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Pearson Correlation Analysis between Radius and Surface Roughness (Ra) Measurements during Turning Processes

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ABSTRACT

According to international standard, surface roughness measurement is one of the important characteristics to define the quality of the machining products. Machine tool's condition is an important factor in determining the workpiece topography. Most the state of the art tool condition monitoring systems employed in-situ techniques to determine the profile of the machined tool. Thus in this study, ex-situ techniques were suggested to conduct the experimental work, particularly to monitor the tool wear during turning processes. In particular, vision measuring microscopes and surface roughness tester were used to measure the radius and surface roughness (Ra) measurements respectively. Prior of the investigations, full factorial design of two levels experiments was designed. Two different workpieces were tested with the value of cutting speed, feed rate and depth of cut were remain constants. Statistical analysis were adopted to determine the correlation of the profile of the carbide insert with the radii and Ra measurements. According to the Pearson correlation analysis towards the experimental results, there is a correlation between the bluntness of the tool with the selection dimension measurements. In addition, it was also found that the wear rate of machining the aluminum is lower compared to the machine steel workpiece.

Key words : Correlation analysis, surface roughness, turning process, machine tool.

1. INTRODUCTION

For decades researchers had studied in the field of monitoring tool wear, particularly for lathe and milling machining processes. Jeon et al (2017) described that cutting force and heat generation would reduce cutting repeatability and stability. A single tool may be used numerous times and machined over distances of millimeters to kilometers during its life. Thus for these reasons, it is crucial to aware the actual state of the cutting tool.

Numerous groups had reported the in-situ and ex-situ approaches to define the condition of the machining tool. Knife-edge interferometry (KEI) [1], acoustic emission signals and monitoring [2], cutting force [3], CCD vision system [4], energy consumptions [5], white light interferometry [6], neural network approach [7]-[9], and vibration [10-11] are the in-situ methods that use to investigate the cutting tool state. However using on the basis of sensor signals for in-situ tool wear monitoring during machining processes, requires an informative insights in order to characterize merely actual profile of the cutting tool [2]. In addition, signal from a single measurement may not give a reliable indication of the tool's condition [3] [8]. This is due to complicated dynamic characteristics of the machining processes and the presents of noise. Hence, the in-situ technique is costly and consume quite a long time in order to build it in for monitoring the machining processes.

On the other hand, monitoring the tool state associated with ex-situ methods is given in [12]-[13] employed the surface roughness measurements to determine the cutting tool's condition. Grzesik and Zalisz (2008) characterize the cutting insert using the microscopy. The investigations is to analyze the wear phenomenon on hard turning operations. While, according to Wang and Liu [15], heat flow and cutting temperature measurements could determine the insert's flank wear state. Although a number of ex-situ techniques for monitoring the tool's condition have been reported, these studies did not focus particularly on the statistical analysis point of view. In particular, some of the knowledge gaps is still exist in this area.

The aim of this is to analyze the correlation between the radii and surface roughness (Ra) measurements towards the wear of the carbide insert during turning processes. Two different workpiece i.e. aluminum and mild steel were used for the experimental analysis. In addition, Pearson correlation was used for the statistical analysis to determine the significant relationships of the selection dimension parameters. Finally, this study will be beneficial for low cost tool wear monitoring. Specifically, as it is does not require to develop new system or modify the cutting machine.

2. EXPERIMENTAL DESIGN

2.1 Turning Processes

In this study a conventional lathe machine model HO 460x1100 was used to conduct the machining processes. In particular, tungsten carbide insert from Mitsubishi Materials was employed to perform the turning processes (refer to Figure 1). Prior to the machining processes, a calibration procedure was systematically carried out. TS-0076 manual lathe calibration record sheet was employed to conduct such operation.

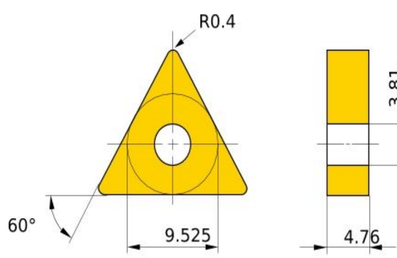

Figure 1: Schematic of the tungsten carbide for turning processes. (From Mitsubishi Materials)

2.2 Design of Experiment

In manufacturing processes, machine parameter setting is an important factors as it could influence the process efficiency and output quality characteristics [16]. Thus the rationale behind of the selection parameters for this particular experiment are as follows.

i. Constant parameters: Speed, feed and depth of cut are the important parameters in turning process as it plays an important role in the efficient use of a machine tool [16]. According to Ghani et al (2011) it is common for turning processes the parameter setting of the lathe machine, particularly for the turning processes are cutting speed, feed rate and depth of cut were at value of 750 m/min, 0.20 mm/rev and 1.0 mm respectively. Thus it was decided to apply such parameter setting on this experimental study.

ii. Variable factors: For this experimental analysis, it is interested to compare the measurements for two different type of workpiece, namely aluminum and mild steel. The rationale behind of these two type of materials were decided to be used in this experimental study is due to the contradiction of the material properties. Gandara (2013) described the aluminum is most commonly a soft and ductile type of material. However, the material properties for mild steel is contradict with the aluminum. Such type of material consist carbon, silicon, sulfur and phosphorous which makes its brittle [19].

Tables 1 and 2 summarize the experimental set-up design for this particular study. Total of the machining trials were eight. The total machined distance for each experiment was 1200 mm. Upon completion of machining processes for each trial, the assessment of the insert wear was conducted at different points across this total machining distances, which are 300 mm, 600 mm, 900 mm and finally 1200 mm.

3. TOOL WEAR ASSESSMENT

For monitoring the wear of carbide insert, Ex-situ monitoring techniques was preferable to use in this experimental study. Vision measuring microscopes and surface roughness tester were used to measured radius and surface roughness (Ra) of the carbide insert and both of the workpiece, namely aluminum and mild steel respectively. In particular, the radius measurement was interested only on the insert's apex.

Principally for every trials, the radius were measured at the height of 6mm from the tool apex (refer Figure 2). This is to ensure the interest area of radii measurements for all the inserts are at least having an equal range.

Table 1: Selected turning process parameters of aluminum workpiece

Trial Number	Workpiece Material	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Length of Cut (mm)
1	Aluminum	750	0.20	1.0	300
2					600
3					900
4					1200

Table 2: Selected turning process parameters of mild steel workpiece

Trial Number	Workpiece Material	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Length of Cut (mm)
1	Mild Steel	750	0.20	1.0	300
2					600
3					900
4					1200

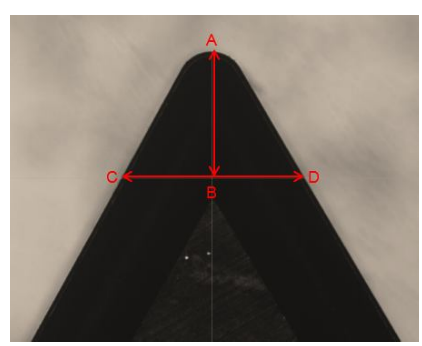

Figure 2: Vision measuring microscopes micrograph of carbide insert with the illustration of the tool apex.

4. RADIUS AND SURFACE ROUGHNESS MEASUREMENTS

4.1 Radius Measurements

Mitutoyo QS-LZB Quick Scope with an accuracy of 0.1µm was used to determine the radius of the insert. Figure 3 and Figure 4 displays the micrographs of the carbide insert for all complete experimental trials during turning processes on aluminum and mild steel workpiece respectively. Hence, prior to the start of the machining processes, the image and radii of the unused insert was respectively recorded and measured. Figure 5 shows plotted graph of the evolution of the insert radii measurement as a function of different type of selection workpiece's material.

From the obtained graph, it shows the radii measurements experiencing gradual increase of values for both of the workpiece materials. It could be expected that the radius should gradually become larger as the machined length of cut increases. The second observation that can be drawn from Figure 5, at Trial 2, the insert worn rate surprisingly increase. More specifically, the difference radius from Trial 1 to Trial 2 was slightly larger. And thus occurred when machining the aluminum and mild steel workpiece. Another conclusion that can be from the plotted graph, after Trial 1 were complete for both experimental studies i.e. machining the aluminum and mils steel workpiece, the rate of inserts worn during turning processes on the mils steel is marginally higher than aluminum. Hence, it is consistent with micrographs of the carbide insert that illustrates in Figures 3 and 4. Particularly, it is obviously could noticed the carbide insert images in Figure 4 experiencing more wear at Trial 2 till complete of the turning processes at Trial 4. Thus, these shows the insert suffering more wear when machining the mild steel workpiece.

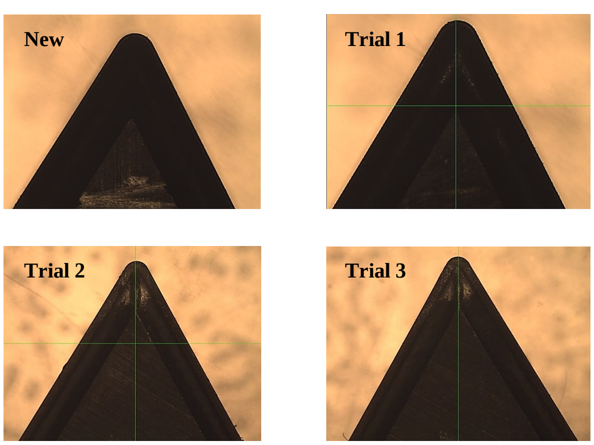

Figure 3: Vision measuring microscopes micrographs of the tungsten carbide insert for all experimental trials when machining aluminum workpiece.

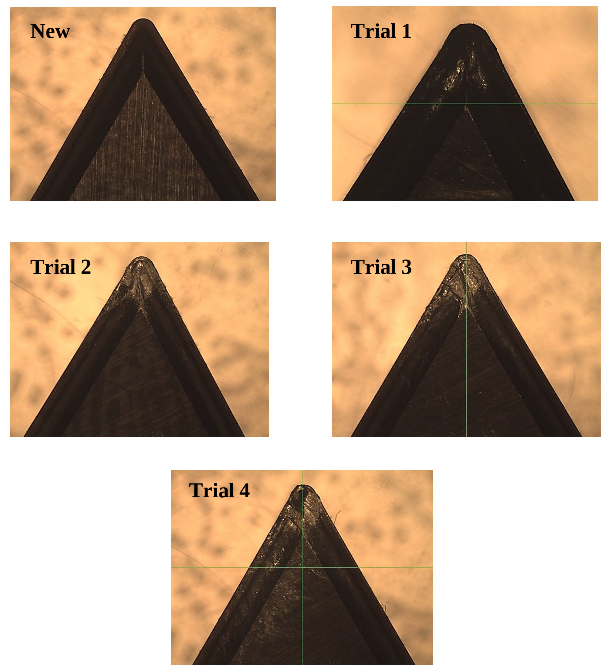

Figure 4: Vision measuring microscopes micrographs of the tungsten carbide insert for all experimental trials when machining mild steel workpiece.

4.2 Surface Roughness Measurements

Ra is an arithmetical mean roughness value. The measurements of the absolute values of the profile deviations obtained from the mean line of the roughness profile. In additional, Ra is the most common roughness parameter used to measure the surface irregularities [20]. For this particular experimental analysis, Tesa-Roughness 10G surface roughness gage was used measure the Ra for both of the selection workpiece i.e. aluminum and mild steel. Figure 6 displays plotted graph of the evolution of the insert Ra measurement as a function of different type of selection workpiece's material. Based on the obtained realts of radii measurements, it was expected that the Ra for both of workpiece will become larger as the increasing of the length of cut during the turning processes. Despite of this fact, the machine steel workpiece plotted graph shows the Ra was considerably higher when machining the mild steel workpiece. This was align with the radii measurement when machining the hard and brittle type of workpiece.

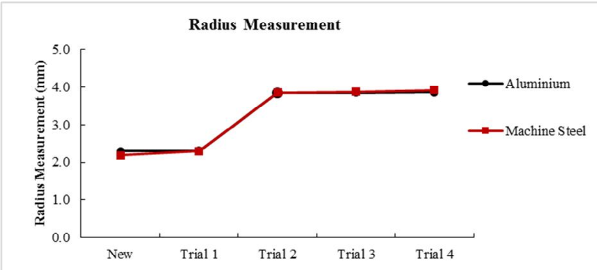

Figure 5: Evolution of the insert radii measurement as a function of different type of selection workpiece's material.

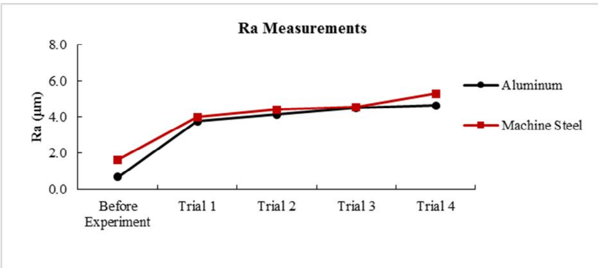

Figure 6: Evolution of the insert Ra measurement as a function of different type of selection workpiece's material.

5. PEARSON CORRELATION ANALYSIS

Correlation is one of the techniques for investigating the relationship between two quantitative of continuous variables. This particular statistical analysis is used to measure the strength and direction of association that exists between two variables [21]. The conducted correlation study for the obtained measurements of radii and Ra were conducted in to two different analyses by using Minitab 17 Software. Specifically, the measurements were takes place according the type on selected workpiece. Hence hypotheses of the analysis were drawn are as follows:

H_o: There is correlation between radii and Ra measurements
H_A: There is no correlation between radius and Ra measurements.

Figure 7 (a) and (b) summarize the analysis of Pearson correlation analysis on the two variables for both aluminum and mild steel workpiece. According to the statistical analysis standard if the p-value is less than 0.05, the H_o will be rejected, otherwise the H_A will be accepted. In particular, the value of 0.05 was based on the confidence interval of 95%, whereby definitely the significance level will be 0.05.Based on obtained values for the correlation analysis for the two variables, both of the p values for aluminum and mild steel were more than 0.05. Thus, the Ho for both of the cases were accepted.

(a)

Correlations: Roughness of Aluminum, Radius of Aluminum

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Pearson correlation of Radius of Aluminium and Roughness
of Aluminium = 0.741
P-Value = 0.152
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(b)

Correlations: Roughness of Mild Steel, Radius of Mild Steel

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Pearson correlation of Radius of Machine Steel and
Roughness of Machine Steel = 0.795
P-Value = 0.108
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Figure 7: (a); Pearson correlation analysis measurements between radii and Ra measurements when machining aluminum workpiece (b); Pearson correlation analysis measurements between radii and Ra measurements when machining mild steel workpiece.

6. CONCLUSION

The objectives of this experimental study was to conduct an investigation on the wear of carbide insert machining different type of workpiece material, namely aluminum and mild steel along different machining distances. In this investigation, vision measuring microscope were used to extracting the apex profiles of the employed tool. In addition, the surface roughness measurements were also measured and analyzed. Finally, the correlation investigations between the radius and surface roughness (Ra) were calculated using Pearson correlation analysis. The conclusions obtained from the work reported in this study as follows:

- The radii and Ra measurements for both of the selected workpiece materials shows the wear rate will become greater as the increasing of the length of cut during the turning processes.
- The wear rate for aluminum was slightly lesser compared when the carbide insert used to machine mild steel workpiece.

The results obtained from Pearson correlation analysis conclude that there were significant relationships between the radius and Ra measurements, regardless when machining the soft or brittle workpiece. Thus, the Ra would be affected as the radius became larger.

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