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Tool wear in drilling using cutting fluid diluted with alkaline aqueous solutions

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Abstract

For precision drilling, it is important to reduce tool wear. Thus, in this study, we investigated tool wear in drilling conducted by supplying a water-soluble cutting fluid diluted with an alkaline aqueous solution. Through-holes with a diameter of 5 mm were drilled while supplying a water-soluble cutting fluid diluted with potassium hydroxide (KOH) or sodium hydroxide (NaOH) aqueous solution. Workpieces were flat plates made of non-heat-treated tool steel, and drills were made of heat-treated high-speed steel. The drilling was conducted at a constant feed rate. The cutting fluid was applied to a machining point at a constant flow rate. After drilling, the top of a drill was photographed with a digital microscope. From the obtained photographs, the wear length of the outer corner was measured. For comparison, through-holes were also drilled while supplying a water-soluble cutting fluid diluted with tap water. Experimental results indicate that the use of an alkaline aqueous solution for dilution is effective for inhibiting the outer corner wear of the drill. The wear was inhibited in the drilling of up to at least 150 holes when the initial pH of the cutting fluid was approximately 12. The length of the outer corner wear when using the KOH aqueous solution was almost the same as that when using the NaOH aqueous solution. It was considered that the wear was inhibited by the passive film generated on the tool surface in the alkaline aqueous solution, which protected the tool surface.

Keywords: Drilling, Cutting fluid, Alkaline aqueous solutions, Tool wear, Tool steel, Potassium hydroxide, Sodium hydroxide

1. Introduction

In recent years, some researchers have investigated the tool wear reduction caused by using a cutting fluid mixed with strong alkaline water produced by electrolysis [1–5]. On the other hand, in our present study, we investigated tool wear in a process by supplying a water-soluble cutting fluid diluted with an alkaline aqueous solution that was not produced by electrolysis. Producing strongly alkaline water by electrolysis requires an electrolysis apparatus and a long time. In contrast, our method only requires the dissolution of granules, making it easy to prepare strongly alkaline water. For precision drilling, it is important to inhibit tool wear. The inhibition of tool wear also allows the increase in productivity because the number of times of changing tools is reduced.

Thus, in the present study, we drilled a steel flat plate while supplying a cutting fluid diluted with potassium hydroxide (KOH) or sodium hydroxide (NaOH) aqueous solution. The wear of the outer edge of the drill was examined. A drill used in this study was made of heat-treated high-speed steel, which was coated with (Al, Ti) N. Such drills are widely used in the manufacturing industry for drilling holes in steel. Therefore, it is industrially valuable to reduce the wear of such tools in a drilling process.

2. Experimental

2.1 Experimental apparatus and material

Figure 1 shows the experimental apparatus, which mainly consists of a drilling machine and a circulation system for the cutting fluid. The drilling machine has an automatic spindle feed function. On the worktable of the drilling machine, the x–y stage and the vessel are fixed. A workpiece is set in the vessel. The cutting fluid is supplied to a machining point through a tube at a constant flow rate. The cutting fluid is allowed to flow from the vessel to the fluid reservoir and is then circulated to the machining point by the pump.

A drill was made of heat-treated high-speed steel coated with (Al, Ti) N, whose diameter was 5 mm. Workpieces were flat plates with a thickness of 7 mm made of non-heat-treated tool steel. The hardness of each workpiece was measured to be 333 HV using a micro Vickers tester.

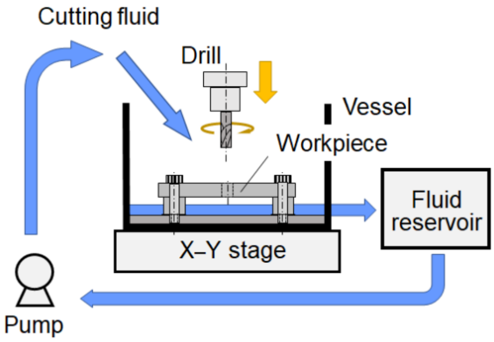

Figure 1. Experimental apparatus.

2.2 Experimental method

Through-holes with a diameter of 5 mm were drilled in each workpiece using the drilling machine. The number of revolutions of the drill was 750 rpm and the feed rate of the drill was 0.07 mm/rev.

KOH and NaOH aqueous solutions were prepared by dissolving their powder in tap water. The cutting fluid was water-soluble and diluted with KOH or NaOH aqueous solution. The cutting fluid was applied to a machining point at a flow rate of approximately 100 ml/min. The pH of the cutting fluid was measured with a glass electrode pH meter.

After drilling several holes, the drill was removed from the machine, and the drill tip was photographed with a digital microscope to evaluate tool wear. In general, flank wear is evaluated to determine tool life in normal drilling operations. The flank wear is greatest at its outer edge, which dominates the drill life. Thus, in this study, we measured the wear length of the outer edge from the obtained photographs. Figure 2 shows an example of the drill tip. The length of the wear of the outer edge was calculated from the change in angle θ on the basis of the initial angle θ_0 as a reference.

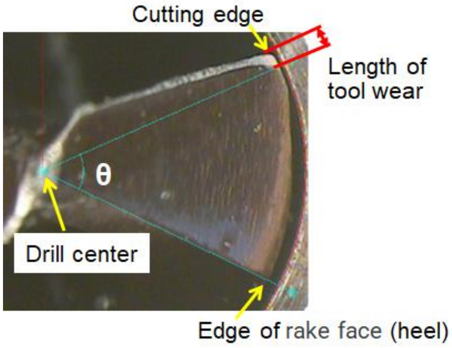

Figure 2. Photograph of the top of drill.

3. Experiment using cutting fluids prepared by diluting the concentrate with KOH and NaOH aqueous solutions

By using the water-soluble cutting fluid prepared by diluting a concentrate (NEOS Company Limited, CFS-100) with the KOH aqueous solution, we drilled through-holes: the pHs of the KOH aqueous solution and the resulting cutting fluid were 12.5 and 11.7, respectively. For comparison, drilling was also conducted using the cutting fluid prepared by diluting the concentrate with tap water: the pHs of the tap water and resulting cutting fluid were 8.3 and 9.5, respectively.

Figure 3 shows increase in the length of the tool wear with the number of drilled holes. In Fig. 3, the length of the tool wear is the average of three replicates. As shown in Fig. 3, the tool wear was inhibited by using the KOH aqueous solution.

Next, by using the water-soluble cutting fluid prepared by diluting the concentrate, which is the same concentrate as that described above, with NaOH aqueous solution, through-holes were drilled: the pHs of the NaOH aqueous solution and the resulting cutting fluid were 12.5 and 12.0, respectively. Experimental results are also shown in Fig. **3,** showing increase in the length of the tool wear with the number of drilled holes. As shown in Fig. 3, the tool wear was also inhibited by using the cutting fluid prepared by diluting the concentrate with the NaOH aqueous solution. Moreover, it was found that the tool wear when using the NaOH aqueous solution is almost the same as that when using the KOH aqueous solution. This result indicates that the cutting fluid prepared by diluting the concentrate with the alkaline aqueous solution inhibitions tool wear.

Figure 4 shows the change in the pH of the cutting fluid sampled from the fluid reservoir during with the number of holes. As shown in Fig. 4, the pHs of the cutting fluid prepared using the KOH and NaOH aqueous solutions after drilling 150 holes reached 11.0 and 11.1, respectively. Thus, the cutting fluid maintains alkalinity during the process.

One reason for the inhibition of the wear is the passive film generated on the tool surface in the alkaline aqueous solution, which protected the tool surface. Generally, passive films can be formed on Fe in an alkaline aqueous solution. Therefore, it is possible that tool wear is reduced by using other alkaline aqueous solutions.

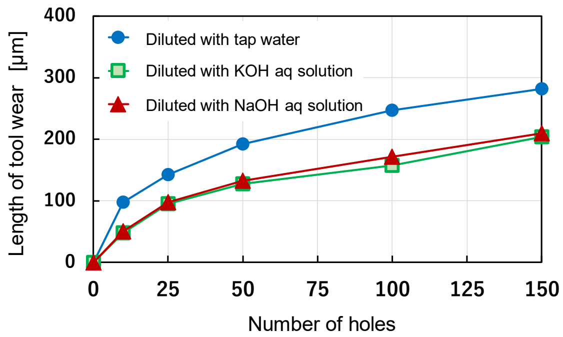

Figure 3. Increase in length of tool wear when using KOH and NaOH aqueous solution with the number of holes.

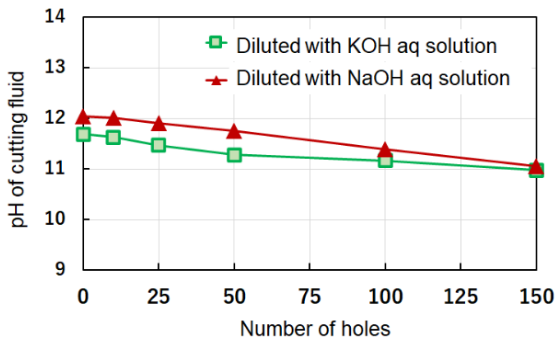

Figure 4. Change in pH of cutting fluids with the number of holes.

4. Conclusions

We investigated tool wear in drilling conducted by supplying a water-soluble cutting fluid diluted with an alkaline aqueous solution, such as KOH or NaOH aqueous solution. As a result, we found that tool wear was inhibited by using a cutting fluid prepared by diluting a concentrate with an alkaline aqueous solution.

In this study, we used only KOH and NaOH, but there are a variety of alkalis. Further cutting experiments using different alkaline solutions are required to select an optimum alkali.

Acknowledgement

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