The Effect of Overlap Ratio and Silicon Carbide Wheel Grinder on Vibration Amplitude and Surface Roughness for Material OCR12VM.

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Abstract. This research aims to find out how big the effect of the overlap ratio and grit size silicon carbide wheel grinder to the vibration amplitude and surface roughness when grinding process and the correlation between the vibration amplitude and surface roughness. This research used the material hardened tool steel OCR12VM. This research using the surface grinding machine KGS818AH model and this research using a variation of process parameters namely 5 variations on the overlap ratio, 4 variations on grit size silicon carbide wheel grinder, 2 variations in the depth of the cut and this research using constant parameters namely constant spindle speed and constant longitudinal feed. The selection the type of abrasive and the selection process parameters (overlap ratio and grit size silicon carbide wheel grinder) can give a great impact on the increased vibration amplitude and surface roughness on material OCR12VM. The conclusion of this study is with increasing overlap ratio, the vibration amplitude and surface roughness will decrease and the finer the grit size silicon carbide wheel grinder, the vibration amplitude and surface roughness will be lower.

1. Introduction
Generally a surface grinding process is the final process in machining to complete a flat surface component. One of the materials that are usually used for this component is the hardened tool steel or equivalent of OCR12VM. Material OCR12VM is hot work tool steel that has a chemical composition of 1.55% C, Si 0.25%, Mn 0.30%, 11.5% Cr, 0.70% Mo, V, so it is classified as high-carbon steel. This type of steel is usually used for tooling equipment. OCR12VM is often used for the manufacture of cutting tools, dies, punches, and mould. The manufacture of dies and moulds need high precision in terms of geometry, sizes, and surface quality in the manufacturing process, to achieve the above requirements, a finishing process is needed. One part of the machine tool that can determine the surface quality and high precision on the results of the production was grinding. The grinding process is a finishing process of the machining process that aims to produce a smooth workpiece surface can even work on a very high precise size demand. The selection of the wheel grinder in the process of machining is also one of the deciding factors for the success to produce a smooth workpiece surface. Silicon carbide is one of the types of wheel grinder used for grinding the workpiece. Silicon carbide wheel grinder is made from silica sand and coal. Grit size is also one of the factors that affect the quality of surface roughness [1, 2]. Aside from the selection of the grit size wheel grinder, good machining process must avoid several factors one of them is vibrations, vibrations can decrease the quality of the production [3]. One of the largest losses if excessive vibration occurs in machining processes, namely
the chisel wear out quickly, broken, and can cause damage to the machine [4, 5]. Chatter grows very quickly when conditions depth cut, wide of grinding, grinding speed, and table speed is increases [6]. with increasing depth of cut, the surface roughness will be increase and the greater the grain size will make the surface roughness decrease [7, 8]. Based on the above research, this research raised about the effect of the overlap ratio and grit size silicon carbide wheel grinder on vibration amplitude and surface roughness for materials hardened tool steel OCR12VM on grinding process. Process parameters in this study is a variation of the overlap ratio, grit size silicon carbide wheel grinder and depth of cut (DOC), and for the response variable examined was the vibration amplitude in the RMS (Root Mean Square) and surface roughness.

2. Method

2.1. Tool used

The vibration amplitude was measured using the PicoScope software. Vibration detected by sensors accelerometer, vibration channelled to ADC through constant current power supply, analog signals are converted into digital and forwarded on to the computer as a spectrum analyser, and data received the computer is ready to be processed with the software engineering math with output value of vibration amplitude. Series of data retrieval can be seen in Figure 1.

![Figure 1. Vibration response test scheme](image)

2.2. Experimental Design

In this study using a surface grinding machine model KGS818AH has a constant spindle speed of 3000 rpm, with dimensions of a work table of 200 x 500 (mm), and the size of a wheel grinder 205 x 25 x 32 / 31.75 (mm). This study uses process variables there are 4 variations in grit size of the wheel grinder, namely GC60LV; GC80LV; GC100LV; and GC120LV; 2 variations depth of cut 5; and 10 (µm), and
5 overlap ratio variations 40; 48; 56; 68; and 80 (%), and in this study using a constant variable, namely the longitudinal feed of 12 mm/s. (See Table 1).

| Grit size | Overlap Ratio (%) | Vibration level x-axis RMS (g) | Vibration level z-axis RMS (g) | Surface roughness (µm) | Vibration level x-axis RMS (g) | Vibration level z-axis RMS (g) | Surface roughness (µm) |
|-----------|-------------------|--------------------------------|--------------------------------|------------------------|--------------------------------|--------------------------------|------------------------|
| 60        | 80                | 0,032                          | 0,025                          | 0,52                   | 0,051                          | 0,045                          | 0,58                   |
|           | 68                | 0,055                          | 0,045                          | 0,56                   | 0,081                          | 0,070                          | 0,61                   |
|           | 56                | 0,071                          | 0,060                          | 0,62                   | 0,110                          | 0,097                          | 0,66                   |
|           | 48                | 0,088                          | 0,067                          | 0,65                   | 0,150                          | 0,110                          | 0,69                   |
|           | 40                | 0,093                          | 0,076                          | 0,69                   | 0,161                          | 0,145                          | 0,74                   |
|           | 80                | 0,027                          | 0,030                          | 0,43                   | 0,045                          | 0,042                          | 0,47                   |
|           | 68                | 0,045                          | 0,041                          | 0,47                   | 0,071                          | 0,058                          | 0,52                   |
| 80        | 56                | 0,061                          | 0,052                          | 0,53                   | 0,094                          | 0,076                          | 0,57                   |
|           | 48                | 0,074                          | 0,059                          | 0,56                   | 0,115                          | 0,092                          | 0,60                   |
|           | 40                | 0,082                          | 0,066                          | 0,62                   | 0,140                          | 0,115                          | 0,66                   |
|           | 80                | 0,023                          | 0,025                          | 0,32                   | 0,036                          | 0,038                          | 0,39                   |
|           | 68                | 0,036                          | 0,037                          | 0,37                   | 0,061                          | 0,051                          | 0,43                   |
| 100       | 56                | 0,050                          | 0,047                          | 0,42                   | 0,082                          | 0,065                          | 0,48                   |
|           | 48                | 0,058                          | 0,051                          | 0,45                   | 0,094                          | 0,076                          | 0,52                   |
|           | 40                | 0,066                          | 0,058                          | 0,48                   | 0,110                          | 0,090                          | 0,56                   |
|           | 80                | 0,015                          | 0,018                          | 0,25                   | 0,030                          | 0,034                          | 0,30                   |
|           | 68                | 0,028                          | 0,033                          | 0,28                   | 0,050                          | 0,043                          | 0,36                   |
| 120       | 56                | 0,042                          | 0,041                          | 0,33                   | 0,063                          | 0,056                          | 0,39                   |
|           | 48                | 0,047                          | 0,044                          | 0,35                   | 0,072                          | 0,064                          | 0,43                   |
|           | 40                | 0,053                          | 0,050                          | 0,37                   | 0,082                          | 0,072                          | 0,47                   |

2.3. Regression

Regression modelling was used as approach method to analyze the correlation between process variables with variable response [9]. In the simple regression analysis, the correlation between the variables are linear, where changes to the variable X will be followed by a change in variable Y permanently. In choosing the right model, usually checked between model variables is linear or polynomial models. In General, measurements of the vibration amplitude can be analyzed with the following mathematical equation:

\[ y_a = C . G_s^{c_1} . O_r^{c_2} . \varepsilon' \]  \hspace{1cm} (1)

From equation (1) linearized by performing a logarithm transformation where \( y_a \) is the vibration amplitude RMS (g), C is a constant, \( G_s \) is the grit size wheel grinder, \( O_r \) is the overlap ratio, and \( \varepsilon' \) is the experimental error, and for \( c_1 \), and \( c_2 \) is the model parameters estimated from the experimental data can be seen below:

\[ \ln y_a = \ln C + c_1 \ln G_s + c_2 \ln O_r + \ln \varepsilon' \]  \hspace{1cm} (2)
After the values obtained from the processing of experimental data then equation (2) can be inverse transformations, so that it can be written:

\[ e^{\ln y_a} = e^{\ln C} \cdot e^{c_1 \ln G_s} \cdot e^{c_2 \ln O_r} \cdot e^{\ln \varepsilon'} \]  

(3)

So the vibration amplitude equation is:

\[ y_a = C \cdot G_s^{c_1} \cdot O_r^{c_2} \cdot \varepsilon' \]  

(4)

Surface roughness for modeling regression equation can be written as follows:

\[ y_{ra} = C \cdot G_s^{c_1} \cdot O_r^{c_2} \cdot \varepsilon' \]  

(5)

Equation (5) linearized by performing logarithm transformation as following:

\[ \ln y_{ra} = \ln C + c_1 \ln G_s + c_2 \ln O_r + \ln \varepsilon' \]  

(6)

After the values obtained from the processing of experimental data then equation (6) can be inverse transformations, so that it can be written:

\[ e^{\ln y_{ra}} = e^{\ln C} \cdot e^{c_1 \ln G_s} \cdot e^{c_2 \ln O_r} \cdot e^{\ln \varepsilon'} \]  

(7)

So the surface roughness equation is:

\[ y_{ra} = C \cdot G_s^{c_1} \cdot O_r^{c_2} \cdot \varepsilon' \]  

(8)

Where \( y_{ra} \) is the surface roughness (\( \mu m \)), \( C \) is a constant, \( G_s \) is the grit size wheel grinder, \( O_r \) is the overlap ratio, and \( \varepsilon' \) is the experimental error, and for \( c_1 \), and \( c_2 \) is the model parameters estimated from the experimental data.

3. Results and Discussion

Based on research data in Table 1 showed the vibration amplitude and surface roughness has correlation to overlap ratio at each grit size wheel grinder and depth of cut tabulated in figure below and can be made correlation between the overlap ratio, grit size wheel grinder, vibration amplitude, and surface roughness with the regression model as in the Table 2.
### Table 2. The result of vibration and surface roughness measurement regression modeling

| Grit size | Overlap Ratio (%) | Depth of cut 5 µm | Response variable | Depth of cut 10 µm |
|-----------|-------------------|-------------------|-------------------|-------------------|
|           |                   | Vibration level x-axis RMS (g) | Surface roughness (µm) | Vibration level z-axis RMS (g) | Surface roughness (µm) |
| 60        | 80                | 0.038             | 0.036             | 0.530             | 0.062             | 0.055             | 0.567             |
|           | 68                | 0.050             | 0.044             | 0.577             | 0.080             | 0.069             | 0.614             |
| 56        | 80                | 0.067             | 0.056             | 0.639             | 0.108             | 0.089             | 0.676             |
|           | 68                | 0.086             | 0.067             | 0.692             | 0.137             | 0.110             | 0.729             |
| 40        | 80                | 0.114             | 0.084             | 0.762             | 0.181             | 0.140             | 0.798             |
|           | 68                | 0.130             | 0.081             | 0.403             | 0.049             | 0.045             | 0.457             |
| 80        | 68                | 0.038             | 0.037             | 0.439             | 0.063             | 0.056             | 0.495             |
| 100       | 68                | 0.052             | 0.047             | 0.486             | 0.085             | 0.072             | 0.545             |
|           | 80                | 0.066             | 0.057             | 0.527             | 0.107             | 0.089             | 0.588             |
| 48        | 80                | 0.089             | 0.070             | 0.580             | 0.142             | 0.113             | 0.643             |
|           | 68                | 0.024             | 0.027             | 0.326             | 0.040             | 0.038             | 0.387             |
| 120       | 56                | 0.043             | 0.041             | 0.394             | 0.070             | 0.061             | 0.461             |
|           | 48                | 0.054             | 0.050             | 0.427             | 0.089             | 0.075             | 0.497             |
| 40        | 80                | 0.073             | 0.062             | 0.470             | 0.118             | 0.096             | 0.544             |
|           | 68                | 0.021             | 0.024             | 0.275             | 0.035             | 0.033             | 0.337             |
| 100       | 56                | 0.036             | 0.037             | 0.331             | 0.060             | 0.054             | 0.402             |
|           | 48                | 0.046             | 0.044             | 0.359             | 0.076             | 0.066             | 0.434             |
| 120       | 40                | 0.062             | 0.055             | 0.395             | 0.101             | 0.084             | 0.475             |

Modelling regression equation below is taken from the regression equations (5) and (8) that has been processed by the software and equation regression modelling for each response can be seen as below:

\[
y_{a(x_5)} = 1483.36 \cdot G_s^{-0.892} \cdot O_r^{-1.577}
\] (9)

\[
y_{a(x_{10})} = 1718.14 \cdot G_s^{-0.846} \cdot O_r^{-1.543}
\] (10)

\[
y_{a(z_5)} = 80.23 \cdot G_s^{-0.5995} \cdot O_r^{-1.196}
\] (11)

\[
y_{a(z_{10})} = 391.89 \cdot G_s^{-0.7321} \cdot O_r^{-1.3392}
\] (12)

\[
y_{ra(5)} = 254.93 \cdot G_s^{-0.9470} \cdot O_r^{-0.5247}
\] (13)

\[
y_{ra(10)} = 105.74 \cdot G_s^{-0.7495} \cdot O_r^{-0.4929}
\] (14)

### 3.1. Overlap ratio with vibration amplitude and surface roughness

Based on research data in Table 1 on the tabulated in the graph can be seen on Figure. 2, 3 and 4 with increasing overlap ratio then the vibration amplitude and surface roughness will decrease, and on the graph can be seen finer grit size silicon carbide wheel grinder then the vibration amplitude and surface roughness will increase followed by vibration level x-axis RMS (g) and vibration level z-axis RMS (g).
roughness will decrease and with increasing depth of cut then the vibration amplitude and surface roughness will increase. At a small depth of cut the load received by the workpiece is also small, so that the vibrations and surface roughness also small, otherwise At a high depth of cut the load received by the workpiece is also high, and made vibrations and surface roughness also high [10]. On the fine wheel grinder has a smaller vibration and surface roughness than the rough wheel grinder.

Figure 2. Overlap ratio vs vibration level in x-axis and z-axis (a) DOC 5 µm and (b) DOC 5 µm

Figure 3. Overlap ratio vs vibration level in x-axis and z-axis (a) DOC 10 µm and (b) DOC 10 µm

Figure 4. Overlap ratio vs surface roughness (a) DOC 5 µm and (b) DOC 10 µm
3.2. Regression modelling

Based on research data in Tables 1 and 2 at the regression data in tabulated in a graph on Figures 5, 6, and 7.

**Figure 5.** The experimental and the regression model of x-axis and z-axis vibration RMS (a) DOC 5 µm and (b) DOC 5 µm.

**Figure 6.** The experimental and the regression model of x-axis and z-axis vibration RMS (a) DOC 10 µm and (b) DOC 10 µm.

**Figure 7.** The experimental and the regression models of surface roughness (a) DOC 5 µm and (b) DOC 10 µm.
3.3. Correlation of vibration and surface roughness

Based on Figure 8 can be seen that the vibrations and surface roughness has a correlation between the vibration amplitude and surface roughness, with increasing vibration amplitude then the surface roughness also increased, this is caused small overlap ratio at each grit size and at each depth of cut therefore cutting force and contact between the wheel grinder and the work piece become high so that made the vibration amplitude increased so that surface roughness also increased.

![Figure 8](a) Vibration amplitude vs surface roughness (a) DOC 10 µm and (b) DOC 10 µm

4. Conclusions

With this, we know with the increasing overlap ratio then the vibration amplitude and surface roughness will decrease. The statement is directly proportional to the correlation between the vibration amplitude and surface roughness with increasing vibration amplitude then the surface roughness will increases. The effect of the selection grit size wheel grinder in which increasingly fine grit size wheel grinder, the vibration amplitude will decrease and surface roughness also will decrease at every depth of cut.

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