Influence of Dry Machining Parameters in Minimization of Tool Wear

S. Sulaiman, M.K.A. Ariffin, and R.M. Norsat

***Abstract*—** Dry machining is among most popular machining process since no lubricant or coolant is used. However, the higher friction between workpiece and cutting tool will lead to elevated cutting, higher wear rates and, consequently unsafe cutting forces. Therefore, the right selection of machining parameters is most important factor to minimize tool wear ending with higher productivity. In this project, the main objective is to examine the tool wear progress at wide operating cutting domain for dry turning of high carbon steel using Conventional Lathe machine with Ti-N coated carbide cutting tool. Low to high levels of cutting parameters; speed, feed and depth of cut, are considered in the current analysis. The design of experiment (DOE) method by STATISTICA software is used to arrange the parameter according to its priority. Furthermore, the relationship between difference parameters is analyzed using ANOVA to investigate the most significant factor influence tool wear. According to the ANOVA, the most significant parameters that influence to tool wear are cutting speed and feed rate. The recommended machining parameters conditions that minimize tool wear is at the lowest cutting speed of 90 rev/min and lowest feed rate of 0.13 mm/rev.

***Keywords*—** Dry machining, Tool wear, Design of experiment, Analysis of variance.

I. INTRODUCTION

IN manufacturing industries, short tool life, dimensional inaccuracy and surface quality problem are most common issues during machining. Several techniques are used to protect tool life and improve surface quality, as an example by application of cutting fluid or coolant. Cutting fluid generally used to improve tool life and surface finish that able to absorb friction and reduce wear, to reduce work piece temperature by cooling cutting zone and to protect machine surface from environmental corrosion.

According to Weinert et.al [1], the application of cutting fluids is around 7% to 17% of manufacturing costs parts. The cost for cutting fluid is high and requires proper disposal. The consumption of cutting fluid in machining process is limited due to environmental hazard and potential health effect to operators. The main problem of using the cutting fluid instead of reducing the cutting zone temperature is the aerosol generation during the machining process [2]. Sutherland et. al [3] carried out a study that the aerosol quantity produces in the lubrication machining could be 12 to 80 times higher compared to the dry machining. Also, it is recommended by many investigators that using cooling may lead to thermal cracks especiall for coated and uncoated carbide and ceramics inserts that are widely used nowadays in most practical machining.

Due to these reasons, dry machining has been proposed as an alternative to replace conventional wet machining [4]. Since no coolant or lubricant is used in dry machining, the implementation of dry machining could help to eliminate the cost of cutting fluid and to protect the environment.

Dry machining seems to be more economical but can cause tool wear problems. According to [5] the friction and adhesion between chip and tool tend to be higher in dry cutting operations, which causes high temperatures, high wear rates and consequently, shorter tool lives. In [5], a dry machining of steel 1045 using two different tools is found that dry machining requires a very hard tool material that is resistant to high temperature. However, it is observed [2] that tool life in dry machining is not affected at small cutting depth in combination with moderate to high cutting speed

Accordingly, the right selection of machining parameters in dry machining is one of the key issues to minimize tool wear. The most appropriate cutting parameters; cutting speed, feed rate and depth of cut are therefore should be selected to be employed in dry machining[6]. The relationship between different parameters is analyzed to investigate the most significant factor that affecting tool wear. The optimum parameter value with minimum tool wear is identified and recommended.

II. RESEARCH METHOD

Test pieces are cut to desired dimensions and, then, their chemical compositions together with mechanical properties are performed. Finally, specimen are heat treated for hardness improvement [7].

The specimens are heated uniformly in a high intensity flame furnace between 800°C to 900°C longer than 30 minutes. After heating, the heat treated work pieces are quenched in water within for few minutes. Such a process involves the rapid cooling of work pieces in selected quenching medium such as water. Hardness test is performed by using Vickers hardness test method to determine the material ability to resist deformation from a normal source [8].

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STATISTICA software is used to generate design of experiment (DOE) in order to control the parameters and to select the right parameters to start with a 3^3 factorial designs of experimental (DOE) are used [9]. The turning process of high carbon steel is performed in 27 runs according to the parameters selection from DOE by using Conventional Lathe machine with coated carbide insert cutting tool [10,11].

The flank wear length of cutting tool is measured [12]. The statistical analysis of quantitative data by using analysis of variance (ANOVA) is performed to identify the significance of each factor. From ANOVA, the relationship between different parameters is analysis to find the most significant factor affecting tool wear.

III. Results and Discussion

The result obtained from the experiment and analysis regards the tool wear determination and further to validate which parameters that mainly influence wear of cutting tool.

A. Hardness Test

The average values of hardness before and after heat treatment are slightly increased from 185.08 to 217.97 respectively. Based on the percentage of changes, the increasing hardness of work piece after heat treatment is approximately 17%. The higher hardness value causing the material is harder. Table 1 lists Vicker's Hardness value which is graphically shown in Fig. 1.

TABLE I
VICKERS'S HARDNESS VALUE (HV)

Indentation No	Vickers Hardness (HV) before hardening	Vickers Hardness (HV) after hardening
1	164.3	221.3
2	179.6	224.8
3	178.0	249.0
4	174.0	224.0
5	174.5	195.2
6	179.0	206.8
7	220.2	214.2
8	195.0	190.9
9	201.1	235.5
	Average = 185.08	Average = 217.97

B. Tool Wear

Based on the observation, the highest length of tool wear is 1.175 mm with cutting speed of 150 rev/min, depth of cut 1.00 mm and feed rate 0.22 mm/rev. While the lowest value of tool wear is 0.625 mm with cutting speed of 90 rev/min, depth of cut 0.80 mm and feed rate 0.13 mm/rev. Fig. 2 and 3 illustrate the highest and lowest tool wear length.

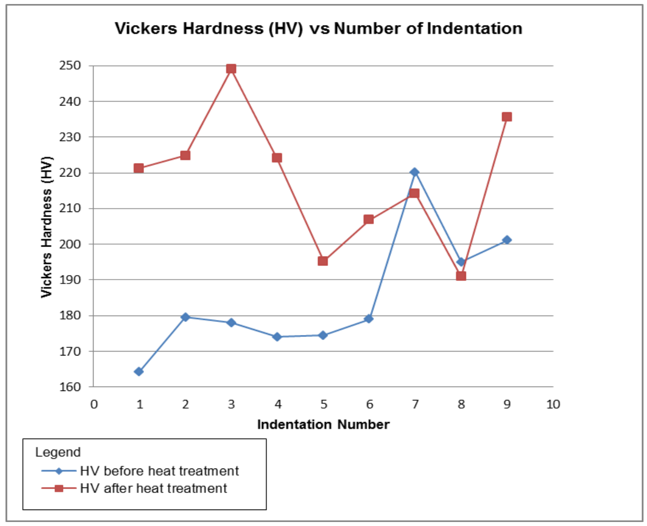

Fig. 1 Comparison of Vickers hardness value

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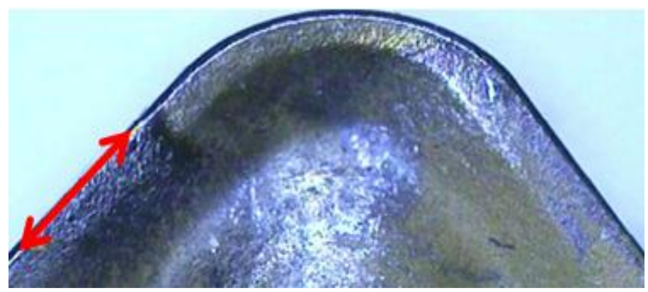

Fig. 2 Highest length of tool wears

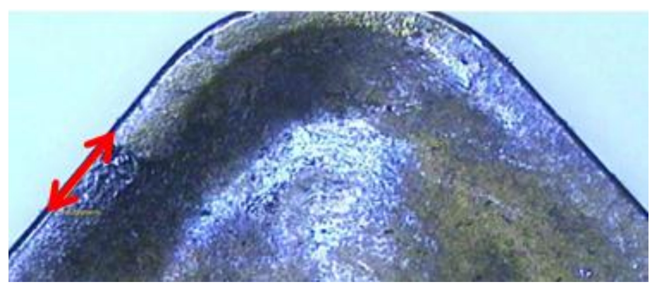

Fig. 3 Lowest length of tool wear

C. Analysis of Variance (ANOVA)

ANOVA is performed to measure the influence of machining parameters and the interaction on selected model according to three independent variables which are cutting speed, depth of cut and feed rate with the length of tool wear as dependent variable.

The result obtained are to compare between three selected models which included no interaction, two way interaction (linear by linear) and two way interaction (linear by quadratic). Depending on R-square value, the interaction of two variables is considered if R-square of two way interaction is greater than no interaction.

According to ANOVA table of no interaction model as shown in Figure 4, the cutting speed is highly significant in both linear and quadratic with P-value of 0.000000 (P≤ 0.05). The P-value of 0.000007 (P≤ 0.05) for feed rate indicates that both linear and quadratic is highly significant. The R-square or coefficient of determination value for no interaction model is 0.91342 which approximately 91.34% of response variable, while the remaining 8.66% is residual variables.

ANOVA; Var.:Tool wear (mm); R-sqr=.91342; Adj:.88745 (3(3-0).sta)
3 3-level factors, 1 Blocks, 27 Runs; MS Residual=.002248
DV: Tool wear (mm)

Factor	SS	df	MS	F	p
(1)Cutting speed (rev/min) L+Q	0.369807	2	0.184904	82.25362	0.000000
(2)Depth of cut (mm) L+Q	0.002333	2	0.001167	0.51900	0.602912
(3)Feed Rate (mm/rev) L+Q	0.102201	2	0.051101	22.73188	0.000007
Error	0.044959	20	0.002248		
Total SS	0.519301	26			

Fig. 4 No Interaction Model of ANOVA

Based on the scatter plot in Fig. 5 shows that the points did not place at closely the straight line, it means that no interaction model is considered as lack of fit model.

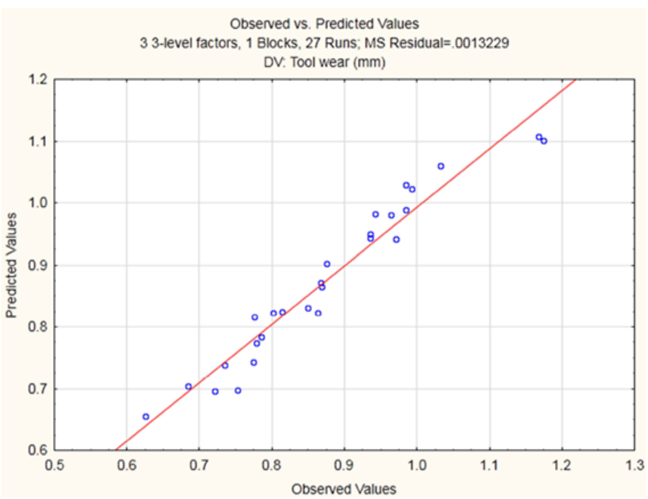

Fig. 5 Scatter diagram of no interaction model

By comparing the interaction between three different variables, the cutting speed and feed rate are most highly significant and cause major influence of tool wear compare to depth of cut.

From the ANOVA analysis with 3D respond surface in Fig. 6, it is found that the tool wear length increased when the cutting speed increased from 90 to 150 rev/min. A similar trend is observed, when the feed rate increase from 0.13 to 0.22 mm/rev. This result corresponds with the statistical result that demonstrates the cutting speed and feed rate have most affecting factors in this analysis.

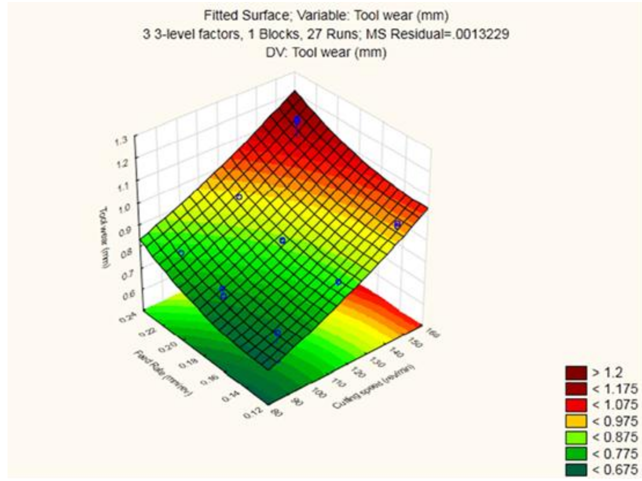

Fig. 6 3D response surface for cutting speed and feed rate

IV. Conclusion

According to the tool wear measures, the lowest length of tool wear of 0.625 mm accompanies the cutting speed of 90 rev/min, depth of cut 0.80 mm and feed rate 0.13 mm/rev. Therefore, the recommended cutting parameter combination to minimize tool wear is cutting speed of 90 rev/min in association with feed rate of 0.13 mm/rev. The ANOVA analysis indicates that the highest tool wear is attained at the extreme high value of both speed and feed rate (cutting speed of 150 rev/min and highest feed rate of 0.22 mm/rev, while minimum tool wear at lowest cutting speed of 90 rev/min and lowest feed rate of 0.13 mm/rev. However, the tool wear length not significantly change when the depth of cut increase from 0.8 mm to 1.2 mm. Since the depth of cut provide insignificant factor in this analysis, the effect to tool wear is consider ignore in machining of AISI 1065.Therefore, it can be concluded that the tool wear in dry turning process of AISI 1065 is mostly affected from the factors of cutting speed and feed rate but less from depth of cut. It because the tool wear length is greater if cutting speed and feed rate increase than increase of depth of cut.

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