

EXAMPLE OF MANUAL PROGRAMMING OF CNC TURN IN HIGHER EDUCATION

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Abstract: This paper describes one example of manual programming of the CNC turn using three mathematical methods depending on the given drawing. Students learn to make the tool path for the given drawing utilizing the knowledge of coordinate systems. As the tool path is generated students calculate each endpoint of the tool tip point using methods of trigonometry and triangle similarities for angular surfaces and Pythagorean theorem for circular surfaces. With the calculated points, the G-code is written and tested on the SINUMERIK 840D control unit. As the machine is processing the part students follow each coordinate of the tool tip point and distance to go on the control unit for each programmed word.

Key words: CNC, programming, education, mathematics

1. INTRODUCTION

Further technology development is causing manual CNC programming to be less used and most companies turn to automated programming using CAD/CAM systems. Manual CNC programming is essential for understanding the G-code in cases where CAD/CAM systems may make mistakes. The programmer with knowledge of manual CNC programming can detect errors and remove them before the start of the machining process to avoid collisions, damage, and additional costs [1]-[2].

Manual CNC programming is used for simple geometrics or operations where the time of calculations and writing the program is shorter than the time spent on generating a 3D model of the workpiece in CAD software and generating tools, tool paths, and operations in CAM software [3]-[4].

The drawing used for the experiment is represented in Figure 1.

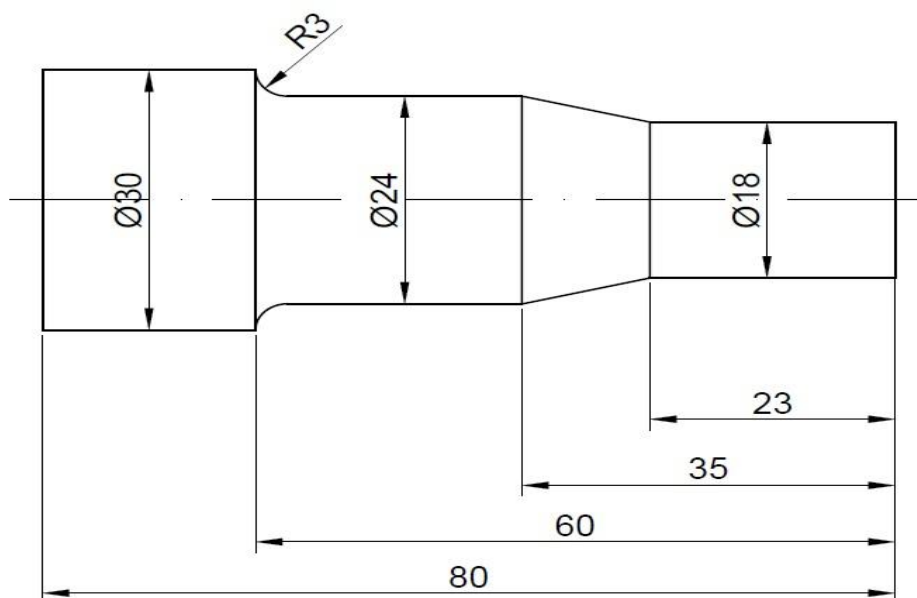


Figure 1- Part Drawing

The machine used for the given part drawing is EMCO Concept turn 55 with a SINUMERIK 840D control unit. Since the machine is mainly constructed for educational purposes the depth of cut of 1 mm is used to avoid crashes and unnecessary errors on the machine. The stock material is made out of aluminum and its dimensions are Ø30 x 80 mm. For used stock material used cutting speed is $v = 80$ m/min and feed rate $s = 0.1$ mm/rev.

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2. METHODOLOGY OF MANUAL CNC PROGRAMMING

The main goal of using manual CNC programming in higher education is that students fully understand the principle of G-code and to be able to read it, the goal enhances their ability to troubleshoot errors in automated generated G-codes [5].

Students are introduced to the three mathematical principles:

- Coordinate system – for creating tool path
- Trigonometry and triangle similarities – for calculating points for angular surfaces
- Pythagorean theorem – for calculating points for round surfaces

The principle to write a program is to activate machine commands (M commands) for the machine to engage its hardware and geometry commands (G commands) for tool movement and engaging geometry commands on the machine [6].

Tool movement is based on guiding the tool tip point in the workpiece coordinate system. The main part of the program mostly consists of tool tip point coordinates in the coordinate system.

Tool used for the experiment is right hand tool with next geometric characteristics:

- Angle of cutting edge: 55°
- Nose radius: $r = 0.4 \text{ mm}$
- Clearance angle: 32°
- Side cutting edge angle: 3°

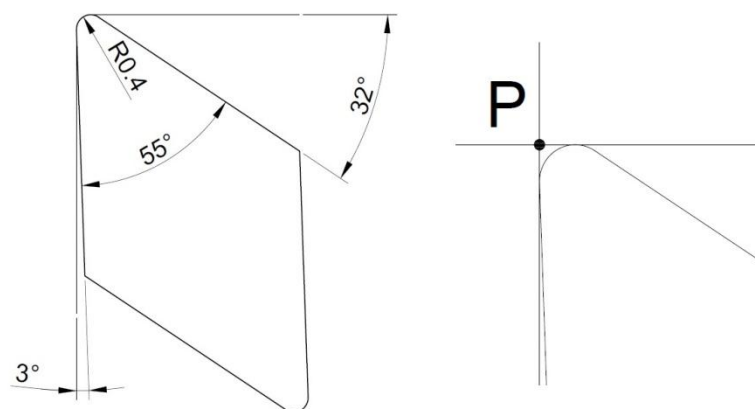


Figure 2 – Tool geometry

Tool movement is divided into four ways: Approaching the material, cutting the material, exiting the material, and retracting from the material. Commands such as G0 and G1 are used for the tool movement. G0 represents rapid movement at maximum feed speed, it is used for approach, exit, and retract. G1 is programmed feed speed, it is used only when the tool is cutting the material, it can also be used to exit the material, depending on the circumstances [7].

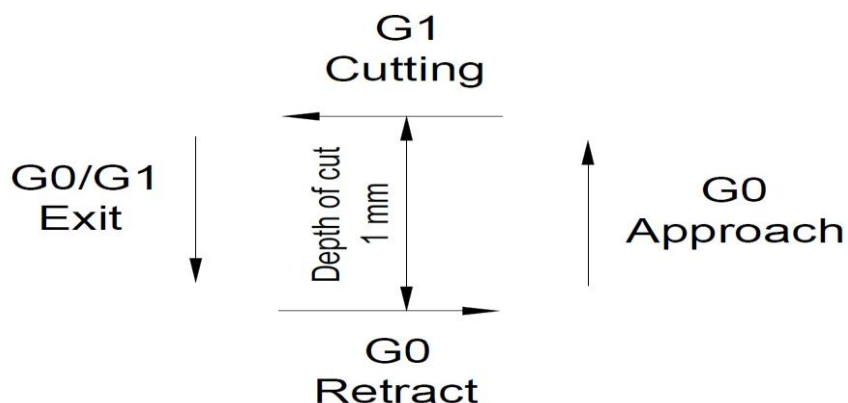


Figure 3 – Tool movement

To initiate the machine the following code is used:

G54 G90 G71; workpiece coordinate system activation, absolute measurements activation, programming in millimeters

LIMS = 2000; limiting spindle for 2000 rev/min

G96 S80 M3; constant cutting speed activation, programmed cutting speed value, spindle spinning at clockwise direction

G40 G95 F0.1; tool cutter compensation off, feed mm/rev activation, programmed feed value

TRANS Z65; moving workpiece coordinate system to the top of the workpiece

T2 D1; activating right hand tool

3. PROGRAMMING OF ROUND SURFACES

For the programming of round surfaces, the Pythagorean theorem is used. First, the start point and the endpoint of the round surface are found. The endpoint can be extracted from Figure 1 via the shown dimensions, where the X coordinate is X30 and the Z coordinate is Z-60.

To calculate the start point the X coordinate of the endpoint is subtracted by 6, due to the radius size being 3, and due to the rotation of the workpiece there are two sides, which results in the X coordinate of the start point being X24. The Z coordinate of the start point is calculated by subtracting the Z coordinate of the endpoint by radius size 3, which results in the Z coordinate of the start point being Z-57.

The radius value R3 indicates that there will be two tool passing.

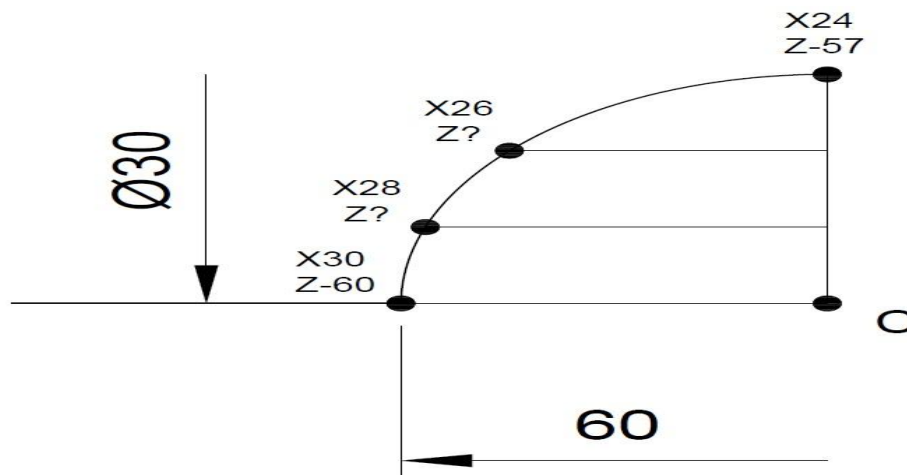


Figure 4 – Point extraction

It is necessary to find the remaining points of the round surface. Since the depth cut is 1 mm, the X coordinates can be found. The x coordinate of the end point is subtracted by 2 to find the X coordinate of the point on the angular surface, which indicates the next X coordinate is X28. The value of the newly calculated X coordinate is also subtracted by two and the new X coordinate is X26.

To calculate the Z coordinates for round surfaces the Pythagorean theorem is used. The first step is to draw triangles from the center of the circle and connect the surface points with the center. Figure 5 shows that the radius represents the hypotenuse, the opposite sides are the depth of cut, where the adjacent sides are calculated:

$$b^2 = c^2 - a^2 = 3^2 - 1^2 = 9 - 1 = 8 \rightarrow b = \sqrt{8} = 2.828$$

$$b^2 = c^2 - a^2 = 3^2 - 2^2 = 9 - 4 = 5 \rightarrow b = \sqrt{5} = 2.236$$

To calculate the Z coordinates of the first and second points of the round surfaces the calculated adjacent sides are added with the Z coordinate of the starting point Z-57. The Z coordinate of the first point is Z-59.828 and the Z coordinate of the second point is Z-59.236.

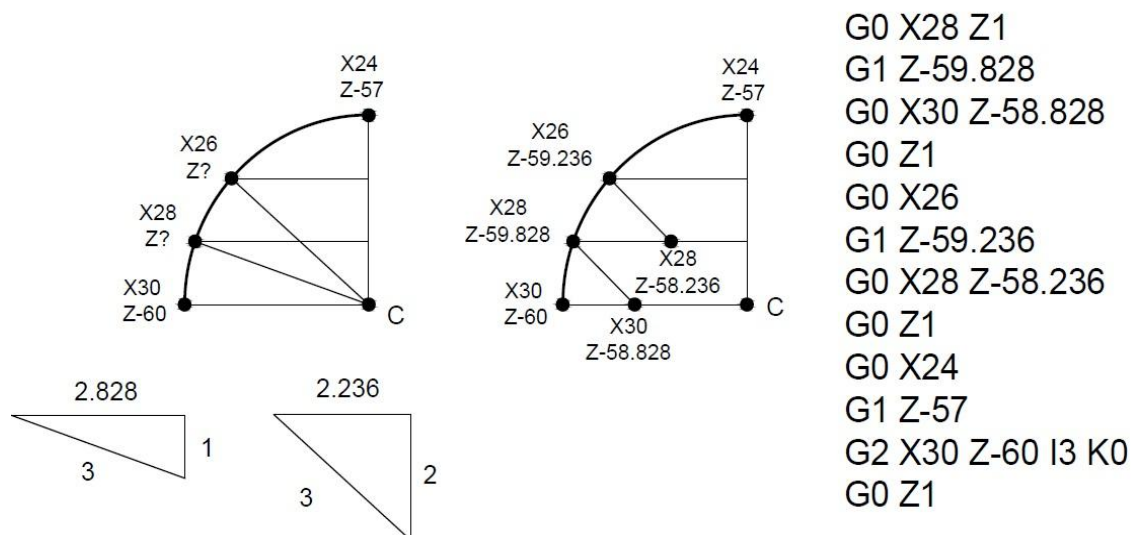


Figure 5 – Point calculation and program

To machine the round surfaces parameters for showing the position of the circle center are extracted. Those parameters show the distance from the starting point to the circle center on the X axis (I) and from the starting point to the circle center on Z axis (K). The relative coordinate system is placed on the starting point to display the value of each parameter, the coordinate system is positioned in the same way as the workpiece coordinate system. Figure 6 represents that the parameter values are I3 and K0.

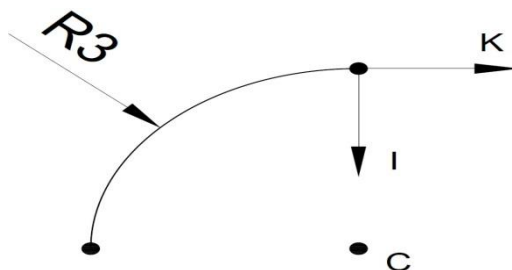


Figure 6 – Circle center parameters

4. PROGRAMMING OF ANGULAR SURFACES WITH TWO DIAMETERS

For programming the angular surfaces with two diameters the triangle similarity method is used. It is necessary to make a triangle out of the angular surface and to extract side dimensions.

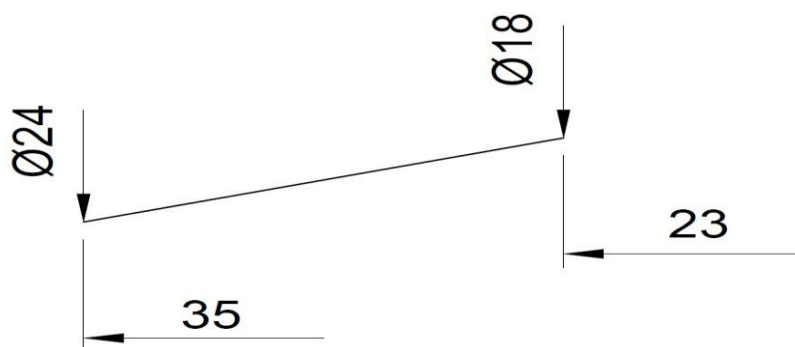


Figure 7 – StartPoint and EndPoint extraction

The adjacent side represents the Z axis and is visible on the drawing which is 12 mm, the result is calculated by subtracting dimension 35 from dimension 23. The opposite side represents the X axis and to calculate its length it is necessary to subtract diameter dimensions and divide the result by 2.

$$a = \frac{24 - 18}{2} = \frac{6}{2} = 3$$

Using depth cut of 1 mm the given results indicates that there will be two tool passing.

To reach the shown points in Figure 8 the triangle similarity method is used where the only known points are the starting point and the end point of the angular surface.

The X coordinates are found using the same principle as with round surfaces. While for the exit X coordinate the endpoint of the X coordinate of the angular surface is added by two, so the X coordinate of the exit point is X26.

To find the Z coordinates for each point, the triangle similarity method is used. For the first point, the sides of the triangle are used as a fraction, then the value of the opposite side of the triangle is subtracted by 1 (depth of cut), and the new fraction is created:

$$\frac{3}{12} = \frac{2}{Z} \rightarrow Z = \frac{12 \times 2}{3} = \frac{24}{3} = 8$$

Where:

Z – length of the new adjacent side

On the new calculated adjacent side the Z coordinate of the start point is added, so the first Z coordinate of the angular surface is Z-31.

The same principle is applied for the second Z coordinate of the angular surface where the length of the first point is subtracted by the depth of cut:

$$\frac{3}{12} = \frac{1}{Z} \rightarrow Z = \frac{12}{3} = 4$$

The newly calculated Z coordinate of the second point of the angular surface is Z-27.

The Z coordinate of the exit point is calculated by adding the length of the last opposite side of the triangle, in this case 4, to the Z coordinate of the endpoint of the triangle. The Z coordinate of the exit point is Z-39.

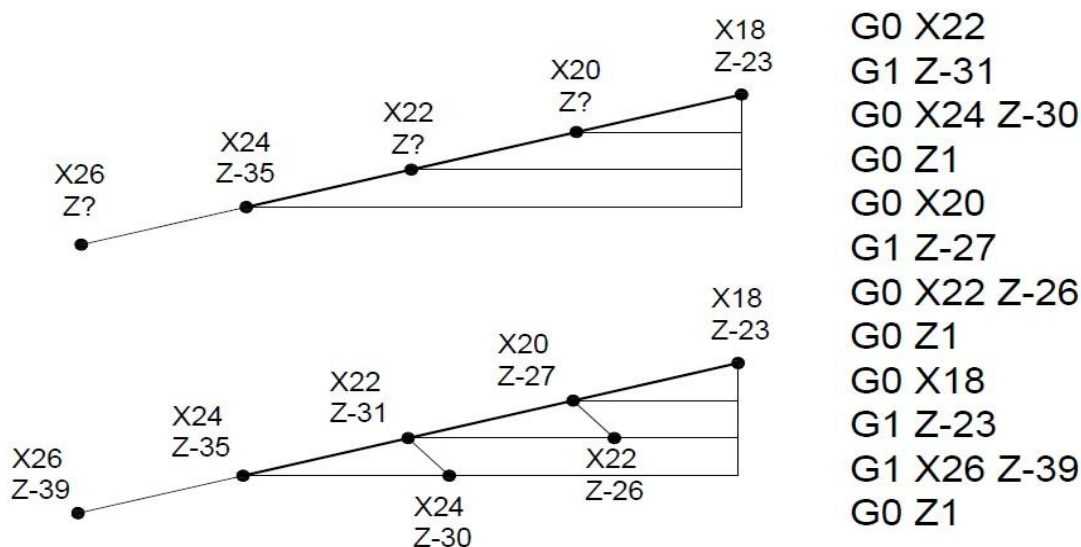


Figure 8 – Calculated points and program

5. CONCLUSION

When the program is finished the stock material is placed in the machine and the machining process is activated. Students can follow the coordinates on the control unit for each written sentence in the program, also the control unit shows the distance left from the tool tip point to reach the coordinate.

When the machining is finished students take part in calculating and generating the program using the same drawing with different dimensions. Students also take part in front of the board, each calculating and explaining to other students, with the help of the professor, their results which improve their calculation, thinking, and public presentation.

After students present their results, with the correction of the professor if necessary students edit their program and place the part in the machine for processing the part with their generated program.

6. REFERENCES

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