Application and Analysis of Thread Milling in NC Machining

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***Abstract* — Thread milling is an advanced thread machining technique. Utilization of CNC milling thread can better the machining quality of the screw threads, reduce machining cost and improve processing efficiency. In this paper, thread milling principle is presented as well as process analysis. Then a part to be R-internal thread milling is studied for illustration by corresponding parameters calculation and programming machining. For NC thread milling, macro program of FANUC is introduced. Finally, the machining codes of CNC milling are presented.**

Keywords - thread milling;macro program;machining process; NC machining

I. INTRODUCTION

Thread can be seen everywhere in industrial equipments. Traditional small-diameter thread machining mostly includes turning, milling, tapping, threading and so on [1]. While, as for small-diameter thread, it is machined usually by single-handedly boring on CNC (Computer numerical control) milling machine based on the relationship between the pitch and the line speed of boring tool tip for programming [2]. Although such machining is convenient, the cutting speed is slow with low efficiency and prone to generate shake profile with unstable processing quality. With the development of CNC machine, there arose an advanced thread processing method, thread milling [3]. Compared with traditional machining, thread milling has better precision and efficiency for advantages with unlimited thread structure and rotation restrictions and only one tool can process internal and external thread with variety of different spins. What's more, for the same pitch and different diameter, thread milling need a single tool to be programmed for adjusting [4]. While, if tapping is used to process, more tools are needed and the thread accuracy is not guaranteed after the taps are worn down. If the cutter of milling worn, it is only needed to modify the tool radius compensation value of the machine parameters so as to process qualified thread. As for high hardness and high temperature materials, it is easy to plug the broken screw holes after the tap is broken, and will cause too much trouble to handle or even scrapping, which will not be involved by thread milling. Therefore, thread milling is considered to have the machining advantages of high efficiency, good quality, versatility and security.

II. THREAD MILLING PRINCIPLE AND PROCESS ANALYSIS

Thread milling is the method to machine threads by utilizing spindle rotation for circular interpolation, which is formed by combinations of three-axis machine helical interpolation and spindle rotation based on G2 / G3 instruction [5]. Under this type of machining, the spiral curve is generated by forming thread mills around the thread axis for circular interpolation motion of X, Y direction and the axial direction (Z or W) linear motion to complete thread processing. Only changing the machining program will be able to process left/right thread, internal/external thread and threads of different diameters. So thread milling is a convenient and flexible machining [7-8]. Due to that machining tool in under local contact and off-chip processing when operating, cutting forces are small, which can result in tool's long life, small wear, and comparative obvious advantage with taping. The processing routes of internal and external thread milling is shown in Figure 1 and Figure 2 respectively.

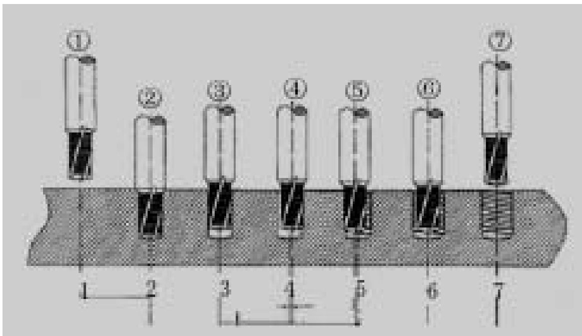
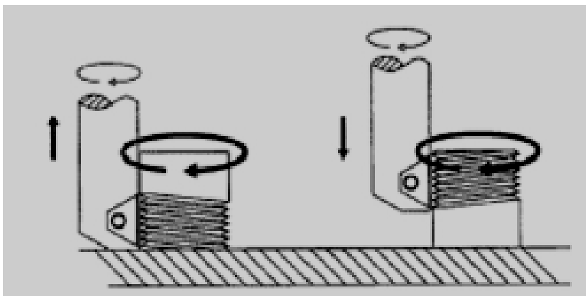


Figure 1. Internal and external thread milling illustration.



a) L-milling b) R-milling.

Figure 2. External and external thread milling illustration

Pre-positioning using the center drill, the below step are for reaming and thread milling as shown in Figure 1:

(1) Drill milling cutter/tool:G00 move fast the cutter to the safety plane(see Figure 1 ①);

(2) The tool reaming: radial dimension as the small diameter of thread and vertical dimension as the hole depth (Figure 1 ②);

(3) raise the thread cutting tool by threading depth dimension (Figure 1 ③);

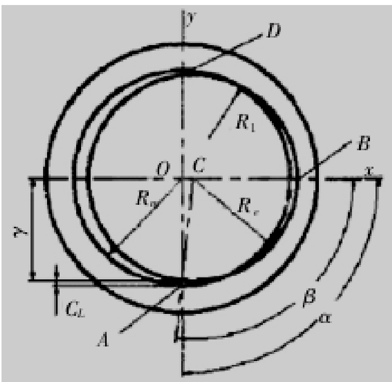
(4) The tool moves to the thread starting point arc by the arc cutting mode (Fig. 1 ④);

(5) The tool make circular interpolation motion in the XY plane and when each circular interpolation motion ends, stroke a pitch along Z+ direction with spiral trajectory, which is realized by variable macro programming (Figure 1 ⑤) ;

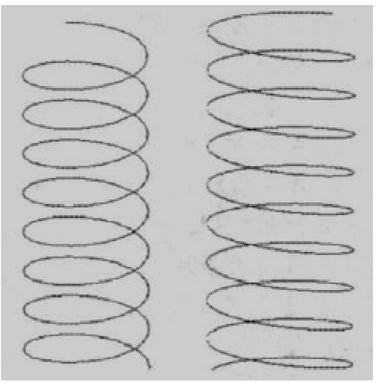
(6) The tool exits with arc trajectory from the starting point (Figure 1 ⑥);

(7) Tool: G00 rapidly exit to a safe plane and proceed for the next step (Figure 1 ⑦).

Like the general milling contour, thread milling will get better machining quality if feeding as 1/4 arc . Meanwhile, the blade width of the cutter for machining should be as large as possible, which can improve processing efficiency. Figure 3 shows the thread cutter trajectory.



a) Sectional view of the trajectory



b) Three-dimensional trajectory view

Figure 3. Thread cutter trajectory illustration.

The mathematical model of thread cutter trajectory can be established as Equation 1.

$$\begin{cases} x = x_c + [d/2 + m \times (D/2 + \delta)] \cdot \cos(n\alpha) \\ y = y_c + [d/2 + m \cdot (D/2 + \delta)] \cdot \sin(n\alpha) \\ z = z_c - p \cdot \alpha / 2\pi \end{cases} \qquad (1)$$

Where d denotes bottom diameter of the thread, D denotes the diameter of thread cutter, m (1 for external thread, -1 for internal thread)and n (1 for R- thread, -1 for (L-thread) denotes the thread type, δ denotes allowance, x_c , y_c and z_c denote the position coordinates respectively, and p denotes the pitch.

III. PARAMETERS CALCULATION OF THREAD MILLING

In this research, a case is provided with a part to be R-internal thread milling, whose material is cast iron, HBS is 156-229, Z depth is 20mm and the dimension is M30*2. The calculation and machining are made by FANUC programming [9-10].

Below are relative parameters of the thread:

trail: $D_i = 27.14mm$;

nominal diameter: $D_0 = 30mm$;

depth: $L = 20mm$;

pitch: $P = 2mm$;

cutter diameter: $D1 = 12mm$;

milling speed: 40 mm / mim;

cutting feed: $f = 0.08mm$ /tooth;

milling: Clockwise.

Thus,

（1）Spindle speed

S= $1000v / (D1 \times \pi)$ = $1000 \times 40 / (14 \times 3.14)$ =1062 $r / \min$

（2）Feed rate

F 1 = $f_z \times N$ = $0.08 \times 1 \times 1062 = 84.96$ $mm / \min$ (the number of utter tooth:1, f_z : 0.08 mm/tooth)

（3）Entering arc radius

$R_e = [(R_i - C_0)]^2 + R_0{}^2] / (2R_0)$ = $[(13.57 - 0.5)^2 + 15^2] / (2 \times 15)$ = 13.194mm （ safe distance C_0 =0.5mm）

（4）Entering arc angle

β = $180^0 - \arcsin[(R_i - C_0) / R_e]$ = $180^0 - \arcsin[(13.57 - 0.5) / 13.194]$ = 99.80^0

（5）Z-axis pitch stride of entering arc

$$Z_{\alpha} = p\alpha / 360^0 = 2 \times 90^0 / 360^0 = 0.5mm$$

（6）Therefore, the coordinate of starting point can be calculated with the above parameters as :

$$\begin{cases} X = 0 \\ Y = -R_i + C_0 = -13.57 + 0.5 = -13.07 \text{ mm} \\ Z = -(L + Z_a) = -(20 + 0.5) = -20.5 \text{ mm} \end{cases}$$

IV. THREAD MILLING PROGRAMMING

The NC machining is completed by FANUC programming with variable macro mode [6]. The parameters such as diameter, pitch, depth and so on are considered as variables to be assigned. Therefore, it needs only once for uses to change the assigned value and use the same program to process threads with different sizes, which will result in improved processing efficiency.

#1=-20.5；(starting point of Z of thread)

#1=#1+0.5；(Z-axis pitch stride)

#2= $[(R_i - C_0)]^2 + R_0^2] / (2R_0)$ + C_0 =-13.07 ；(starting point of Y of entering arc)

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N10 G90 G54 G40;
N20 G0 X0 Y0 S1062 M03;
N30 G0 Z5
N40 G1 Z#1 F200
N50 X0 Y#2
N60 G03 X0 Y#2 I0 J-#2 F84.96
N70 IF [ #1 GE 0 ] GOTO40
N80 G0 Z5
...............
N000 M30
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V. CONCLUSIONS

As can be seen from the above, the programming of thread milling is simple and convenient. It has good versatile and improved machining effiency for threads with different diameters and pitches and depth to only change the parameters of the program can be processed. The thread milling has proved to be good after actual machining with good output quality. In summary, compared with traditional tapping, the thread milling has a great advantage to be more flexible, efficient, and has a broad application prospects.

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