한국기계가공학회지, 제17권, 제6호, pp.61～67(2018.12) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol. 17, No. 6, pp.61~67(2018.12) ISSN 2288-0771(Online)

https://doi.org/10.14775/ksmpe.2018.17.6.061

A Study on Characteristics of Dimensional Accuracy using Planning Number of Machining in Machining Center

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머시닝센터 평면가공 시 가공횟수에 따른 치수정밀도 특성에 관한 연구

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(Received 30 September 2018; received in revised form 10 September 2018; accepted 13 September 2018)

ABSTRACT

The face milling cutter, which is mainly used for the face milling, is used to cut the Carbon steel(SM20C) in the machining center for 5 times and 10 times respectively. This study clarify the dimensional accuracy characteristics according to the number of fine machining varied the condition of cutting depth, table feed speed and spindle speed. Cutting depth is varied 0.05 ˜ 0.2mm, table feed speed is varied 0.05 ˜ 0.2mm/min and spindle speed is varied 1500 ˜ 2500rpm.

As a result, the dimensional accuracy was stable 6 times machining with table feed speed 150mm/min and 10 times machining with table speed 100mm/min and cutting depth 0.05mm regardless times of machining.

Key Words : Measur Values(측정값), Depth of Cut(절삭깊이), CMM (3차원 측정기)

1. Introduction

A machining center can do two-dimensional (2D) cutting such as face, pocket, milling, drilling, tapping, and boring as well as three-dimensional (3D) cutting that processes special curves. Since the range of applications is very wide, it can be used in molding, shipbuilding, automobile manufacturing, new and renewable energy, and general industry machinery part machining. In particular, the demand on machining centers has increased in high-speed and precision machining due to various changes in industrial demand and product life cycle. A large number of studies on face-milling cutters in machining centers have been conducted to obtain superior precision because a machining center has the advantage of being able to machine a large cut area with a single feed[1,2]. The small-diameter face-milling cutter tool that is attached to a collet chuck has been widely used as a high-speed and precision machine tool since it has the advantage of

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reducing the chattering caused by machine vibration and cutting, as a result of its small centrifugal force even in high-speed rotation. More recently, much attention has been paid to precision machining with the development and advancement of machine tools. In particular, it is important to select suitable cutting tools and conditions for cost-effective production to ensure enterprise competitiveness in quality improvements and production cost reduction[3]. The economic cutting condition in machine processing is one of the most important considerations for machine operation. Thus, a large number of studies have been conducted on the selection of economic cutting conditions to ensure enterprise competitiveness, product quality improvements, and high cutting efficiency through efficient machine operations[3,4]. Several of these studies have proposed a large number of measures to improve dimension precision, which can directly affect product quality[4-7]. Cutting machining is normally affected by the material and shape of tools, materials to be cut, spindle speed, feed rate, cutting depth, and whether cutting oil is used or not. With the increase in the need for precision machining for quality improvements, it is necessary to have optimal cutting conditions that can improve productivity and maintain dimension precision within an allowable tolerance[8,9]. The status of dimension precision after product machining is one of the most important measures of quality, and the tolerance level of the required dimension precision significantly affects the post-machining process.

Thus, this study aims to apply dimension change characteristics according to the number of machining processes during finishing while cutting and machining carbon steel (SM20C) for a machine structure. A face-milling cutter is used in the machining center five times and 10 times separately, and the conditions are changed variably as follows: cutting depth from 0.05 mm to 0.2 mm, table feed rate from 0.05 to 0.2 mm/min, and principle spindle speed from 1,500 to 2,500 rpm.

2. Coordinate measuring machine theory

2.1 Coordinate measuring machine

The coordinate measuring machine(CMM) consists of a body, an electronic control device, and a computer system to detect the dimensions or coordinates of complex 3D structures through 3D movements. It has many useful functions, including output of measurement results (structured with various geometrical shapes such as points, lines, circles, and planes) through free software, or automatic calculation of correlation between user's preferred shapes. The coordinate measuring machine has three feed axes, X, Y, and Z, which are arranged in directions perpendicular to each other. Generally, the contact probe is mounted in the Z-axis, thereby providing reference signals that read the coordinate value through contact with the target to be measured[10,11].

2.2 Principle and structure of ball probe

The electric ball probe generates signals by changing the state of the electric contact through gauging pressure as soon as the probe needle, located in the lower end of the probe body, makes contact with the object to be measured (as shown in Fig. 1). The probe needle is attached to the connecting rod, which is fixed to the probe body

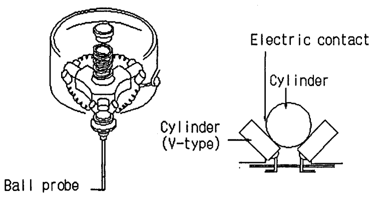


Fig. 1 A configuration of the electric contact boll probe

with three supporting points, and the pressure at the supporting points controls the upper spring[10,11].

3. Experiment device and method

3.1 Experiment device

The experiment was conducted to verify the effects that several factors have on dimensional change, including changes in cutting conditions and the number of cutting procedures. To do this, the experiment device presented in Table 1 was utilized. Fig. 2 shows the photo of the entire experiment device, and Fig. 3 shows the specimen measurement location utilizing the coordinate measuring machine. The measurements were derived by selecting 6.5 mm in the right and left directions from the center based on a 20 mm-wide specimen (Y-axis) and a 20-mm distance on the machining side (X-axis) using the ball probe (measuring unit).

Table 1 Instrument and model

Instrument	Company	Model
Machining center	Tong IL	TNV-40
CMM	Mitutoyo-corp	Bnd-crysts-c9166

Fig. 2 Schematic diagram of experimental

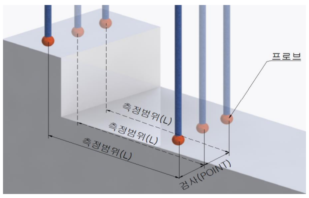


Fig. 3 Measur position of coordinate measuring machine

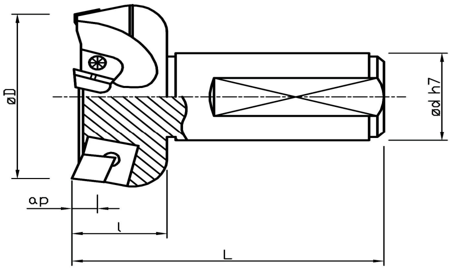


Fig. 4 Configuration of the face milling cutter

Table 2 Dimensions of the face milling cutter(mm)

Type	D	L	l	ap
HP15S-63-12	63	115	35	10

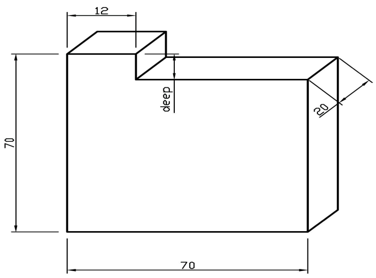


Fig. 5 Dimension of test piece

3.2 Cutting tool and material to be cut

The SPKN1203 EDR carbide tool, which is widely used in production sites, was employed as the cutting tool in this study, and FEM65A–ST32 was used as the tool holder. The entering angle was 75°, and three tipped blades were inserted in the face milling cutter. The shapes and specifications are presented in Fig. 4 and Table 2. Machine structural carbon steel (SM20C) with dimensions of 70 × 70 × 20 mm was used as the specimen in this experiment. Fig. 5 shows the fabricated specimen.

3.3 Experiment method

In this experiment, a three-blade carbide insert tip was installed in the 63 mm-diameter face mill cutter

Table 3 Cutting conditions

Spindle speed(rpm)	1500, 2000, 2500
Depth of cut(mm)	0.05, 0.1, 0.15, 0.2
Table feed rate(mm/min)	100, 150, 170, 200
Cutting counts	5, 10

so that the cutting tool was fixed at the principle spindle after it was connected to the collet chuck. To minimize the effect of dimensional change according to the tool's degree of wear, the cutting tool was replaced whenever principle spindle speed, cutting depth, and table feed rate were changed. Cutting oil was not used in all cases. Tests were conducted with down cut milling to identify how the number of cutting machining processes affected the measurements. These occurred after the machining program was added to the machining center input device under the following cutting conditions: a principle spindle speed of 1,500 to 2,500 rpm, cutting depth of 0.05 to 0.2 mm, table feed rate of 100 to 200 mm/min, and a number of cutting iterations of five or 10 times. The protrusion length of the face-milling cutter was set to 30 mm to maintain the rigidity of the tool according to the vibrations generated during machining center cutting. The coordinate measuring machine was used to determine the dimensional change of the specimen. The cutting conditions applied to the experiment are presented in Table 3.

4. Experiment results and discussion

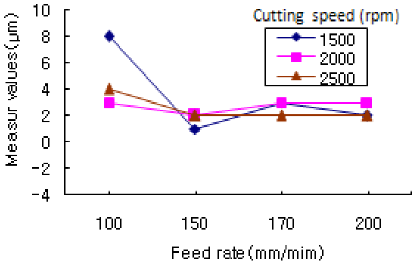
4.1 Characteristics of machining dimensions throughout five iterative machining processes

To observe the effects of changes in principle spindle speed and table feed rate, the coordinate measuring machine took five sets of measurements of machining iterations while changing the cutting depth from 0.05 to 0.2 mm, principle spindle speed from 1,500 to 2,500 rpm, and table feed rate from 100 to 200 mm/min. The changes are depicted in Fig. 6 (a), (b), (c), and (d).

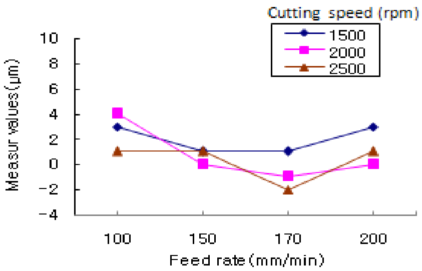
Fig. 6(a) shows the measurements at a 0.05-mm cutting depth. As shown in the figure, the measurements tended to increase at a 100-mm/min table feed rate. When the table feed rate was too slow during the initial cutting, the contact time between tool and workpiece became longer and produced interference among the cutting chips, workpiece, and tool. This resulted in a sensitive reaction to dimension precision, indicating a significant effect by the repetitive friction of fine cutting machining. At a fast table feed rate of 150 to 200 mm/min, the dimension measurements did not change significantly but showed a stable trend. This is because the measurements of straight machining are generally more affected by cutting depth than by principle spindle speed and table feed rate. Thus, the ideal circular feed and vibration between the tool and workpiece were not disturbed at a cutting depth of 0.05 mm and a table feed rate of 150 mm/min, resulting in an insignificant effect.

Fig. 6(b) shows the measurements at 0.1 mm of cutting depth. As shown in the figure, the measurement increased at a table feed rate of 100 mm/min, and the measurement somewhat decreased at a table feed rate of 150 to 170 mm/min. The measurement tended to increase as the table feed rate became fast at 200 mm/min.

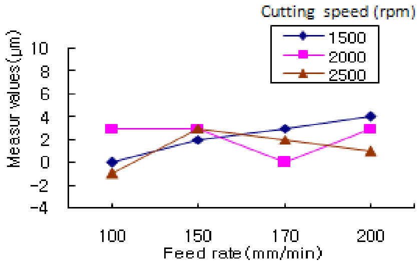
Fig. 6(c) and (d) show the measurements at 0.15 mm and 0.2 mm cutting depths. At a 100-mm/min table feed rate, as the principle spindle speed was increased to 2,500 rpm, the measurement became smaller than the value of the command dimension. This phenomenon occurs due to the following rationale: when the cutting area is large, the table feed rate is slower so that the machining time increases along with the contact time between the tool and workpiece. As the cutting depth becomes deeper, the discharge amount of chips also increases,



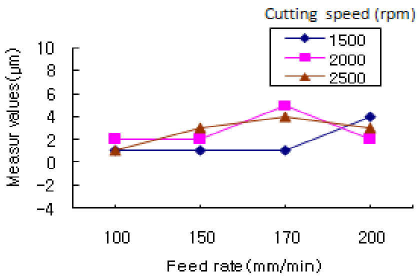
(a) 0.05mm



(b) 0.1mm



(c) 0.15mm



(d) 0.2mm

Fig. 6 Measur values depth of cut according to 5 times of machining

rapidly intensifying tool wear due to the heat generated through inter-friction among the tool, workpiece, and cutting chips.

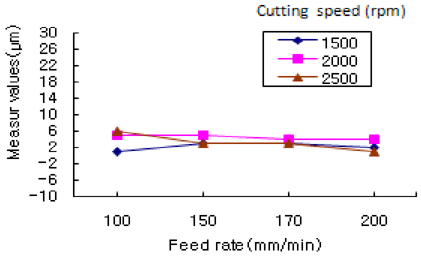
4.2 Characteristics of machining dimensions throughout 10 iterative machining processes

To observe the effects of changes in principle spindle speed and table feed rate, measurements were taken with the coordinate measuring machine throughout 10 machining iterations while changing cutting depth from 0.05 to 0.2 mm, principle spindle speed from 1,500 to 2,500 rpm, and table feed rate from 100 to 200 mm/min. The changes are depicted in Fig. 7 (a), (b), (c), and (d).

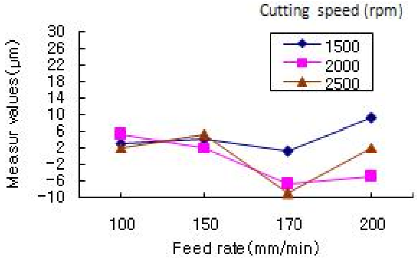
Fig. 7(a) shows the measurements at 0.05 mm of cutting depth. As shown in the figure, the measurements did not change significantly at a 0.05-mm cutting depth even when the number of machining processes and table feed rate moved fast and showed a stable trend as shown in Fig. 6(a). When the cutting area was small, the cutting chips were fused to the blade to protect it as cutting progressed iteratively, even with the increase in cutting times. Cutting chip flow thus had only a small interference, resulting in an insignificant effect on dimension precision despite the increase in machining times and table feed rate.

Fig. 7(b) shows the measurements at a 0.1-mm cutting depth. As shown in the figure, the measurement was stable at a 100-mm/min table feed rate. As the table feed rate moved quickly to 170 mm/min, the measurement increased, which was due to the prevention of ideal feeding as a result of vibration and interference among the tool, workpiece, and cutting chips. The iterative execution of cutting resulted in significant effects to tool wear caused by friction.

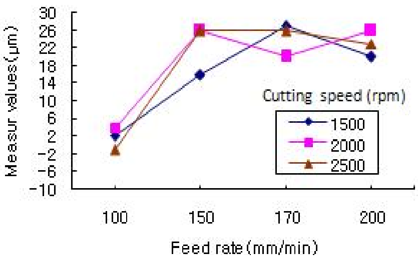
Fig. 7(c) and (d) show the measurements at 0.15-mm and 0.2-mm cutting depths. As shown in the figure, the measurement was good at a 100-mm/min table feed rate and tended to worsen considerably above 100 mm/min. This is because the inter-friction between the cutting tool and workpiece becomes larger as the table feed rate speeds up,



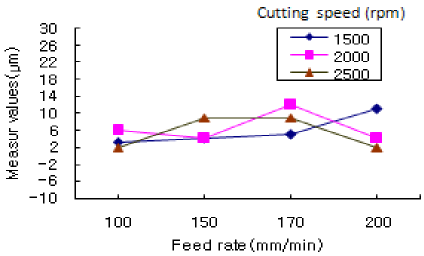
(a) 0.05mm



(b) 0.1mm



(c) 0.15mm



(c) 0.2mm

Fig. 7 Measure values depth of cut according to 10 times of machining

thereby increasing the cutting resistance and making the structure shake rapidly due to the intermittent cutting. This in turn prevents ideal feeding and facilitates tool wear, resulting in worse dimension precision. Thus, it is necessary to maintain good dimension precision by controlling the table feed rate properly as the cutting depth grows deeper.

5. Conclusions

Using a face-milling cutter in a machining center, this paper analyzed and discussed the effect of changing machining conditions on measurements, and it assessed this according to changes in the number of iterative cutting processes.

1. When the cutting depth was shallow, tool wear progressed slowly due to small interference from chip flow, and changes in dimension precision values were minimal despite the increase in machining times. As the cutting depth became deeper, tool wear progressed rapidly due to chip flow interference with the cutting, thereby increasing changes in the measurements.
2. The dimension precision showed stable and good measurements for five cutting machining iterations and a 150-mm/min table feed rate, and it also showed good measurements for 10 cutting machining iterations and a 100-mm/min table feed rate.
3. The measurements were good and stable at a 0.05-mm cutting depth during straight cutting using the face-milling cutter, regardless of the number of machining times.

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