and tool overhang 38.5%. The most influential parameters on the vibration amplitude is tool overhang while the most influential parameter on surface roughness value is feed rate.

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