High-Efficiency Grinding Using a Fine Bubble Coolant Generated by a Microporous Fine Bubble Generator

超微細孔方式によるファインバブルクーラントを用いた高能率研削

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Abstract

When processing hard materials such as cemented carbide and ceramics, there are problems such as frequent clogging of the grinding wheel and long non-processing time required for truing and dressing. Previous reports have described that a fine bubble (FB) coolant decreases the grinding force. However, few studies have been reported on the method for generating FBs using microporous ceramics. In this study, the number density of FBs generated by a microporous FB generator and the static contact angle of the FB coolant droplet were investigated. The static contact angle of the FB coolant was 2° lower than that of the non-FB coolant, and the grinding force was reduced by 15% during surface grinding of cemented carbide with a diamond wheel.

超硬合金やセラミックなどの硬質材料は高硬度であり，これらを加工する場合は，その研削砥石が頻繁に目詰まりするため，ツルーイング・ドレッシングに要する非加工時間が長いなどの問題がある．ファインバブルクーラントは研削抵抗を低減する効果があることが知られているが，その生成原理に超微細孔方式を適用した事例はほとんど報告されていない．本研究では超微細孔方式によるファインバブルの生成と計測を行った．クーラントの静的接触角は2°低下し，ダイヤモンドホイールを用いた超硬合金の平面研削において研削抵抗は15%低下した．

1. Introduction

In recent years, fine bubbles (FBs) have been studied and their applications are progressing in various fields. Iwai and his team reported that the lifetime of the grinding wheel for harden steel was improved by 20% generating FBs in a coolant[1]. Takahashi observed that FBs are negatively charged[2].

In this study, we developed a new FB generator using a microporous ceramic. Furthermore, we measured the static contact angle of the FB coolant droplets and investigated surface grinding of cemented carbide with a diamond wheel.

2. Fine bubbles

2.1 About fine bubbles

FBs are bubbles with a diameter of less than 0.1 mm. In this paper, bubbles with diameter of 1–100 µm are called microbubbles (MBs) and bubbles with diameter of less than 1 µm are called ultra-fine bubbles (UFBs). When there is no need to distinguish between MBs and UFBs, it is called bubbles.

2.2 The number density of FBs

A schematic illustration of generation of the FBs is shown in **Fig. 1**. A microporous ceramic is filled with tap water and compressed air passes through the microporous ceramic from the bottom side to the top side. A photograph of the FBs generated in tap water is shown in **Fig. 2**.

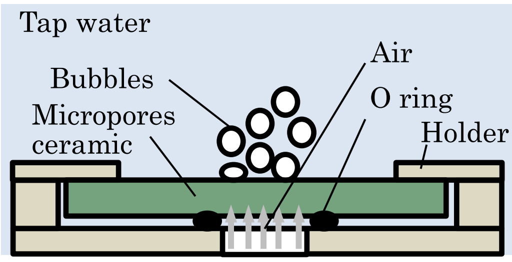

Fig. 1 Schematic of the FB generator

Fig. 2 Photograph of FBs in tap water

The UFBs were measured with ZetaView (measurement range of 0.02 - 1 µm, Microtrac Bell), which is based on the nanoparticle tracking analysis method. Tap water was used in this study because the presence of coolant components can affect the measurement results by generating scattered light even if UFBs are not present. The number density of UFBs generated in tap water is shown in **Fig. 3**. The number density of the bubbles showed a sharp peak at approximately 0.1 µm in diameter.

The MBs were measured with Particle Insight (measurement range of 1 -100 µm, Shimadzu Corporation), which is based on the image analysis method. The number density of MBs generated in the coolant is shown in **Fig. 4**. The number density of the bubbles showed a broad peak between 25 and 75 µm in diameter.

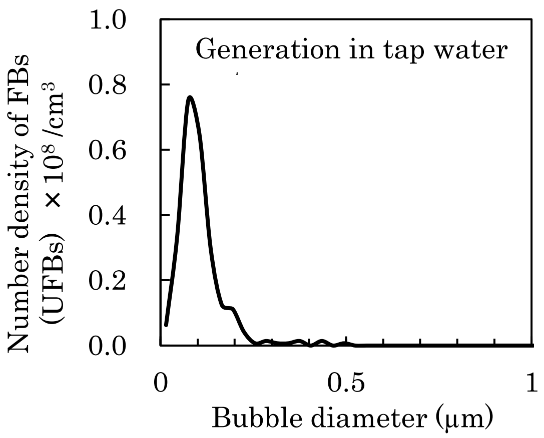

Fig. 3 Number density of FBs (UFBs)

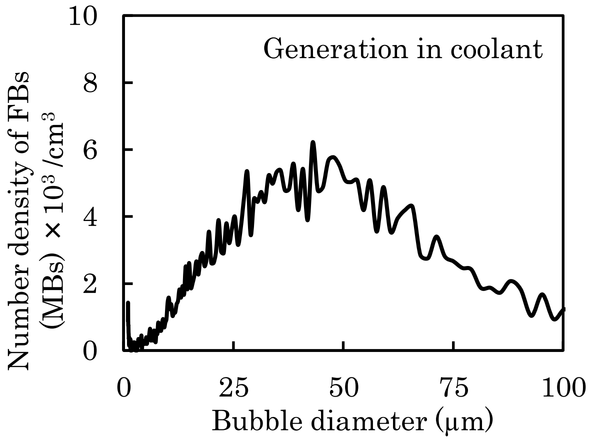

Fig. 4 Number density of FBs (MBs)

3. Characteristics of the FB coolant

3.1 Static contact angle of a FB coolant droplet

A photograph of the equipment used to measure the static contact angle (DMe-211, Kyowa Interface Science Co., Ltd.) is shown in **Fig. 5**. The needle is close to the substrate surface and 1 μL of the coolant is dropped on the substrate surface. After 10 s, the shape of the coolant droplet is observed by a camera, and the static contact angle is automatically calculated by computer. A photograph of a droplet on the substrate surface is shown in **Fig. 6**.

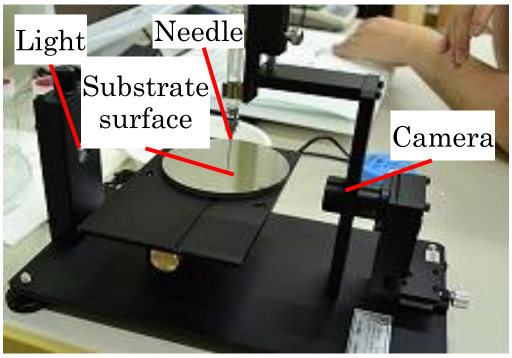

Fig. 5 Photograph of the Measuring equipment

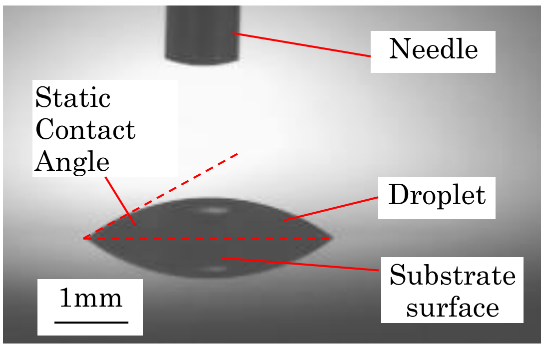

Fig. 6 Appearance of a coolant droplet

The static contact angles measured 10 s after drops of the non-FB coolant and FB coolant were dropped on the stainless-steel substrate are shown in **Fig. 7**. The static contact angle of the FB coolant was 2° lower than that of the non-FB coolant.

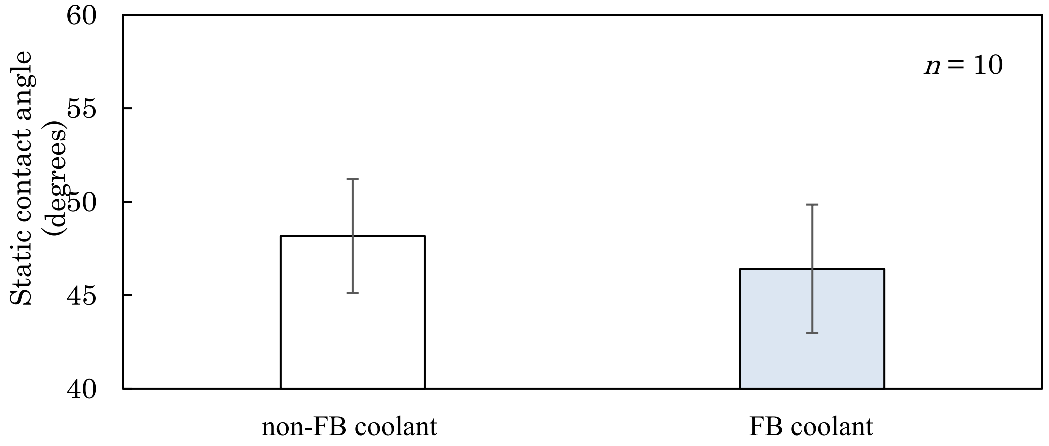

Fig. 7 Static contact angles of the non-FB coolant and FB coolant on a stainless-steel substrate

3.2 Grinding force of surface grinding with the FB coolant

A photograph of the grinding machine is shown in **Fig. 8**. The FB generator (FB-ASSIST P series MGC-205, Nippon Tungsten) was installed near the diamond wheel. A coolant tank was installed near the grinding machine. Sufficient FBs were generated by circulating the inside of the FB generator approximately 1,000 times using a pump installed in the coolant tank. The equipment measured grinding force is given in **Table 1**, and the experimental conditions are given in **Table 2**.

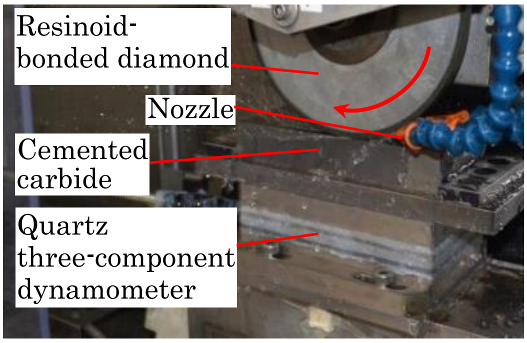

Fig. 8 Photograph of the grinding equipment

Table 1 Equipment used for grinding

Grinding equipment	Three-axis controlled machine MSG-618CNC-HS （Mitsui High-Tec, Inc.）
Measuring equipment	Quartz three-component dynamometer 9257B （KISTLER）

Table 2 Experimental conditions

Workpiece	Cemented carbide G30 (Nippon Tungsten)
Hardness	HRA88.0
Size	84 mm × 178 mm × 25 mm
Feed	V_w = 23 m/min
Wheel	Resinoid-bonded diamond
Grain size	#200
Cutting speed	V_s = 1800 m/min (30 m/s)
Diameter	180 mm
Width	10 mm
Depth of cut	a = 10 μm
Total depth of cut	b = 500 μm
Cutting fluid	Water-solution coolant oil (E-52CW, NTC National Trading Co., Ltd.) at a concentration of 5%

The total grinding amount and the change in the grinding force F_n using the FB coolant and non-FB coolant are shown in **Fig. 9.** The grinding force decreased by approximately 15 N (15%) using the FB coolant compared with using the non-FB coolant.

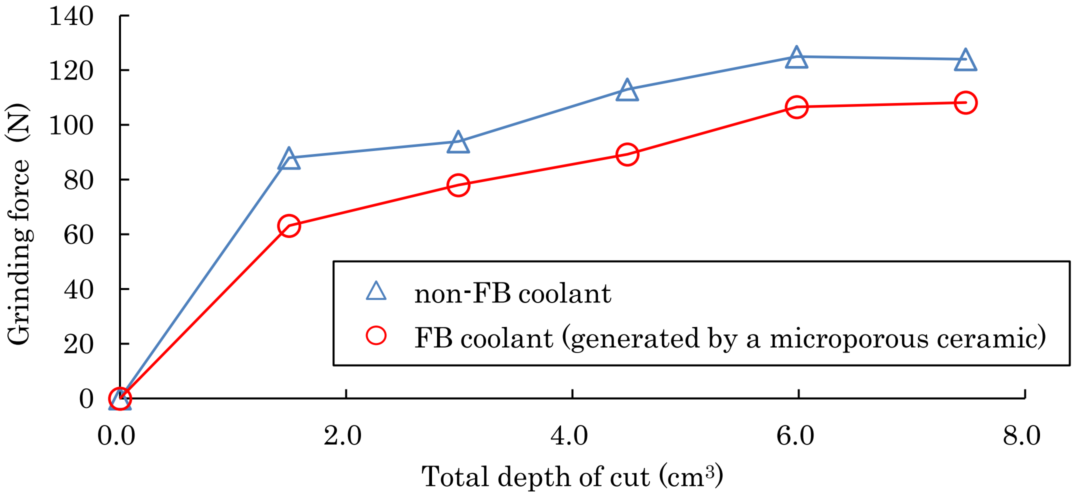

Fig. 9 Comparison of the grinding forces using a non-FB coolant and the FB coolant

4. Conclusions

(1) The number density of UFBs generated in tap water and the number density of MBs generated in the coolant were measured. The UFBs had a sharp peak at approximately 0.1 μm in diameter and the MBs had a broad peak between 25 and 75 μm in diameter.

(2) The FB coolant droplet showed a 2° lower static droplet contact angle than those of a non-FB coolant.

(3) The grinding force was reduced by 15% using the FB coolant compared with using a non-FB coolant.

References

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[2] M. Takahashi : ζ Potential of Microbubbles in Aqueous Solutions: Electrical Properties of the Gas-Water Interface, J. Phys. Chem. B., 109 （2005）, 21858.