The Study on Evaluation of Hybrid Drilling Command under Deep Hole Drilling

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Abstract - The hybrid drilling command was proposed in this study. The hybrid drilling command is established by combined the merit of G73 (high speed peck drilling cycle) and G83 (small hole peck drilling cycle) using custom macro command. The concept of hybrid drilling command is to divide the total drilling depth into several distances and its distance is shortenned gradually. The drilling chip is breaking with the G73 in the distance between each one and banishing from the hole with the G83 after drilling a distance each time. The evaluation on the merit of hybrid drilling command was carried out by deep hole drilling test on CNC machine center. After experiments, the hybrid drilling command can reduce wearing, extending the tool life of the driller and shorten processes time.

Keywords –Deep hole drilling, Hybrid drilling command, Custom macro, CNC Machine.

I. INTRODUCTION

Drilling is one of the methods commonly used in machining by rotary movement of the end part of the cutting tool. It is defined as the following: By rotating cutting tool, using its top edge (cutting lips), remove the material from the workpiece to produce a hole or aperture of the expansion process [1], and most commonly tool is the drill.

Deep hole drilling is defined as a hole depth greater than five times the diameter of the hole [1].These types of holes require special equipment to maintain the straightness and tolerances. Other considerations are roundness and surface finish.

Deep hole drilling is generally achievable with a few tooling methods, including gun drilling [2] or Boring and Trepanning Association (BTA) drilling [3-5].
With a standard twist drill, it is difficult to drill a straight and accurately sized hole of a depth more than about 5 times the diameter. It is a problem in many manufacturing processes, especially the firearms industry [1].

Deep hole drilling is often carried out by CNC machining center. There are the two standard cycle commands on the general CNC Machining center, namely G73 (High-speed peck drilling cycle or chip breaking cycle) and G83 (peck drilling cycle or interrupted cut drilling cycle), respectively[6-9].

The peck drilling (G83), or interrupted cut drilling, is used to keep swarf from detrimentally building up when drilling deep holes (approximately when the depth of the hole is three times greater than the drill diameter). Peck drilling involves plunging the drill part way through the workpiece, no more than five times the diameter of the drill, and then retracting it to the surface. The process is repeated until the hole is finished.

A modified form of this process, called high speed peck drilling (G73) or chip breaking, only retracts the drill slightly. This process is faster, but is only used in moderately long holes otherwise it will overheat the drill bit. It is also used when drilling stringy material to break the chips [6-8].

The chip is not removed entirely easily which cause the breakage of the drill bit during G73 process. In the other hand, the G83 process cause drill bit possibly because of the wear of margin, the drill bit will form. It also take longer drilling time by the process.

This study proposed a hybrid type of drilling techniques which combines the advantages of G73 and G83 commands but without the disadvantages of both. The reducing drilling time and extending the tool life can be also achieved.

II. THE CONSTRUCTION OF HYBRID COMMAND OF DEEP HOLE DRILLING

A. Analysis of Commonly Used Commands Deep Hole Drilling

The general CNC machining center can only carried out by the two standard cycle commands, namely G73 and G83 [6-9]. The cycle of action was shown in Fig. 1 and Fig. 2. The command format were listed:

Format of G73 command: G73 X_ Y_ Z_ R_Q_F_;
Parameter description：
X, Y: drilling position in the X-Y-axis
Z: The end position of hole
R: Z-axis position of the intermediate R
Q: Once a pecking amount
F: Drilling feed rate

Format of G83 command: G83 X_ Y_ Z_ R_Q_F_;
Parameter description：
X, Y: drilling position in the X-Y-axis
Z: The end position of hole
R: Z-axis position of the intermediate R
Q: Once a pecking amount
F: Drilling feed rate

Timing of its application is described below: when the hole depth and diameter ratio is about 4.5 over, high-speed peck drilling cycle G73, the chip will not be entirely removed and the cutting fluid can not cool the hole and drill during the whole process. As results the Q quantity in each drilling will return d value faster that is repeated during the whole process end as shown in Fig. 1. In the beginning, the chips can be smoothly removed, but when drilling to the deeper depth, the chips can not be completely removed away from the hole. It will increase the intense friction between the chips and the hole which may result in poor roughness on the hole wall surface and the drill breaking or wear.

The G83 command, although chips can be removed away from the holes as shown in Fig. 2, but every stroke, the drill are exited out the hole quickly, , resulting in increased drilling time. It has a intense friction between the margin of drill and the hole wall, caused by poor roughness of hole wall surface and other defects.

B. The Hybrid Command of Deep Hole Drilling

In this paper, the hybrid command of deep hole drilling, namely G251, can be development by the custom macro command to combine the advantages of G73 and G83 commands but without the disadvantages of both. The reducing drilling time and extending the tool life can be achieved.

The idea is that the total depth of drilling was divided into the number of strokes and the stroke is gradually shortening, each stroke in the drilling carried out within the G73, so that a smooth chip breaking and when finished a stroke each drilling, and then G83 was used to completely removed the chips.

The format of hybrid command of deep hole drilling, G251 as follows:

G251 X__Y__A__B__D__Z__R__Q__F__ ；

Parameter description：

- X, Y: the X-Y-axis position of drilling (mm)
- A: the set value of first stroke by G73 drilling (mm)
- B: decreasing rate of each stroke by G73 drilling (%)
- D: buffer distance (mm)
- Z: the end position of drilling depth (mm)
- R: the intermediate point R in Z-axis position (mm)
- Q: G73 each trip (mm)
- F: Drilling feed rate (mm / min)

The G251 subroutine as follows:

```
O9011；
   #28 = #4003；
   #30 = #5003；
   #31 = ABS[#26]；
   #4 = 1－#2；
   #12 = #1；
   #13 = #1；
   G90 G98 G73 Z-#1 R#18 Q#17 F#9；
   G00 Z#18；
   #1 = #1×#4；
   #13 = #13 + #1；
   G00 X#24 Y#25；
   WHILE [#13 LT #31] DO1；
   G98G73 Z-#13 R [#12-#7] Q#17 F#9；
   #12 = #12 + #1；
   #1 = #1 × #4；
   #13 = #13 + #1；
   END 1；
   G73 Z#26 R [#12 - #7] Q#17 F#9；
   G00 Z#30；
G#28 M99；
```

III. EXPERIMENTAL PROCEDURE

A. Deep Hole Drilling Test

The workpiece shown in Fig. 4. Firstly, center drill was used to position, then use the same machine and cutting conditions to carry out the 50 deep holes drilling test (10 workpieces) by G73, G83 and G251. In order to understand the inluence of different drilling command (G73, G83 and G251) on the hole position accuracy, drilling time and the spindle load.

The drilling command, equipment and drilling conditions are as follows:

1. drilling command
   (a) G73 X__Y__R3. Z -104. Q 2. F 55 ;
   (b) G83 X__Y__R3. Z -104. Q 2. F 55 ;
   (c) G251 X__Y__A20. B0.1 D0.5 Z-104. R3. Q2. F55 ;
2. Machine: M-VS 25/20 CNC five-face machining center (MITSUBISHI com., Japan).
3. Controller: FANUC-18MB [9]
4. Drilling conditions
   (a)Drill Specifications: NACHI HSS, ø20mm
   (b) Workpiece material: S50C
   (c) Total drilling depth: 104mm (with the workpiece depth 95mm, drilled through the angle and the amount of depth 6 mm 3 mm)
   (d) Drilling speed: 23 m / min (366 rpm)
   (e) Drilling feed rate: 55 mm / min
   (f) G73 each trip (Q): 2mm
   (g) first stroke by G73(A): 20 mm
   (h) decreasing rate (B): 0.1 (10%)
   (i) buffer distance (D): 0.5 mm
   (j) Cutting fluid: water-soluble emulsifier

B. Measurement of Hole Eccentricity

In this paper, the measurement of hole eccentricity carried out by micrometer and shown in Fig. 5. The micrometer was used to measurement the distances between the hole inside and the edge of the workpiece, and then the hole eccentricity can be calculated.

C. Spindle Load Measurement

In this study, the M-VS 25/20 CNC five-face machining center (MITSUBISHI Com., Japan) was used. And the spindle loads was directly measured from spindle load detecting device of M-VS 25/20 CNC five-face machining center.

IV. RESULTS AND DISCUSSION

Following the experimental procedures in Section 3, the experimental results were listed in from Table 1 to Table 3. The position accuracy of hole was listed in Table 1, the processing time was listed in Table 2, and the spindle load of the machine was listed in Table 3.

A. Influence of Different Drilling Command on The Hole Position Accuracy

From Table 1, the G251 process shows higher position accuracy than G73 and G83. It can be found that the performance of G251 is good and can improve standard command inadequate generally in deep hole drilling CNC controller provides.

B. Influence of Different Drilling Command on The Drilling Time

From Table 2, the G251 process shows larger drilling time than G73 (increases 6.45%), but shorter than G83, (reduces 19.56%). Although the drilling time of G251 is slightly increased compared with G73, but G251 can avoid the drill broken or wears by G73.

C. Influence of Different Drilling Command on The Spindle Load

From Table 3, compares the spindle load at first hole and the 25 holes, it can be found that the spindle load at 25th hole drilling is larger 15% than first hole drilling during the G251 process. And the G73 process is larger 26% and the G83 process is larger 24%. Therefore, the spindle load of G251 is smaller than G73 and G83. Drilling test confirmed that tool life time using the G251 command in deep hole drilling is longer than G73 and G83 command and saving the tool cost.

V. CONCLUSIONS

In this paper, the hybrid command of deep hole drilling, G251, was successfully built by the custom macro command to combine the advantages of G73 and G83 commands but without the disadvantages of both.

The evaluation on the merit of hybrid drilling command was carried out by deep hole drilling test on CNC machine center. After experiments, the hybrid drilling command can reduce wearing, extending the tool life of the driller and shorten processes time.

And the hybrid command of deep hole drilling, G251 is easy to use, easy application, with practicality, and without external addition of the software interface, easy to be accepted by the industry.

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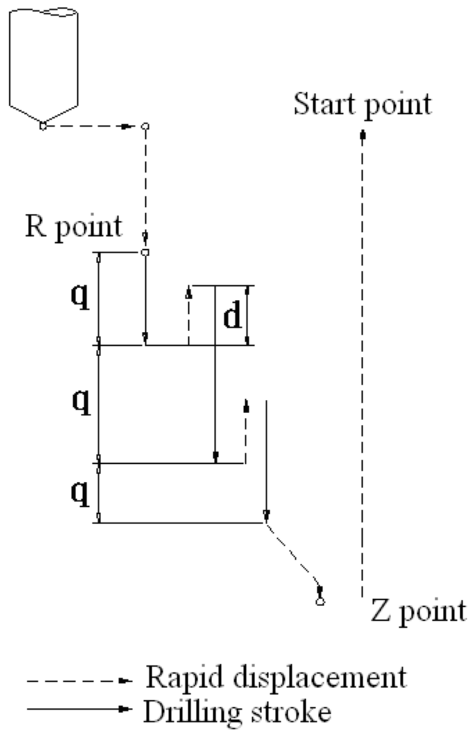


Fig. 1 Illustration of G73 (high-speed peck drilling cycle)

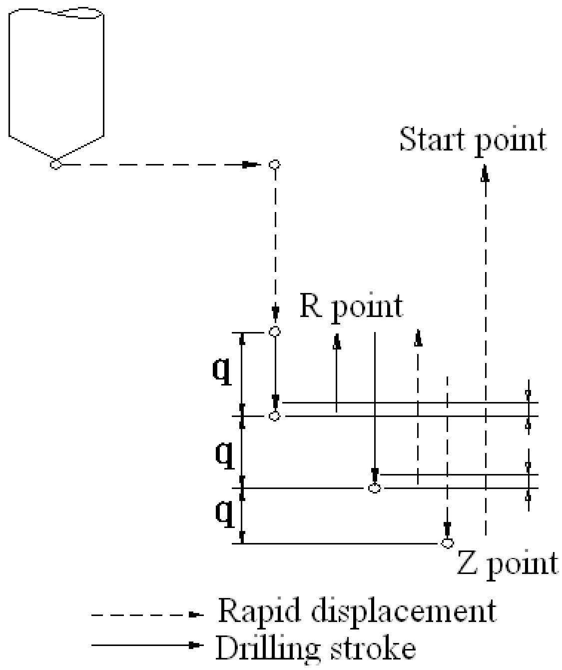


Fig. 2 Illustration of G83 (peck drilling cycle)

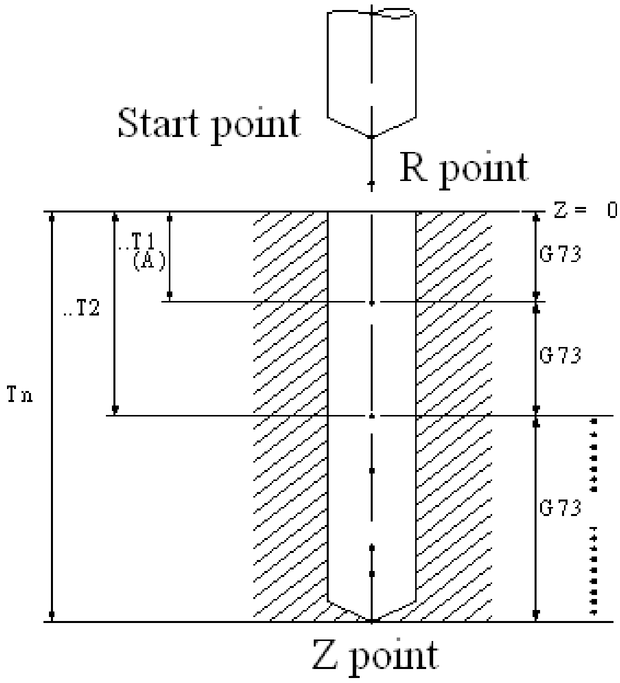


Fig. 3 Illustration of the hybrid command of deep hole drilling G251

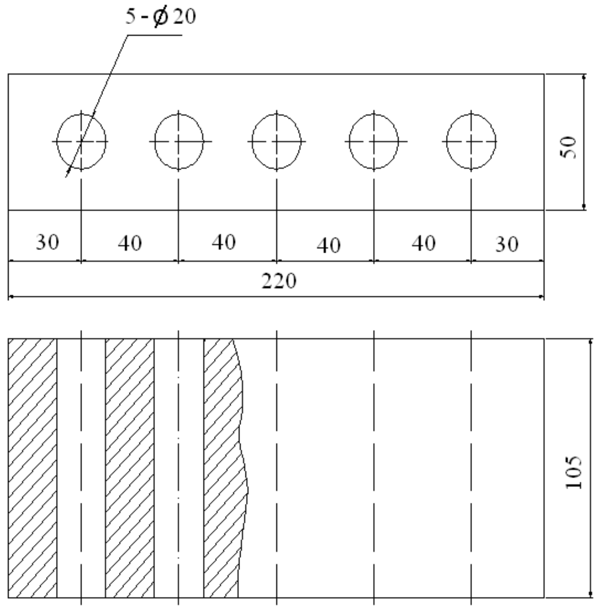
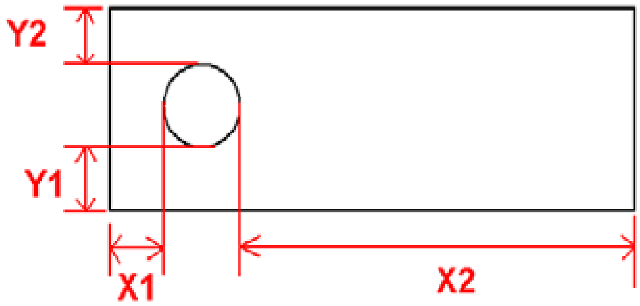


Fig. 4 The drawing of workpiece



$$\Delta C = \sqrt{\left(\frac{X1-X2}{2}\right)^2 + \left(\frac{Y1-Y2}{2}\right)^2}$$

Fig. 5 Illustration of the measurement of hole eccentricity

Table 1 The position accuracy of hole (units: mm)

Hole number / Drilling command	#1 △C	#2 △C	#3 △C	#4 △C	#5 △C	Average △C
G73	0.153	0.201	0.185	0.194	0.167	0.180
G83	0.196	0.211	0.214	0.250	0.220	0.218
G251	0.142	0.175	0.114	0.124	0.132	0.137

Table 2 The processing time

Drilling command	Average drilling time (unit workpiece)
G73	11 min 37 sec
G83	15 min 19sec
G251	12 min 22 sec

Table 3 The spindle load of the machine (unit: N-m)

Spindle load / Drilling command	Spindle load (N-m)	
	First hole	25th hole
G73	68.31	145.53
G83	68.31	139.59
G251	68.31	112.86