The Analysis of Polishing Process of Cold Forging Die in Axial Symmetric Form and Axial Non-symmetric Form

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Abstract. In forging parts production, the die life is important for the production efficiency. If the die is fractured under production accidentally, it may cause a big damage to the productivity. One of die broken mode is a scratch on die surface caused by polishing in order to meet the design. It is for finishing the pre-mature die by polishing. It is required for more skillful craftspeople because the die life depends on damage of scratches. Therefore it is important to succeed their expertise constantly. It takes several years for craftspeople to be the expert on the job training. In this study, in order to accelerate their expertise transferring, we analyzed their expertise in focusing on quality of polishing in a forging part.

Keywords: Skill transfer level · Forging · Die life · Polishing

1 Introduction

Cold forging processing is a method of manufacturing parts that involves inflicting damage on the die used as tool. Therefore, the die life is key to maintaining manufacturing with stability. The mode of damage is of two forms (see Fig. 1). One is breakage in the product's forming area, generally an issue of die construction including press fit rings. The other is frictional wearing of the product's forming area through contact with a processing material, thought to be caused by the surface condition, in other words the way it is polished. Die-making for cold forging is distinguished by hand polishing of the processing part known as product area, which adds greatly to the die life. The polishing work is dependent on a person referred to as "die craftspeople" and though from the past a technical approach has been given trial, the skill has not been fully explicated. This research is aimed at accelerating expertise transfer of expert through analysis of the polishing work.

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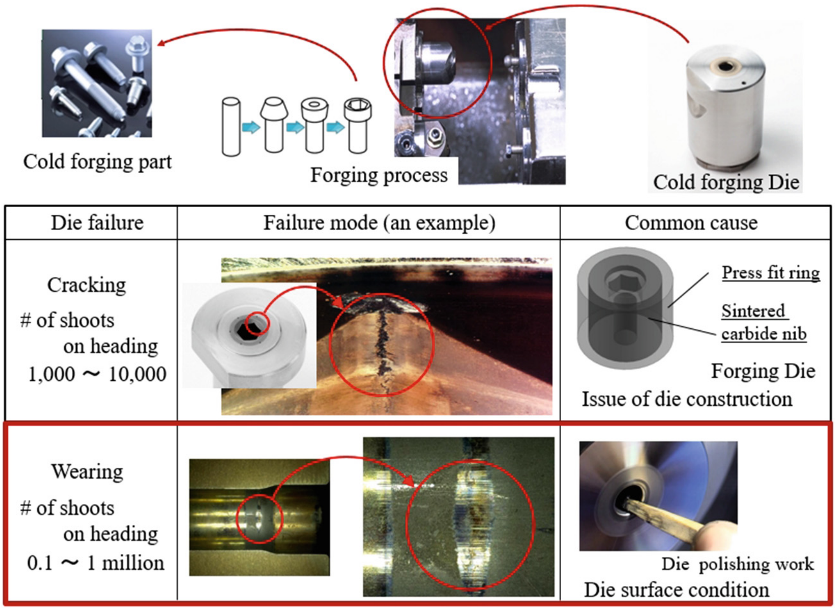

Fig. 1. Die life in a cold forging

2 Polishing Skill of Cold Forging Die

Die manufacturing consists of multiple procedures with machine processing at the core. Generally polishing work is called "finishing process" and comes into play at the end (see Fig. 2). Polishing work has the following two purposes.

- Operation to create a shape that cannot be made by machine processing.
- Operation to draw the surface condition needed for manufacturing of parts.

Even with a polishing process that is treated as a single operation, the craftspeople mentally plans the order for polishing area and the processing method to be used (see Fig. 3). In other words, a single process of polishing work has a procedural design, and the processing method follows the procedural design. Several years is required to learn polishing work. One factor is the ability to work out the procedural design mentioned above. The other requirement is expert operational ability to faithfully implement the procedural design.

In polishing work, some cold forging dies are considered that, even though they are relatively similar in shapes, only specific experts are able polish them. This is thought to be due to the shape and specification of the die, the necessary polishing skill is changed and it demands a new polishing skill that is not an extension of familiar techniques. In this study, we aim to clarify the nature of the new polishing skill demanded in the polishing work of specific dies only the expert can polish by comparing it to the polishing of dies that beginners can also polish [1].

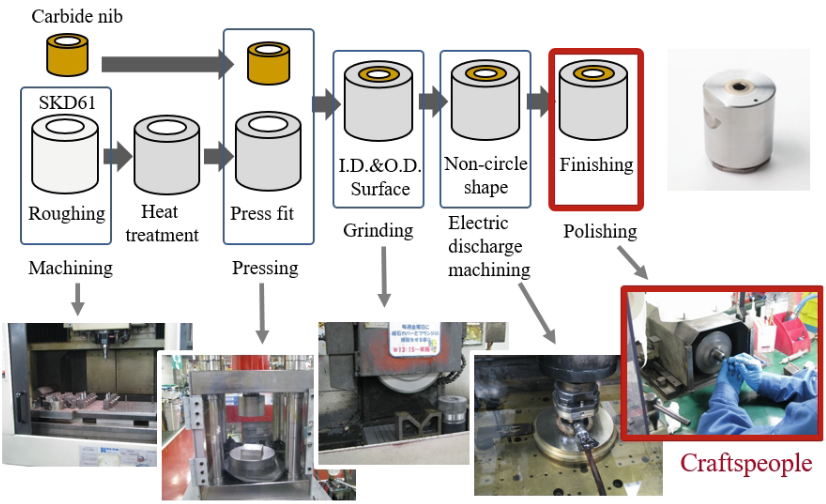

Fig. 2. Cold forging die manufacturing process

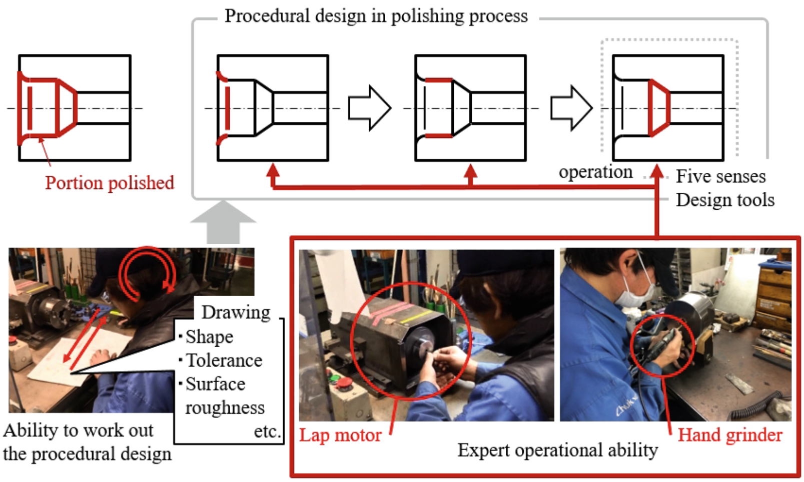

Fig. 3. Ability of craftspeople required to be an expert

3 The Analysis of Polishing Process of Cold Forging Die in Axial Symmetric Form and Axial Non-symmetric Form

3.1 Die Specification

As the die that even a beginner can handle, an axial symmetric shape die consisting of two cylinders in different diameters was chosen. For the die only an expert can polish, in order to make the analysis of the required polishing skill relatively easier, we selected a die that is as close as possible in shape with the die for the beginner. Consequently, we chose a die consisting of a cylinder and a hexagonal prism, which has the axial non-symmetric form in a part of the axis symmetry form. The cross section of die shown in the Fig. 4 is representative subject to testing. The figure only shows parts called carbide nib which is used to form product part. The dark-hatched surface in the figure is the work area to be polished.

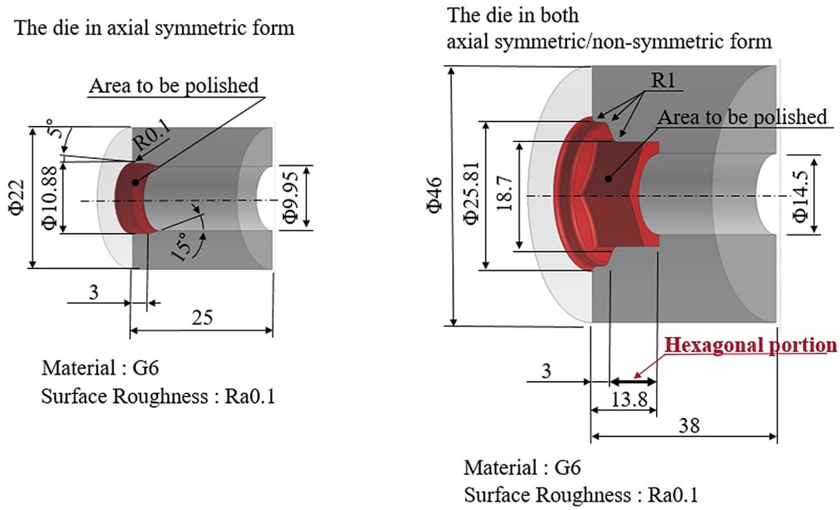

Fig. 4. Die specifications

For the die comprised of axial symmetric form, cutting process was provided by turning machine before the polishing work. On the other hand, the ones comprised of both axial symmetric/non-symmetric form are treated with electric discharge machining. In addition to that, a special-ordered processing jig is used to treat flat surfaces of hexagonal prism for rough-semi finishing. Since cutter marks remain on the cut surface, it needs to be polished at least in the range of 5 μm. Likewise, altered-layers remain on the surface treated with electrical discharge, it also requires removal process with the range of 10 μm.

Commonly, for the polishing of a cold forging die with an axial symmetric shape, the polishing is done after attaching the die to a rotation mechanism called lap motor. For the die chosen for the expert, part of the work cannot be conducted with a lap motor (see Fig. 3).

3.2 Experimental Method

As the purpose of this study is to determine and compare the polishing skill required for the polishing of each die, the focus of the analysis was on the polishing process and the polishing tools used. Moreover, in order to numerically verify the intentions of the workers at each step in the polishing, the dimensional transition of the work area that requires polishing was measured.

The polishing work process and the polishing tools used for analysis should meet the standard. We also selected skilled and experienced workers who are handling test pieces as test subjects. A test subject for the die comprised of axial symmetric form is a skilled male worker with 11 year-experience in polishing work and 6 year-handling-experience of this kind of die. A test subject for the die with both axial symmetric/non-symmetric form is also a skilled male worker with 15 year-experience in polishing work and 10 year-experience in handling this kind of die.

4 Experimental Results

Figure 5 shows the polishing work process of dies in axial symmetric form, the used polishing tools and abrasive grain. Working hours on a representative example are also shown for reference. Work process mainly consists of two parts. One is manual processing around the mouth R0.1 which is not machinery processed. The other is the polishing work on an entire polishing area. In the latter polishing work, the side and the bottom of the cylinder are not separately polished, but polished as continuous plane. The polishing is done after attaching the die to a lap motor.

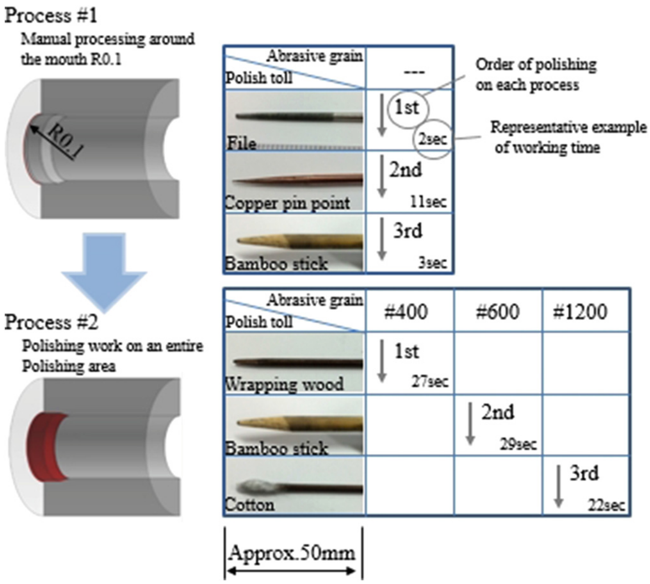

Fig. 5. Polishing work process of the die in axial symmetric form

Figure 7 shows the polishing work done to the die in both axial symmetric/non-symmetric form. Process 1 is the polishing work for the mouth R1 of hexagonal prism for which dimension accuracy should be guaranteed by manual work. Process2 is rough-semi finishing in polishing area excluding the mouth R1 and the side of hexagonal prism. And process3 is final finishing of the entire polishing area. Lap motor was used only in Process 2. Due to its hexagonal shape of the base of the inside, lap motor was used only for polishing of its inscribed circle and manual polishing was applied to the remaining part without rotation. For Process1 and 3, the work is conducted after gripping the circumference side on the V block. For the polishing work on the V block, the polishing work is conducted with rotating tool attached to the hand grinder. We use copper wire, wrapping wood, bamboo stick and cotton as common polishing tools for both test pieces. Copper wire and wrapping wood are used with the intention of scraping off bumpy surface caused by machine processing. Bamboo and cotton are used as if using its grain as abrading agent to level the surface.

Figures 6 and 8 show distinguishing changes to shape and surface roughness before and after the polishing work in each process. Chamfering process is manually provided in the initial process of Fig. 6. The required surface roughness Ra0.1 is adequately satisfied after the polishing work. Figure 8 shows that R-dimension was maintained according to the required dimension in Process1. As notable characteristics of work in Process2, it can be observed that the subject proactively polishes ridgeline in concave shape comprised of hexagonal prism and cylinder. The trace of work can be seen in the vicinity of ridgeline of the inner base. The required surface roughness Ra0.1 is sufficiently met after the work.

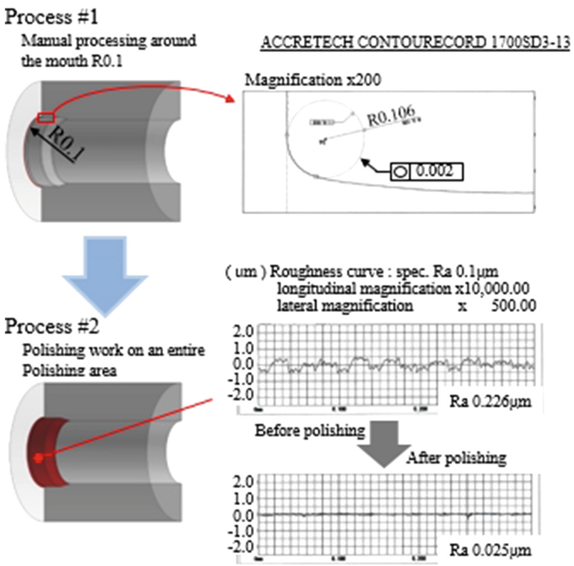

Fig. 6. Shape and surface roughness before and after polishing of the die in axial symmetric form.

It is considered that using rotation is to improve work efficiency in die polishing. It is interesting to note that work-rotating polishing is used together with tool-rotating polishing in the polishing process of the die comprised both axial symmetric/non-symmetric form. It consequently requires many types of polishing tools. Suppose that

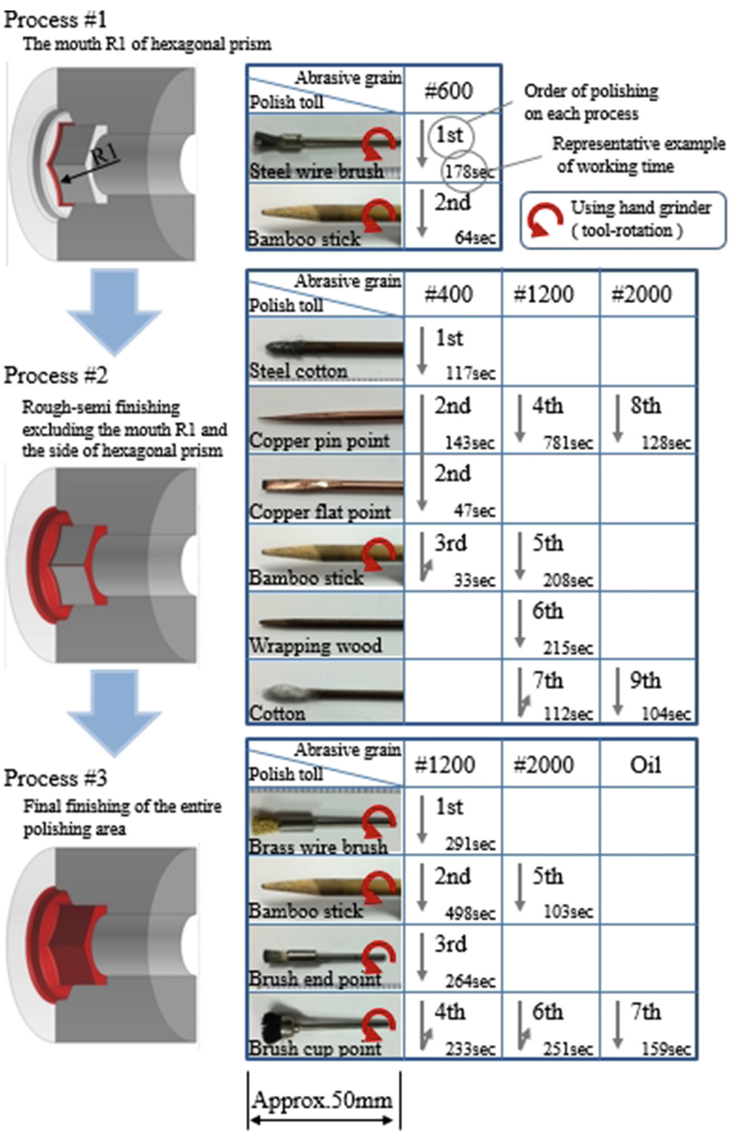

Fig. 7. Polishing work process of the die in both axial symmetric/non-symmetric form

making the work as simplified as possible is a shortcut to acquisition of skills, the number of tools used should be decreased. The reason of using work-rotation simultaneously is thought not to simplify the polishing work but to make it easy to assure quality in terms of roundness and coaxiality. In work-rotation, the subjects should focus on the shape of two-dimensional plane including symmetrical axis. As a result, the work is equally transferred along the direction of circumference. Figure 9 shows differences in movement from subjects' point of view. Looking at work-rotation from

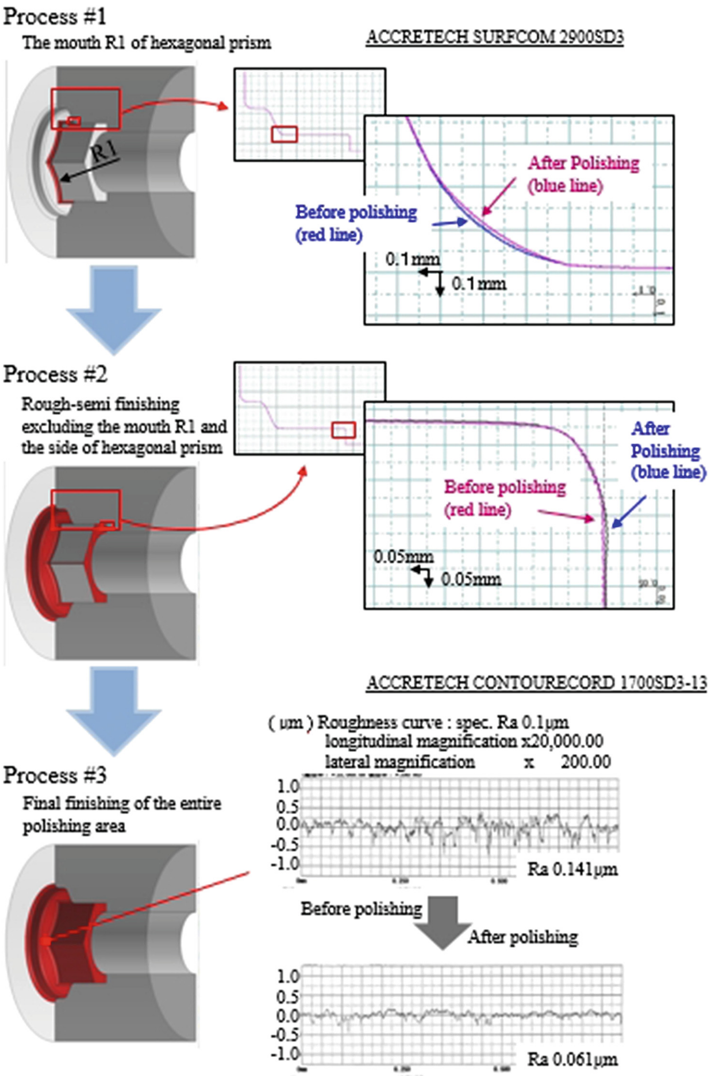

Fig. 8. Shape and surface roughness before and after polishing of the die in both axial symmetric/non-symmetric form.

subjects' point of view, when polishing three-dimensional plane, it can be said that they should focus on only bi-axes with leaving the remaining axis to rotation. It is thought that smaller number of working axis makes it easier to control movement. In other words, it can be thought that the difficulty level increases when handling dies in axial non-symmetric form since it requires tri-axial motion to complete the work. Furthermore, polishing tools used are rotary ones with which a subject needs to be familiar. Craftspeople are required to obtain skills to overcome difficulty in guaranteeing shape accuracy of work range with tri-axial motion.

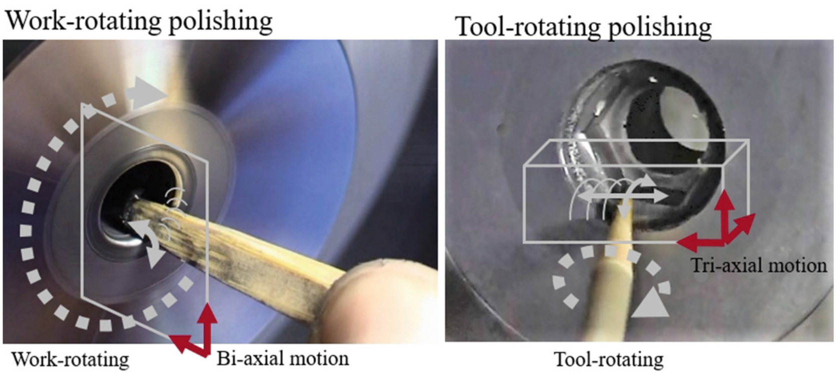

Fig. 9. Differences in polishing motion from subject's point of view

5 Conclusion

The following information was gained by analyzing the polishing of each test piece. For the polishing of the die comprised only of axial symmetric form, even if it is three-dimensional polishing work, the process itself only requires attention on two-dimensional plane because it uses work-rotation. In other words, the work-rotation mechanism along the direction of circumference guarantees the accuracy of the repeated work, and the worker only needs to focus on the movement that follows the contour of two-dimensional plane along the direction of the axis. On the other hand, the polishing work of a die that includes axial non-symmetric form demands the accurate movement in three-dimensional plane. Therefore, it requires a skill that can produce continuously changing shape itself in the three-dimensional space. Moreover, in order to achieve it, it requires the ability to precisely comprehend forms in the three-dimensional space based on the measurement data.

Reference

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