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Study of heat generation and cutting force according to minimization of grain size (500 nm to 180 nm) of WC ball endmill using FEM

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Abstract. As the industry develops, miniaturization and refinement of products are important issues. Precise machining is required for cutting, which is a typical method of machining a product. The factor determining the workability of the cutting process is the material of the tool. Tool materials include carbon tool steel, alloy tool steel, high-speed steel, cemented carbide, and ceramics. In the case of a carbide material, the smaller the particle size, the better the mechanical properties with higher hardness, strength and toughness. The specific heat, density, and thermal diffusivity are also changed through finer particle size of the material. In this study, finite element analysis was performed to investigate the change of heat generation and cutting power depending on the physical properties (specific heat, density, thermal diffusivity) of tool material. The thermal conductivity coefficient was obtained by measuring the thermal diffusivity, specific heat, and density of the material (180 nm) in which the particle size was finer and the particle material (0.05 μm) in the conventional size. The coefficient of thermal conductivity was calculated as 61.33 for 180nm class material and 46.13 for 0.05 μm class material. As a result of finite element analysis using this value, the average temperature of exothermic heat of micronized particle material (180nm) was 532.75 $^{\circ}\text{C}$ and the temperature of existing material (0.05 μm) was 572.75 $^{\circ}\text{C}$. Cutting power was also compared but not significant. Therefore, if the thermal conductivity is increased through particle refinement, the surface power can be improved and the tool life can be prolonged by lowering the temperature generated in the tool during machining without giving a great influence to the cutting power.

1. Introduction

Density, specific heat, and thermal conductivity vary depending on the particle size of the material. As a result of analysis of the influence of the heating part of each material property (density, specific heat, thermal conductivity) through the preliminary experiment, it was found that the thermal conductivity has the greatest influence. In addition, the influence of the properties (density, specific heat, thermal conductivity) on the cutting force was not influenced. In this study, the finite element analysis is performed to investigate the change of heat generation and cutting power depending on the thermal conductivity which is changed by miniaturization of tool material.

Table 1. Result of measuring properties.

	Thermal conductivity	Specific heat	Density	Thermal diffusivity
Unit	$\text{W}/(\text{m} \times ^{\circ}\text{C})$	$\text{J}/[\text{kg} \times ^{\circ}\text{C}]$	kg/m^3	mm^2/s
0.5 μm	46.913	190	14.439	18.1
0.18 μm	71.063	244	14.784	19.7



The material sizes of 500 nm and 180 nm were measured using the flash method, and the finite element analysis was performed using the measured values. Material property of table is table 1. The tool performance is evaluated by cutting force analysis, thermal analysis can be used to measure the maximum temperature of the tool and expect tool life to be prolonged at low tool temperatures.

2. FEM Set up

In this study, The tool is a ball-end mill which has a 2mm diameter and the workpiece is STD61 (HRC 52) which is used as a mold steel. The shape of the tool was fabricated using CAD(Fig.1). In the case of the analysis Fem is using by the commercial software “Advant Edge”. the tool is rotated 720 ° (Fig.2) it means the cutting is happen 4 times. As the analysis condition, the mesh size of the workpiece set to 0.01mm. the mesh size of tool and contacting part(interface with workpiece and tool) define to 0.01mm. Cutting conditions is specified as down-milling, RPM 20000, FeedRate 800 (mm / min) cutting width 0.4 (mm) and cutting depth 0.4 (mm).

Cutter Diameter [Do]	2	mm
Core Diameter [Di]	1.5	mm
Number of Flutes	2	mm
Radial Rake Angle [a]	3	deg
Helix Angle [c]	29.5	deg
Radial Relief Angle [b]	30	deg
Edge Radius [r]	0.04	mm
Flute Radius [Rf]	0.08	mm
Width of Land [wol]	0.331	mm
Tool Length [ta]	5	mm



Figure 1. Modelling tool by 3D CAD

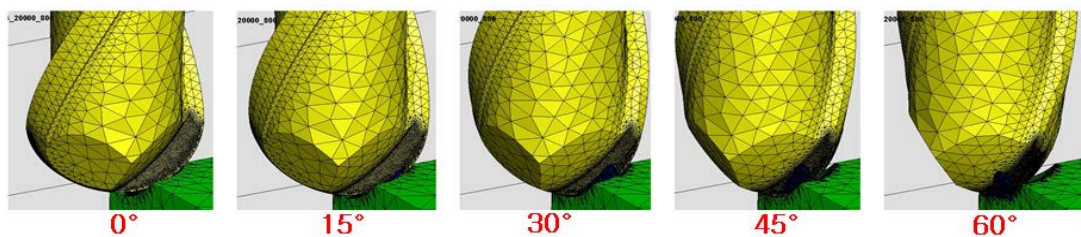


Figure 2. Example of FEM Boundary condition

3. FEM result

The temperature change according to the thermal conductivity is shown in the graph in Fig. 3, and the graph of cutting power and cutting force appears almost the same. Changes in thermal conductivity affect the tool temperature and have no significant effect on cutting power. Thermal analysis is performed by changing the temperature distribution at the cutting edge. Figure 4 shows the heat generated by the rotation angle. Indicates the temperature distribution change that occurs when cutting

of the first blade proceeds. In a tool with a low thermal conductivity, thermal diffusion is not easy and the maximum temperature of the tool is increased due to heat concentration at the tip of the blade. Also, it is expected that the material with higher thermal conductivity will have more heat coming through the tool. However, as the tool receives the same amount of heat, the range of diffused heat spreads and the maximum temperature at the tool tip.

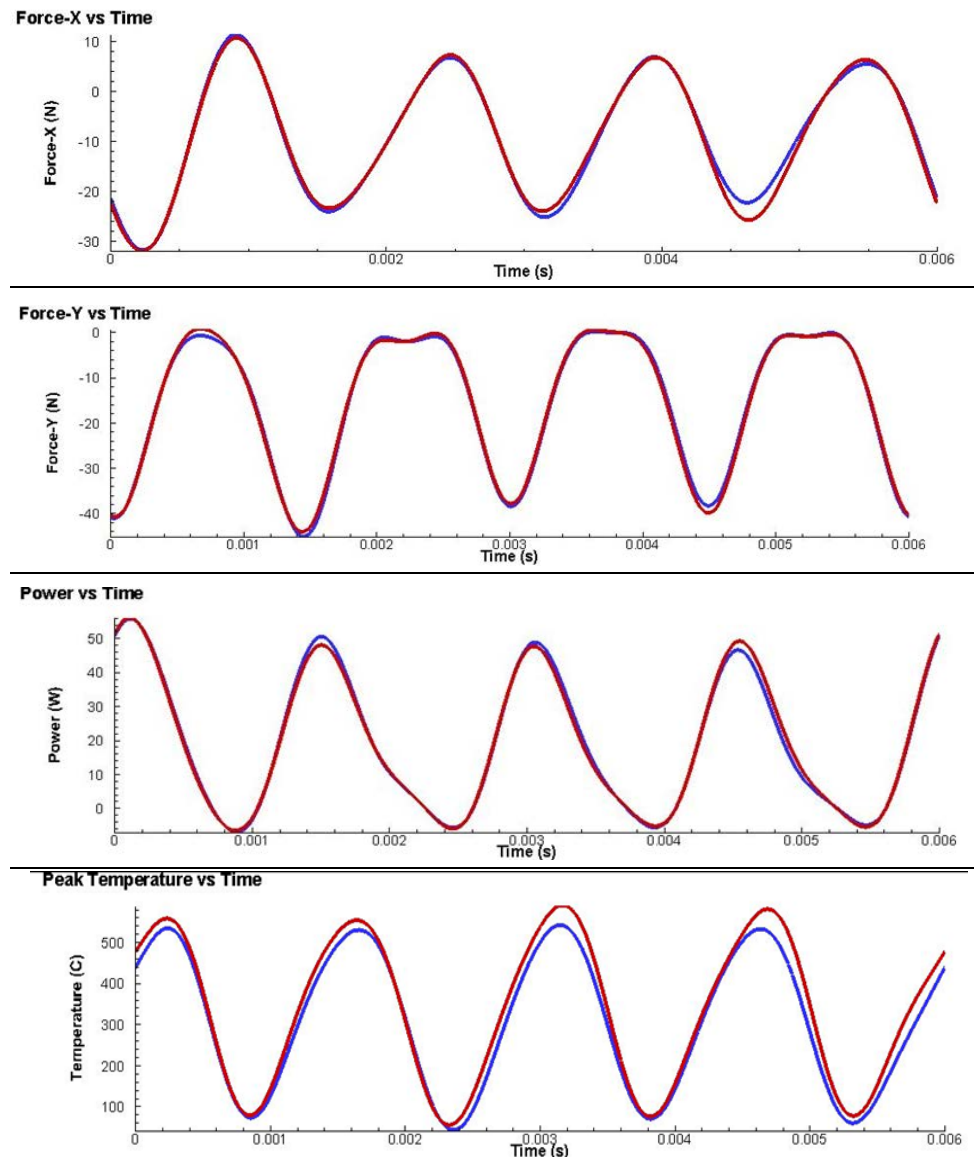


Figure 3. Cutting force & Cutting power & Temperature of tool [Red : 500nm ,Blue 180nm]

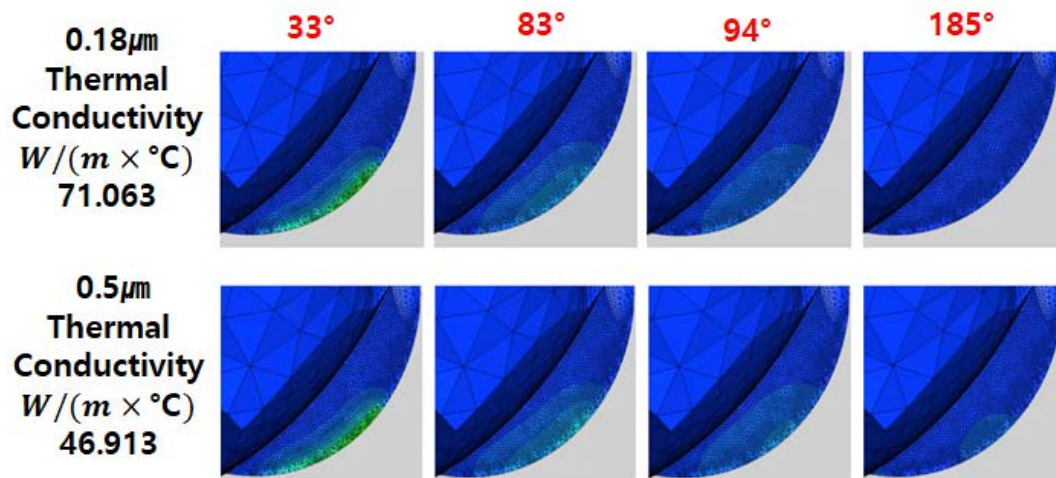


Figure 4. Heat transfer on blade

4. Conclusion

The change in thermal conductivity does not have a significant effect on the cutting force and cutting power. As a result of comparing the maximum temperature of the blade part, the temperature of 180nm tool with high thermal conductivity is low temperature. It means that at high thermal conductivity, the temperature distribution range is wide due to heat diffusion, and the maximum temperature of the blade is low. It also benefits on fast heat removal after cutting. Same as the result of the preliminary experiment.

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