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New polishing technology of free form surface by GC

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Abstract

Polishing is an important finishing process in die and mold manufacturing. It is very popular to do hand polishing for free form surface although it takes long time and a lot of labor. From this point of view, many trials have been conducted in order to decrease polishing process or to develop the automatic polishing technology, which keep the form accuracy generated in cutting process. Recently grinding center (GC) which has the same ability of cutting as a MC (machining center) has been developed. In this paper a new polishing technology on free form surface with GC is presented. This new polishing technology applies the same CL used in cutting process to remove only cusp height effectively keeping the form accuracy generated in cutting process.

Keywords: Polishing; Free form surface; Grinding center; Ball type wheel; Die; Mold

1. Introduction

Die and mold are constructed with various free form surfaces and they play an important role in manufacturing field. In the machining of die and mold, it takes a long time to finish the curved surface. Therefore, high efficient machining and finishing technology are strongly desired for a long time. Recently grinding center (GC) had been developed for the grinding of various types of machine parts [1,2]. It is available to use GC in free form surface grinding and finishing of die and mold with elastic ball type wheel.

A basic study of grinding on free form surface with a ball type wheel was conducted and also new polishing technology of free form surface by GC was developed with elastic ball type wheel.

2. Concept of new polishing technology

Usually free form surface of die and mold is machined with a ball end mill by MC (machining center).

In the machined surface cusp height is produced due to pick feed of the ball end mill. In polishing process it is very important to remove this cusp height without decreasing machined form accuracy (Fig. 1). The main points of this new polishing technology are as follows:

(1) Polishing is conducted with the same machine tool used in cutting process.
(2) Elastic ball type wheel is used in polishing, which is exchanged by automatic tool changer (ATC) after cutting process.
(3) In polishing process the cutting locus (CL) used in cutting process is applied effectively.
(4) As elastic wheel contacts with wide area, it is possible to give large pick feed amount.
(5) In polishing process only cusp height is removed in order to keep form accuracy that is produced in cutting process with a ball end mill.

This concept will make high productive polishing process and achieve automatic polishing technique. To succeed this polishing technology, basic polishing process must be understood and optimal polishing condition must be selected, which does not decrease the form accuracy generated in cutting process. To get the polishing characteristics, many basic experiments were carried out.

3. Polishing characteristics of an elastic ball type wheel

Depending on the Preston's experience, it is known that the amount of removal in polishing process is in proportion to the polishing pressure and speeds. In order to know the polishing characteristics of elastic ball type wheel, basic experiments were conducted. The experimental conditions are shown in Table 1.

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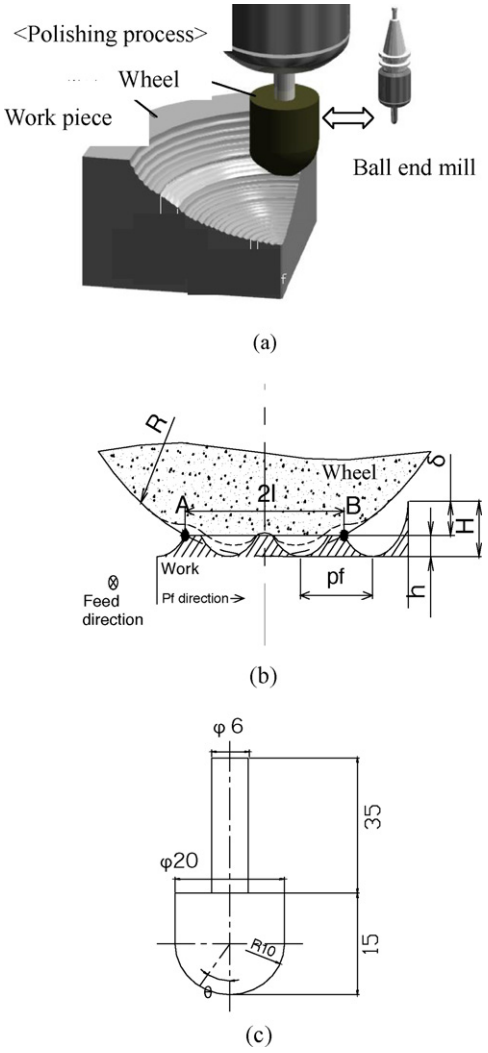

Fig. 1. Polishing process by elastic ball type wheel: (a) application of milling CL, (b) removing cusp height, (c) angle of position.

A peripheral speed (V) of ball type wheel changes depending on the acting position due to its different rotational radius. The acting position is represented with angle θ as shown in Fig. 1.

Polishing experiments were conducted in many polishing conditions by changing setting depth of cut (t), contacting angle (θ), feed rate (f) and Young's modulus of elastic wheel (E) on inclined flat surface in one pass polishing. Fig. 2(a) and (b) show the surface photo and profiles obtained by cutting with a ball end mill and polishing respectively at $\theta = 0°$. It is recognized that coarse surface roughness generated in cutting process

Table 1
Experimental conditions

Ball type wheel	BN3000J74BS20, WA3000UN89
Spindle speed N (rpm)	9000
Feed rate v (mm/min)	25, 35, 50, 150
Setting depth of cut (μm)	9, 12, 15, 18, 21
Work material	SKD61 (HRC53)
Coolant fluid	Soluble Cool
Position angle θ (°)	0, 10, 20, 30, 45, 60

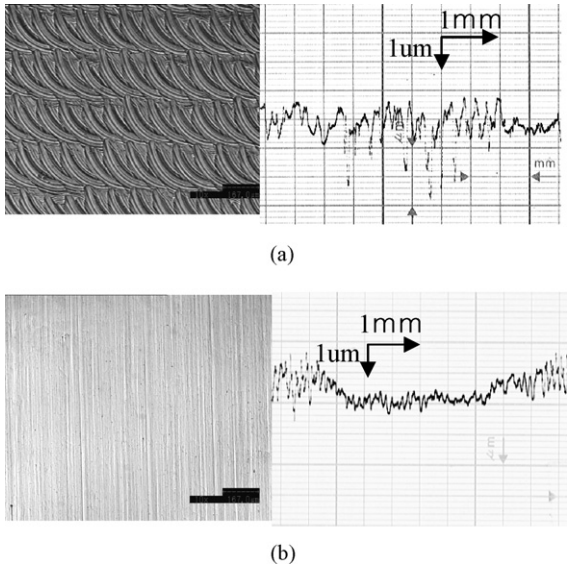

Fig. 2. Photo and profile of work piece surface ($\theta = 0°$): (a) machined surface by ball end mill, (b) polished surface by elastic ball type wheel.

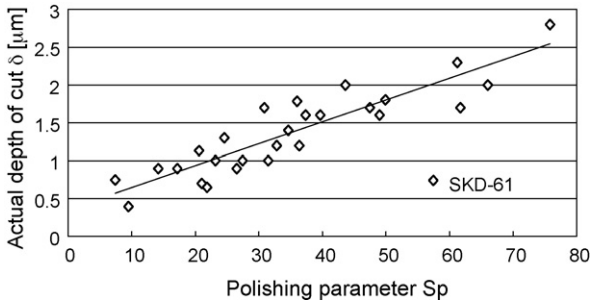

Fig. 3. Polishing parameter and actual depth of cut.

is improved by polishing and only cusp height is removed in polishing process. This means that only surface roughness is improved without decreasing form accuracy generated in cutting process. To represent polishing characteristics polishing parameter shown in Eq. (1) is proposed. The polishing parameters were obtained experimentally by changing the values of polishing speed V, feed speed f, contacting pressure P and hardness of work piece Hv. Fig. 3 shows the relation between polishing parameter and the amount of removal by polishing with elastic ball type wheel. From this experimental result it is known that the actual removal amount is proportional to this parameter Sp.

$$\mathrm{Sp} = \frac{(V + f)p}{f\,\mathrm{Hv}} \tag{1}$$

4. Simulation analysis of polished surface

To develop this polishing method into various type of work piece, it is better to make it possible to estimate the polished surface by simulations. Using polishing parameter, removal amount can be obtained and polished surface is possible to estimate. Fig. 4 shows a model of contact between elastic ball type wheel and machined surface that has triangular cusps gen-