euspen's 18th International Conference & Exhibition, Venice, IT, June 2018
www.euspen.eu

Improvement of grinding performance by using inert gas filled micro bubble coolant

Manabu Iwai [1)], Shinichi Ninomiya [2)], Kazuhide Kamiya [1)], Daisuke Noda [3)], Kiyoshi Suzuki [4)]

[1] *Toyama Prefectural University,* [2] *Nippon Institute of Technology,* [3] *Nippon Institute of Technology,* [4] *K.Suzuki New R & D Office*

iwai@pu-toyama.ac.jp

Abstract
The authors have proposed a micro bubble coolant in which micro bubbles (20-50µm in diameter) are included in water soluble coolant. In the previous study, it was confirmed that the tool life was improved by applying the micro bubble coolant to various machining operations such as drilling, turning and grinding. Also, purification effects of the micro bubble coolant were found. In this study, micro bubble coolant in which inert gases (N_2 and CO_2) were mixed was proposed to be applied to grinding processes for further improvement in grinding performances. When nitrogen gas (2L/min) was mixed with the micro bubble in the water soluble coolant (70L), amount of the dissolved oxygen in coolant decreased to 0.5mg/L. And concentration of the carbon dioxide gas in the coolant increased to 100mg/L when carbon dioxide gas (2L/min) was mixed in. From the result of grinding test on high speed steel, it was found that grinding performances improved when the micro bubble coolant with any of air, N_2 and CO_2 gases was used. The grinding force decreased by a factor of about 15% and the tool life increased by 20-30%. When nitrogen gas was mixed in, the surface roughness improved by about 15%. In grinding stainless steels, performances such as grinding force, tool life and surface roughness improved by 10% when nitrogen gas was mixed in.

Coolant, Micro bubble, Grinding

1. Introduction

The authors proposed an application of a micro bubble (fine bubble in another expression) coolant in which micron-sized (20-50µm) bubbles that are generated in a water soluble coolant for the material removal processing, and have demonstrated positive effects such as a tool life improvement by around 20% in drilling, turning and grinding operations [1,2]. It was also demonstrated that the micro bubble coolant had a function to suppress or purify putridity of the water soluble working fluid [3]. In recent years, micro bubble generation devices for material removal processing have been put on the market by several domestic manufacturers, but a mechanism of the effect development has not been made clear by anyone. A device which can generate fairly small (nm sized) bubbles has been developed as well, and under these circumstances it is required to optimize a size and a density of the bubbles depending on a specified workpiece material or specified machining conditions.

In order to develop a high-functional ultrafine bubble (nano-bubble in another expression) coolant, effects of inert gases mixed in the micro bubbles were examined.

2. Proposal of a high-functional ultrafine bubble coolant

Researches applying inert gases such as nitrogen or carbon dioxide to material removal processing have been ongoing as an environment-friendly processing method [5,6]. Though the method shows advantages in lowering a frictional resistance and suppressing a tool wear, an amount of the gas required is enormous as 10L/min and its effect is limited to the time while the inert gas is sprayed, which are the problems. Instead, it is expected to suppress the degradation of a tool wear and a workpiece surface condition caused by oxidation by mixing inert gases such as nitrogen or carbon dioxide in the water soluble working fluid as a form of a micro bubble which can decrease an amount of dissolved oxygen in the fluid. Further, in the method to seal the inert gases in the fluid, an amount of the gas to supply can be largely reduced. This is another advantage. The method proposed in this research is thought to bring an effect on lowering the supply amount of gases and suppression of oxidation at the cutting and grinding point.

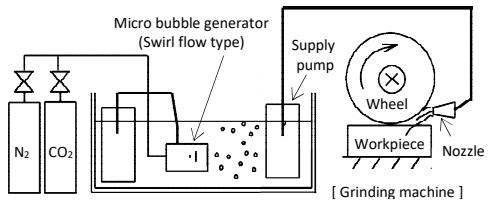


Figure 1. Setup by using inert gas filled micro bubble coolant

3. Effect of inert gases on the characteristics of fluid

Changes in a content of dissolved oxygen and carbon dioxide gas were examined when micro bubble gases of nitrogen and carbon dioxide were mixed in the city water and water soluble working fluid (2% dilution, 70L). A diagram of the experimental setup is shown in Fig.1. In the experiment, a swirl flow type micro bubble generator utilizing the vortex cavity phenomenon was used. Each gas of air, nitrogen and carbon dioxide was supplied at each flow rate of 1L/min and 2L/min through the gas intake port. The results are shown in Fig.2.

In the case of the city water, it was noted that the amount of dissolved oxygen markedly decreased when nitrogen gas was mixed in at the flow rate of 2L/min. In the case of the water soluble working fluid, changes in both the amount of dissolved oxygen and the carbon dioxide were found gentle. It required more than 15 minutes to make a content of dissolved oxygen and carbon dioxide gas in the fluid to the level equal to the case of city water. Though it is not shown here, the water soluble fluid with the nitrogen gas mixed in maintained the low value of the dissolved oxygen as 2.5mg/L even after passing one day. When the grinding performances were examined using the inert gas mixed coolant, it was decided to mix the nitrogen and carbon dioxide gases in the water soluble fluid preliminary for 15 minutes prior to starting the experiments.

4. Grinding performances by using fluid with inert gas bubbles mixed in

4.1. Experimental conditions

As shown in Fig.1, micro bubbles were generated in the fluid tank of the grinding machine and the fluid was supplied to the grinding point at a flow rate of 2L/min through a lock line nozzle (ϕ6mm) using a supply pump. Using a conventional wheel (WA60) surface grinding was conducted on the workpieces of high speed steel (SKH51) and stainless steel (SUS304).

4.2. Results of grinding high speed steel

Fig.3 shows the results of grinding high speed steel (SKH51) using the conditions of wheel speed V_S=2000m/min, depth of cut a=2μm and feed rate V_W=6m/min. As shown in Fig.3(a), grinding forces shifted higher when the fluid without bubbles was used marking the highest of F_n=32N after 2000 passes. When the gases of air, nitrogen and carbon dioxide were mixed in the micro bubbles, the grinding forces shifted lower marking F_n≒28N at 2000 passes, which was 15% lower than the case without bubbles. It seems that the micro bubbles containing any kind of gas improved the lubricating action which contributed to lowering the grinding forces.

Comparing the grinding ratios (G) in the range of steady wear (1000-2000 passes) as shown in Fig.3(b), G=13.5 with air, G=15.0 with carbon dioxide gas and G=15.7 with nitrogen gas were resulted exceeding the value G=11.3 marked without bubbles. Though it is not shown, after the nitrogen gas was mixed in for 15 minutes to reduce the amount of dissolved oxygen in the fluid, the carbon dioxide gas was mixed in for 15 minutes, and the effect was examined. No notable effect was seen and the result was comparable to the case when carbon dioxide gas alone was mixed in.

As for surface roughness values (Fig.3(c)), R_a=0.71μm without bubbles, R_a=0.74μm with air, R_a=0.81μm and R_a=0.57μm with nitrogen gas were resulted. As seen, 15% improvement was resulted when nitrogen gas was mixed in.

4.3. Results of grinding stainless steel

Fig.4 shows the grinding results up to 1000 passes on the stainless steel (SU304) using the conditions of V_S=2000m/min, a=5μm, V_W=6m/min, b=3mm. Compared to the case using the micro bubble with the air mixed in, grinding forces decreased by 10% (Fig.4(a)), the grinding ratio increased by 10% (Fig.4(b)) and the surface roughness improved by 20% (Fig.4(c)) in the case where the amount of dissolved oxygen was reduced by mixing the nitrogen gas in the fluid.

A reason why significant improvement was seen in the machining performances when the fluid with microbubbles filled with nitrogen was used seems to be due to the effect of suppressing the heat generation or wheel wear caused by oxidizing reaction. From now on, the authors would like to clear up the development mechanism in addition to the effect of carbon dioxide gas.

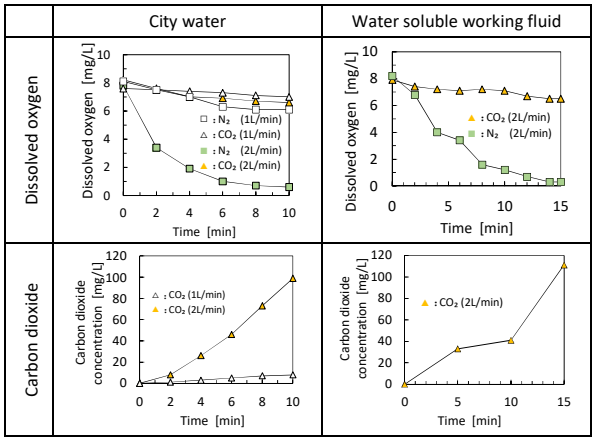
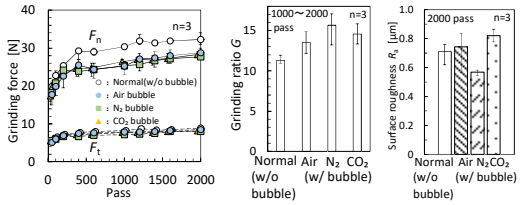


Figure 2. Effect of inert gases on the characteristics of fluid

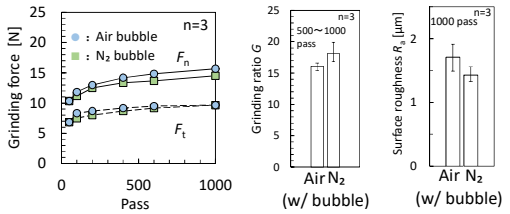
(Volume of water: 70L, Dilution: 2%)



(a) Grinding force (b) G ratio (c) Roughness

Figure 3. Results of grinding high speed steel (SKH51)

(V_S=2000m/min, V_W=6m/min, b=3mm, a=2μm, Q=400mm³/mm)



(a) Grinding force (b) G ratio (c) Roughness

Figure 4. Results of grinding stainless steel (SUS304)

(V_S=2000m/min, V_W=6m/min, b=3mm, a=5μm, Q=400mm³/mm)

5. Conclusion

In this research, a method of mixing nitrogen gas or carbon dioxide gas in micro bubbles was proposed for the purpose of developing a high-function micro/nano bubble coolant and the effects were examined. As a result, it was found that the amount of dissolved oxygen or concentration of the carbon dioxide gas could be changed by mixing nitrogen and/or carbon dioxide gases in the micro bubbles. Further, it was also found that machining performances were improved in the grinding of high speed steel and stainless steel when nitrogen gas was mixed in.

Acknowledgements

The authors would like to express their gratitude to NEOS Co., Ltd. and "Technical Committee for Future-oriented

precision machining Tool" under Japan Society of Grinding Engineers for their kind cooperation.

References

[1] Suzuki S, Ninomiya S, Iwai M, et.al 2004 *Proc. of ABTEC Conf.* 241 (in Japanese)
[2] Suzuki k, Iwai M, Ninomiya S, et.al 2007 *Advances in Abrasive Technology* **X** 25
[3] Ninomiya S, Iwai M, Suzuki K, et.al 2009 *Advanced Materials Research* **76-78** 651
[4] Shizuka H, Suzuki Y, Sakai K 2008 *J. of JSPE* **74**, 7 730
[5] Ninomiya S, et.al, 2016, Proc. of ABTEC Conf. 77 (in Japanese)