Basic study to reduce polishing process in mold manufacturing
- Relationship between the surface pattern after machining
and the polishing property -

Takekazu Sawa¹, a *

¹Shibaura Institute of technology, 3-9-14 Shibaura, Minato-ku, Tokyo 108-8548, Japan
asawa@sic.shibaura-it.ac.jp

Keywords: Mold manufacturing, Polishing property, Polishing process, Surface pattern, Machining, Ball endmill.

Abstract. This research examines the method to reduce the polishing work of a large press die by completing the cutting process with one ball endmill and not causing joints by tool change. The cutting distance is determined by tool life, so there is a limit to the finished surface roughness. Therefore, even if the surface roughness is not small, it is possible to reduce the polishing work by processing the cutting surface to pattern that is easy to polish. Namely, this research will investigate the cutting process considering the polishing work which is the next process. This research reduces the manufacturing cost of large press dies and contributes to strengthening the competitiveness of Japanese mold manufacturing.

As a result, the polishability changes depending on the pattern of the finished surface after machining. The polishing efficiency becomes higher when polishing from the vertical direction to the mountains of the concave-convex pattern. Further, it was clarified that polishing efficiency is improved without depending on the polishing direction by cutting the finishing surface of ball endmill into a cross pattern. In other words, it was found that the polishing work can be simplified by cutting the surface pattern in consideration of polishing easiness in addition to reducing the surface roughness in cutting process.

Introduction

Die and molds are usually made through two processes of machining and polishing. However, it is difficult to quantify small production like die and mold. Therefore, polishing is not automated, and it is done by manual work of worker. Polishing work requires advanced skills. However, workers with advanced skills are decreasing every year. Furthermore, there are few successors due to the declining birthrate, skills are not inherited. A large press die such as an automobile has a simple shape and there are few narrow portions, but there are problems peculiar to a large press die. Because of the large cutting area of a large press die, it is difficult to finish the surface roughness which can be polished with one ball endmill due to limitation of tool life, and multiple ball endmills are necessary. When using a plurality of ball endmills, slight joint occurs on the cutting surface due to the accuracy of tool exchange and the difference of tool length. Figure 1 shows the image of the joints occurring on the cutting surface by tool change. In other words, in the polishing work of a large press die, in addition to removing the cutter mark of the ball endmill, work to blur the joints caused by tool

Fig.1 Image of the joint occurring on the cutting surface by tool change.
change is added. This work requires a great deal of labor and time because advanced skills are required. In companies where production sites are scattered throughout the world, local workers do their polishing work and the finished surface depends on the skill of workers. Work to blur the joints are a source of uneven quality.

The surface roughness of the cutting surface is usually made small in order to reduce the polishing work in the mold manufacturing. However, if the surface roughness is decreased, it is necessary to reduce the pick feed or the feed per one blade of the ball endmill, so the cutting distance inevitably increases. The surface roughness of the cutting surface made by the ball endmill is evaluated by the roughness in the pick feed direction, that is, the cusp height. However, there is also minute roughness in the feed direction, which is caused by the feed per one blade. The roughness of the feed per one blade is extremely small compared to the roughness in the pick feed direction and is ignored. Increasing the feed per one blade increases the machining efficiency, but the roughness in the feed direction increases and the surface roughness deteriorates. However, the surface roughness is a value obtained by evaluating the roughness of the entire cutting surface, and if both roughness of the pick feed direction and the feed direction are made equal, it is considered that both the surface roughness and the processing efficiency can be improved. [1]

In this way, when considering the cutting surface by the ball endmill, pay attention to the surface roughness in the feed direction, and by setting the feed per one blade to the same value as pick feed, it is possible to reduce the surface roughness without lowering the machining efficiency. However, this method requires a long cutting distance to finish the surface roughness to enable polishing work. For this reason, it is difficult to apply this method to cutting process of large press dies due to restriction of tool life. Although it is conceivable to use a CBN ball endmill to lengthen the tool life, it is difficult to realize appropriate cutting conditions in a large type machining center or an old type machining center used in a large press die. [2]

**Experimental method**

A concave-convex pattern due to the pick feed occurs on the cutting surface by ball endmill. This concave-convex pattern is in the vertical direction or the parallel direction depending on the standing position of the worker performing the polishing work. If this concave-convex pattern is inconvenient to the worker performing the polishing, it is necessary to improve it. From such a thing, a basic experiment was conducted to investigate the relationship between the concave-convex pattern and polishability. The polishing work after machining in the mold is performed by manual work of the worker. Therefore, it is necessary to quantify the polishing work. In this experiment, the cutting surface is polished with a brush attached to the machining center, and the polishability is evaluated by measuring the surface roughness after brushing. Figure 2 shows the schematic diagram of the brushing process. Table 1 shows the processing conditions of brushing. Non-contact 3D profile-measuring instruments (KEYENCE VR-3200) was used for the surface of the workpiece. Brushing force was measured using a dynamometer (KISTLER 9257A).

<table>
<thead>
<tr>
<th>Table1</th>
<th>Processing conditions of brushing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brush</td>
<td>Ceramic fiber φ 100 Xebec Technology A31-CB100M</td>
</tr>
<tr>
<td>Brushing speed</td>
<td>250 m/min</td>
</tr>
<tr>
<td>Table speed</td>
<td>2880 mm/min</td>
</tr>
<tr>
<td>Depth of cut</td>
<td>1.0 mm</td>
</tr>
<tr>
<td>Work piece</td>
<td>NAK55</td>
</tr>
<tr>
<td>Work piece size</td>
<td>50 mm × 50 mm × 50 mm</td>
</tr>
<tr>
<td>Cutting fluid</td>
<td>Nothing (Dry)</td>
</tr>
</tbody>
</table>

Fig.2 Schematic diagram of the brushing process
Experimental results

Figure 3 shows the direction of brushing and 3D image of cutting surface. As shown in the figure, Experiment ① was brushed at parallel direction to the mountain caused by pick feed. Experiment ② was brushed at vertical direction to the mountain caused by pick feed.

Figure 4 shows the relationship between the brushing direction and the surface roughness. From the figure, surface roughness of vertical brushing decreases faster than parallel polishing.

Figure 5 shows the relationship between the number of brushing and the brushing force. There is almost no difference in the brushing force between vertical brushing and parallel brushing, but it is found that the brushing force in the X axis of vertical brushing is larger than parallel brushing. From these results, it was found that polishing efficiency is increased by polishing in the vertical direction to the mountain of pick feed.

However, when considering manual polishing by worker, it is desirable that the polishing efficiency does not depend on the polishing direction. From this viewpoint, a brushing experiment was carried out on an isotropic cutting surface. In this experiment, the cutting surface was processed into a cross pattern. Brushing of cross pattern is experiment ③.

Figure 6 shows cutting surface and 3D image. Figure 7 shows the relationship between the number of brushing and the surface roughness. From the figure, it was found that the surface roughness of the cross pattern is faster than that of the vertical brushing shown in Fig. 4, and the polishing efficiency is high. Also, Figure 8 shows the relationship between the number of brushing and the brushing force.
From the figure, the brushing force of the cross pattern is lower than the vertical brushing. The main reason is that the removal volume of the cross pattern is smaller than that of the vertical brushing.

Next, in order to confirm the superiority of the cross pattern, polishability of the cross pattern (pf=2.0mm) and the vertical polishing (pf=1.0mm) were compared. The machining time of ball endmill of the cross pattern (pf=2.0mm) and the vertical polishing (pf=1.0mm) becomes the same. Figure 9 shows the relationship between the brushing direction and the surface roughness. From the figure, it was confirmed that the surface roughness of the cross pattern improves faster than the vertical brushing.

The figure 10 shows the volume of the mountain in the same area in the cross pattern and the vertical brushing. The volume of the mountain per 4.0mm$^2$ is $6.69 \times 10^{-2}$mm$^3$ in the cross pattern (pf=2.0mm) and $3.34 \times 10^{-2}$mm$^3$ in the vertical polishing (pf=1.0mm). The volume of the mountain of the cross pattern is twice the vertical brushing. From these results, it became clear that there is a surface pattern that improves polishing efficiency even when the volume of the mountain to be polished is large. Namely, even if the surface roughness is not small, it can be said that the polishing work can be reduced by processing the cutting surface into a pattern that is easy to polish.

Fig.6 Direction of brushing and 3D image of cutting surface

(a) Direction of brushing (b) 3D image of cutting surface

Fig.7 Relationship between the brushing direction and the surface roughness

Fig.8 Relationship between the number of brushing and the brushing force

Fig.9 Relationship between the brushing direction and the surface roughness
Summary

In this study, focusing on the polishing work of large molds such as automobile press die, I examined the possibility of reduction of polish work. Main conclusions obtained in this study are as follows:

1) Polishing at a vertical direction to the mountain of pick feed leads to high polishing efficiency.
2) On the cutting surface after machining using the ball endmill, there are easy-to-polish patterns. In this experiment, it was clarified that the polishing efficiency is high even if the surface roughness is not small by making the cutting surface into a cross pattern.

The polishing work of the mold usually depends on the skill of the worker. And, finished condition of the mold is managed by standard operation manual. In this study, it was clarified that by making the cutting surface a cross pattern, it is easy to polish from any direction and the polishing efficiency becomes high. On other words, even if the surface roughness is not small, it can be said that the polishing work can be reduced by processing the cutting surface into a pattern that is easy to polish. And, if the polishing characteristics do not depend on the skill of the worker and do not depend on the polishing direction, it also leads to automation of the polishing work. It is an important attempt to low cost, high quality, and stable products supply globally.

References