

Cutting Process in Turning of Super Heat-Resistant Alloy Inconel 718 under Oil Mist Application

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Abstract

The purpose of this study is to clarify the possibility of the eco-cutting process for the super heat-resistant alloy Inconel 718. In particular, the effects of the oil mist application were examined with reference to the cutting process, through observation and measurement of the form of the generated chips in a series of experiments under various cutting conditions. As a result of these experiments, and through observations of the cross-sections of the chips, it was quantitatively possible to measure and confirm the effects of the oil mist application.

1 Experimental Methods and Devices

In order to confirm the machinability of Inconel 718 under various kinds of the oil mist application, the cross-section of the chip was observed and measured at every 50μm up to 600μm length by microscope (Keyence VH-6300). In the experiment, a diamond-shaped throwaway tip was used as a cutting tool. This material is equivalent to the cemented carbide tool HW-K10. The machine used in the experiment was a CNC lathe and a round bar was cut at a constant peripheral speed at 40m/min. The oil mist instrument used in the experiment was an external oil supplying type of system as shown in Fig.1, and is able to control the amount of vegetable oil and the air pressure.

In the experiment, the oil mist mixed with 0.1MPa air and 0.5MPa air were supplied. In the oil mist and air supplying processes, a cutting tool with an oil hole was used as shown in Fig.2. The oil mist was injected on both the flank and on the rake face of the tool. This method is considered to be most effective in lubricating and cooling the tools in the cutting operation.^[1] The experimental conditions are shown in Table 1.

2 Experimental Results and Discussion

2.1 Actual form of the chip generated

For the form of the generated chip, as shown in Fig.3, cutting was implemented under a cutting depth of 0.25mm by a 0.4mm round corner of a cutting edge. And then the chip of the flow type was generated along with the circular arc of the corner radius.

Moreover, when the removal part on the figure by using the brand new cutting tool shown with the hatching in Fig.4 and the cross-section of the chip which was actually generated were compared, an almost similar shape was observed in the initial stage of cutting. On the other hand, as shown in Fig.5 it is evident that the cross-section of the chip is severely deformed at a 600m cutting length.

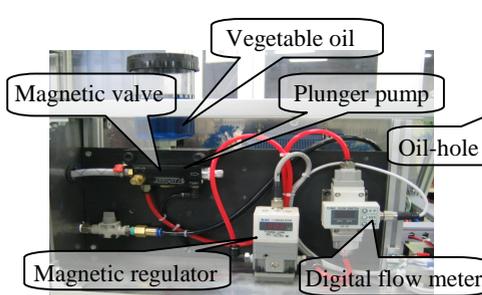


Figure 1: Overview of external oil supplying system

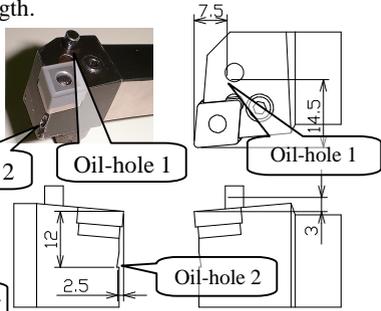


Figure 2: Overview of cutting tool with $\phi 1$ mm oil holes placed on the rake face and the flank sides

Table 1: Experimental conditions

Work material	Inconel 718 $\phi 60 \times 210$ HB415
Tool material Heat conductivity Hardness	Cemented carbide HW-K10 79 W/(m·K) HRA 92
Tool geometry deg , mm	-6, -6, 6, 6, 5, -5, 0.4
Cutting conditions Cutting speed m/min Depth of cut mm Feed rate mm/rev	40 0.25 0.25
Environmental conditions and coolant	Dry Emulsion (0.1MPa) A1-1 \times 20 Room Temp. Air (0.5MPa) Misty 6 mL/h + Room Temp. Air (0.1MPa) Misty12 mL/h + Room Temp. Air (0.1MPa) Misty12 mL/h + Room Temp. Air (0.5MPa)

2.2 Cutting cross-section ratio

A new cutting parameter, the cutting cross-section ratio as shown in Fig.6 which numerically expressed the cutting state and was compatible with three-dimensional cutting was proposed. The cutting cross-section ratio (r_c) was defined as the cutting area (S_1) divided by the cross-section of the generated chip (S_2) shown in the equation (1).

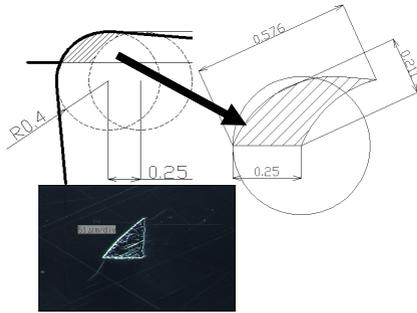


Figure 3: Cutting cross-section when cutting by a round corner of the cutting edge

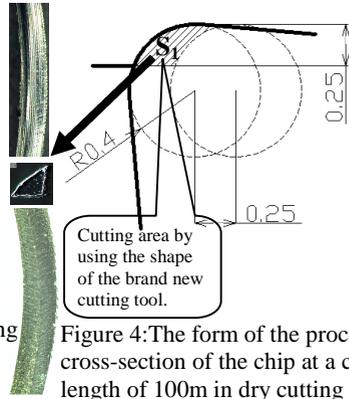


Figure 4: The form of the processed cross-section of the chip at a cutting length of 100m in dry cutting

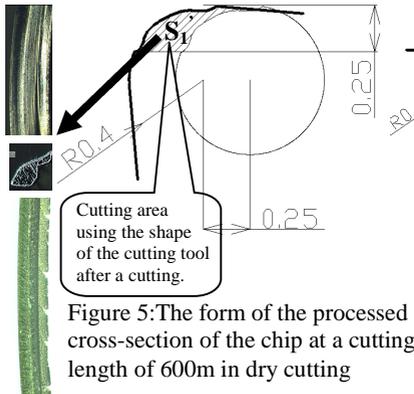


Figure 5: The form of the processed cross-section of the chip at a cutting length of 600m in dry cutting

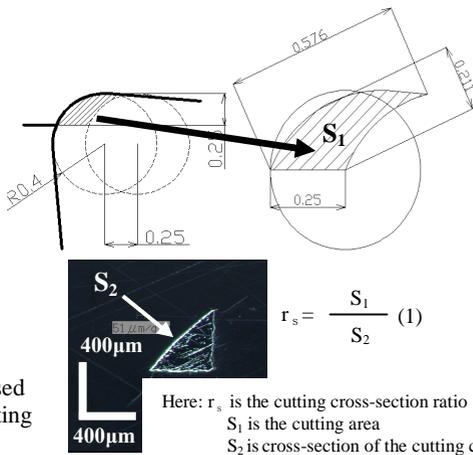


Figure 6: Equation for cutting cross-section ratio (r_s)

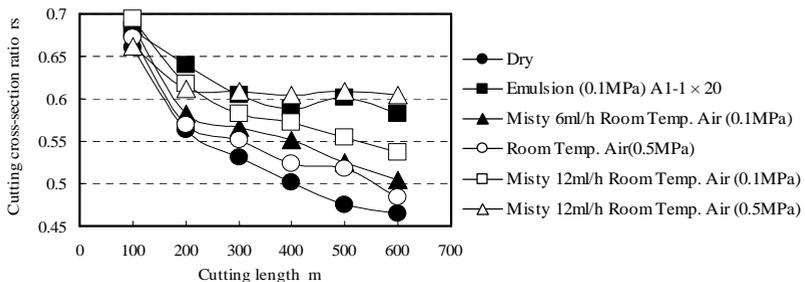


Figure 7: Cutting cross-section ratio when Inconel 718 was cut by HW-K10 cemented carbide insert at the various coolant conditions

The generation of the chip is a phenomenon that occurs in cutting to be attended with the plastic deformation. A good cutting condition refers to a case where the plastic deformation during cutting was small and the deformation of the cross-section of the chip is small as well. Therefore, it was thought that the cutting cross-section ratio was suitable for expressing the effect of oil mist as a lubricant numerically in the series of experiment implemented by the author. Figure 7 shows the values of the cutting cross-section ratio (r_s) at each cutting length. For example, in the case of the dry cutting that did not expect any lubrication and cooling, the value of r_s always had the tendency of decreasing rapidly and the value of r_s became smaller than 0.5 at a cutting length of 600m compared to the other cutting conditions. On the other hand, in the case of the emulsion coolant cutting that could expect some kind of lubrication and cooling, after the value of r_s decreased to 0.6, the value of r_s was kept at around 0.6 until a cutting length of 600m. Next, the tendency of the value of r_s was discussed at the oil mist cutting. At the oil mist cutting (Oil mist 12mL/h room temp. air 0.5MPa), after the value of r_s decreased at 0.6, the value of r_s was kept at around 0.6 until the cutting length of 600m which had the same value of the emulsion coolant cutting.

3 Conclusions

The main conclusions obtained from this experiment are as follows.

[1] In the case of the oil mist application (oil mist 12mL/h, Room Temp. air 0.5MPa), the processed cross-section of the generated chips had a similar degree of deformation to in the case of emulsion coolant (0.1MPa A1-1×1).

[2] The effects of using the oil mist could also be quantitatively demonstrated from the series of experimental results, by proposing a new cutting parameter – the cutting cross-section ratio – which numerically expresses the cutting state and which is compatible with three-dimensional cutting.

Reference:

- [1] Y. Hanada, Study on Environment Cooling Air Machining Technology, Saitama Prefecture Industrial Technology Center Research Report, 2(1999) pp. 62-66.