# Application and Effects of Fine Bubbles for Machine tools

2024. April. 2.

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## I. INTRODUCTION

Bubbles have been a part of people's lives since ancient times. In nature, bubbles from large to fine bubbles are generated and exist, and it has been found that intentionally generating a large amount of these fine bubbles has a great effect and can be solutions for so many things. When fine bubbles were used in Hiroshima for controlling red tide, they also promoted the growth of oysters and was reported in the press and created quite a stir. This sparked deep interest in fine bubbles, which led to further research and applications in fisheries, agriculture, medicine, the food industry, the chemical industry, wastewater and water purification, and other fields. Currently, application & technological examples have taken the lead, and scientific elucidation are still behind. Especially, the mechanisms such as biological activation remain unresolved.

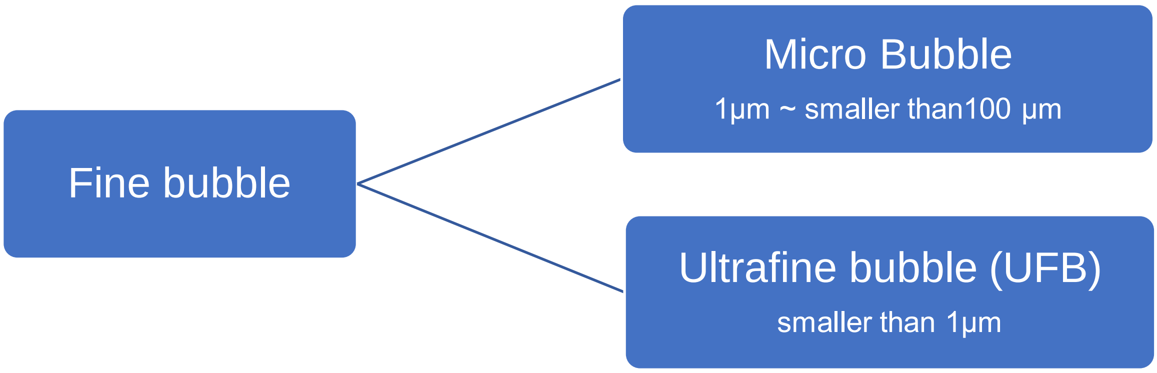
Here, we will explain about fine bubbles and introduce examples of applications and effects in machine tools using “loop-flow OK Nozzle”, our fine bubble generator. We hope you will find this information useful as a means of solving a problem that is troubling you at your cutting manufacturing site.

## II. WHAT IS FINE BUBBLE?

Fine bubble is a generic term for microbubbles and ultrafine bubbles. Ultrafine bubbles (UFB) are nanobubbles (NB). By international standards, bubble diameters below are defined:

- Microbubbles: At least 1μm to less than 100μm
- Ultrafine bubbles (nanobubbles): less than 1μm

[Reference: ISO 20480-1, 2017 Fine bubble technology-General principles for usage and measurement of fine bubbles-




**Ultrafine bubble (UFB) = Nano bubble (NB)**

Fine bubbles, especially microbubbles look more like white turbidity than bubbles. Although microbubbles are visible, they become difficult to be seen when they are below 5 microns. The density of turbidity varies depending on the amount of gas in the water. For example, if water with sufficient gas dissolved in a pressurized dissolution tank is injected through the nozzle, it becomes pure white like milk (Fig. 1). Also, hot water from a water heater is cloudier and whiter than tap water. This is because tap water is warmer and closer to saturation.

If surfactants, oils, alcohols, etc. are added to water, it will generate a larger amount of fine bubbles than fresh water. Also, if the water contains a lot of minerals such as NaCl, as in seawater, more fine bubbles will be generated. This is because the above substances in water gather around the fine bubbles and prevent them from coalescing.

In the case of machine tool coolant fluid, water-soluble coolant fluid or even oil generates a large amount of fine bubbles, which produces a significant effect.

↓ Simple air dissolution tank

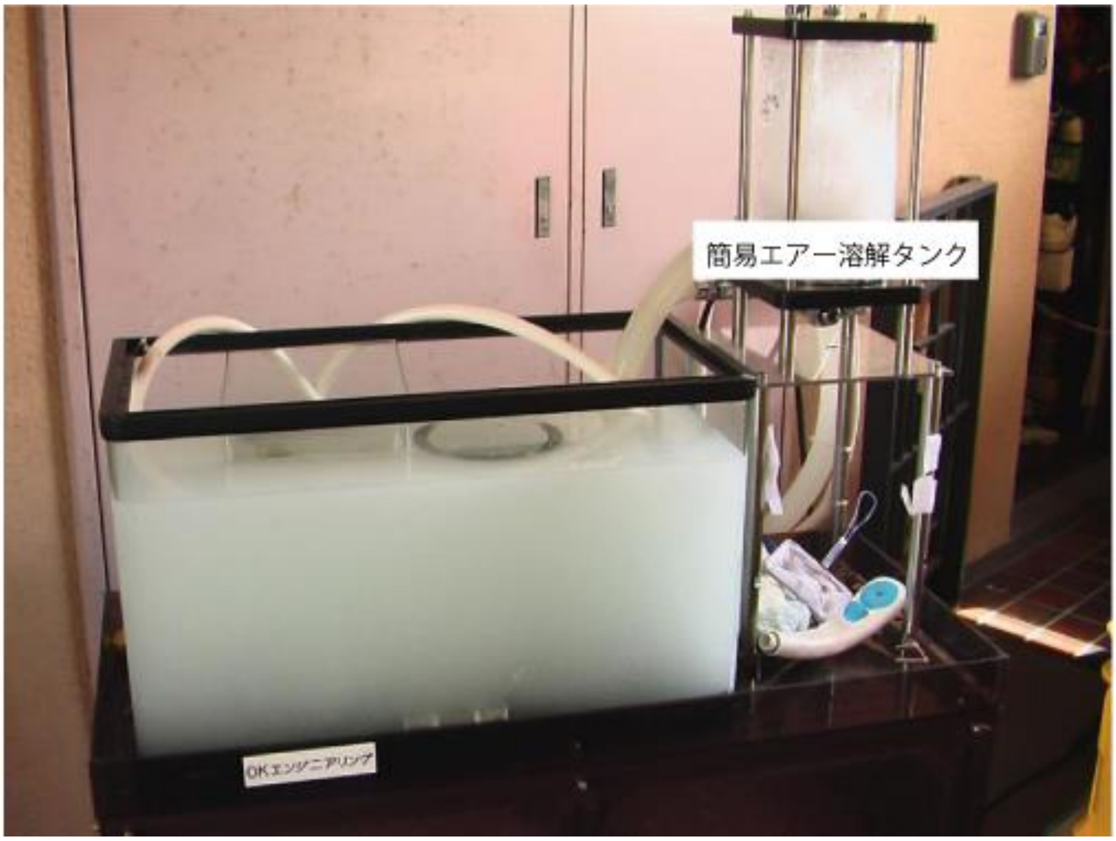



Fig 1: The tank with white turbid fine bubble water

Ultrafine bubbles (nanobubbles) are invisible to the naked eye due to their small size, but can be visualized indirectly when irradiated by a laser beam. The loop-flow OK Nozzle can generate approximately 400 million ultrafine bubbles in just 1 ml (400 million bubbles/ml). Bubbles in atmospheric fresh water have a lifespan of a few days. They drift in the movement of the water without floating up. Under good storage conditions, they can exist for several months to a year.

## III. APPLICATION EXAMPLES AND EFFECTS OF FINE BUBBLES ON MACHINE TOOLS

Machine tools require that the equipment always be in the best condition for use. For this reason, they must be closely checked and cared for daily. Removing chips, which are always generated in cutting, and cleaning the coolant tank are necessary for efficient operation. The followings describe the combined effects of generating fine bubbles in the coolant solution on machining.

### 1) <u>Aluminum-constituted cutting edge peeling effect</u>

During cutting, the tool cutting edge is hot and subject to high pressure. At this time, a portion of the chips are welded to the tool cutting edge, producing a shape similar to that of the cutting edge. This is called the built-up edge. Fine bubbles detach the built-up edges generated during aluminum machining, making it difficult for them to form. This ensures surface roughness in accordance with cutting conditions and significantly reduces the defect rate during aluminum machining.

The mechanism that prevents the formation of the built-up edge is considered to be due to the force and shock waves when the fine bubbles burst. Since the cutting edge at the time of cutting becomes close to 800 °C, fine bubbles peel off the built-up edge by their rapid thermal expansion and rupture. It is also possible that the heat radiation effect of fine bubbles makes it difficult to form the built-up edge. Also, it can be considered that fine bubbles expand thermally and continuously create a space in the cutting-edge parts and make it difficult for the built-up edge to be generated.

In the automotive industry, aluminum parts are increasingly being used to reduce the weight of automobiles. In the future, fine bubble generating nozzles are expected to be permanently installed in machine tools to reduce the machining defect rate of aluminum products.

**2) <u>Reduction of Grinding Time for Small Molds</u>**

In the creation of small molds such as terminal molds, precise cutting and grinding are required. In the case of this mold grinding process, the depth of cut was normally 4 μm, but the use of fine bubble cutting fluid made it possible to reduce the depth of cut to 7 μm. This mechanism is considered due to the shock wave from fine bubble bursting removes chips attached to the grinding wheel, ensuring that the cutting edge of the grinding wheel is always maintained. By devising the fine bubble generating condition and the grinding conditions, machining time can be significantly reduced.


Normal cutting fluid

With fine bubbles
Cutting depth: 5 μm → 7 μm
(Same dressing frequency)

Fig 2. Small mold grinding coolant oil becoming milky in appearance with FB

### 3) Mirror Polishing of Silicon Wafers

Silicon wafers are component materials for semiconductors. Although we rarely see silicon wafers in our daily lives, they are used in all kinds of electronic devices. As the name implies, silicon wafers are made from silicon and are thin disks. The surface is processed to be strictly flat, and this process has a great influence on the performance of silicon wafers. Therefore, smoother surface roughness is required year after year. Mirror polishing is a process in which the surface irregularities of a workpiece are uniformly finished by means of fine abrasive grains. Generally, a surface roughness of Rz 200 nm or less can produce a cloudless surface like a mirror. When it comes to ultra-mirror polishing, the surface roughness becomes even finer. This ultra-mirror polishing is incorporated to obtain the exact flatness of silicon wafers. The use of fine bubbles in this ultra-mirror polishing has produced significant results. The following reports have been received from engineers in the field.

- We took several measures to increase the surface roughness, but could not achieve the required. However, by using fine bubbles to process silicon wafers to an ultra-mirror surface, we were able to easily achieve the required surface.
- We installed an OK Nozzle for generating fine bubbles in the middle of the Cutting fluid piping, and were able to supply the products that passed the test. We are very pleased.

The mechanism by which fine bubbles enable high-quality mirror finishing is considered to be that chips adhering to the grinding wheel are peeled off by the shock wave when the fine bubbles burst, the cutting edge of the grinding wheel is always maintained, and the grinding chips on the workpiece are cleaned to achieve the required surface roughness.

Fig. 2: Using 60L/min OK Nozzle for the silicon wafer ultra-mirror polishing

## 4) Effects of Coolant Tank Cleaning and Liquid Purification, etc.

A coolant tank is a container permanently installed in a machine tool for cooling, and the liquid in the tank is called coolant fluid. Coolant cools the heat generated during machining and prevents expansion. This helps to maintain machining accuracy and extend the service life of the machine.

The use of fine bubbles in coolant fluid has been found to be effective in removing biofilm, floating and separating lubricating oil, preventing water-soluble coolant fluid from spoiling and suppressing odors, and controlling the temperature rise of coolant fluid. Four examples of its use are introduced below.

### a. Biofilm removal

Biofilm is a slimy substance formed by microorganisms on the inner surface of tanks containing water. Fine bubbles can inhibit the formation of biofilm and remove it. In addition, although Fine Bubble is negatively charged, it has the characteristic of adhering to and absorbing even debris floating on the water surface or submerged in water, regardless of positive or negative charge, when the specific gravity is close to 1. Fine bubbles are used for cleaning in large water tanks for fish and shellfish, as biofilms adhering to the wall surfaces are removed, and fine bubbles separates debris by floatation. This cleaning method is also beginning to be used in aluminum processing plants that handle auto parts. Fine bubbles can also remove aluminum fines attached to coolant tank walls along with biofilm.

### b. Floating separation of lubricant oil

During machining, lubricant oil mixed with coolant fluid can cause the cutting tool to slip during cutting. Fine Bubble floats and separates lubricant oil mixed in coolant liquid and removes it in advance and prevent the danger. Fine bubbles are also used in machining centers (machine tools that can automatically change multiple cutting tools and perform drilling and surface grinding operations under NC programming control).

### c. Spoilage prevention and malodor suppression of water-soluble coolant

Fine bubbles prevent spoilage by activating aerobic microorganisms in the tank. At the same time, you can suppress bad odors. The above effects can be easily obtained only by installing a fine bubble generation nozzle in the coolant tank or in the middle of piping to generate fine bubbles.

## IV. CONCLUSION

Now you know almost all about fine bubbles and machine tools, but what do you think? As this case study clearly shows, fine bubbles may soon become a fundamental technology that supports the very foundations of various industries. In addition, expectations for fine bubbles to address environmental issues such as pollution of rivers, lakes, marshes, and oceans are growing, and they are beginning to be utilized.

However, as mentioned above, there are some effects of fine bubbles which mechanisms have not yet been scientifically elucidated. In particular, there is an urgent need to clarify the mechanism of biological activation.

Additionally, the machine tool examples listed in the text are all applications of the “loop-flow OK Nozzle” that we have developed. We hope that this technology will be spread throughout the world as one of the environmentally friendly technologies (SDGs) with your support and cooperation in the future.

**SDGs** certification mark

**OK Nozzle**: Our loop flow fine bubble generator has received the SDGs certification from the Fine Bubble Industry Association (FBIA).
“SDG001” indicates that our company is the first SDG certified company.

FBIA
RUM0016
SDGs0001