International Journal of Current Research and Applied Studies, (IJCRAS)

ISSN: 2583-6781

available at https://ijcras.com/

Volume 5 Issue 3 May-June 2026, Page 12-20

To cite this article: Nguyen Thi Le Hang (2026). BASIC CUTTING PROBLEMS ON CNC MILLING CENTERS, International Journal of Current Research and Applied Studies (IJCRAS) 5 (3): Article No. 148, Sub Id 257

BASIC CUTTING PROBLEMS ON CNC MILLING CENTERS

Nguyen Thi Le Hang

College of Economics and Techniques
Group 8, Thinh Dan ward, Thai Nguyen city, Viet Nam

DOI : https://doi.org/10.61646/IJCRAS.vol.5.issue3.148

ABSTRACT

These are the physical entities involved in the machining process: Machine tools: Provide the necessary energy and movements (e.g., lathes, milling machines). Cutting tools (Tools): Must have higher hardness than the workpiece and a suitable cutting-edge geometry. Workpiece (Machining material): The object from which excess metal needs to be removed. Fixtures: Used to position and clamp the workpiece, ensuring accuracy during machining. Cutting movements (Movements) The surface shaping process only occurs when there is relative movement between the tool and the workpiece: Main movement (Cutting movement): This is the movement that creates the cutting speed and consumes the most power (e.g., workpiece rotation in turning, tool rotation in milling). Feed movement: This is the movement that moves the cutting edge to new areas of metal for continuous cutting (e.g., tool translation along the longitudinal or transverse direction). Cutting Parameters (Quantitative) To optimize the process, the operator needs to determine 3 main parameters: Cutting speed. Relative speed of the cutting edge on the workpiece surface (m/min). Feed rate: Distance the tool moves after one revolution or one workpiece stroke (mm/revolution). Cutting depth: Thickness of metal removed in one movement of the tool (mm).

Keywords: Depth of cut, cutting speed, cutting width, cutting area.

1. INTRODUCTION

Milling is a machining method in which chips are removed from the workpiece by a rotating cutter, and the cutting process is maintained by the workpiece's translational movement. The axis of rotation of the milling cutter is perpendicular to the direction of the feed motion.

Figure 1. Image of the actual milling process.

The cutting tool used in milling is the milling cutter. Based on their structure, milling cutters include various types: face milling cutters, cylindrical milling cutters, end milling cutters, disc milling cutters, profile milling cutters, etc.

Figure 2. Cutting tools used on a milling machine.

Milling is performed on various types of milling machines, such as vertical milling machines, horizontal milling machines, etc., and can also be done on other types of machines.

2. METHOD

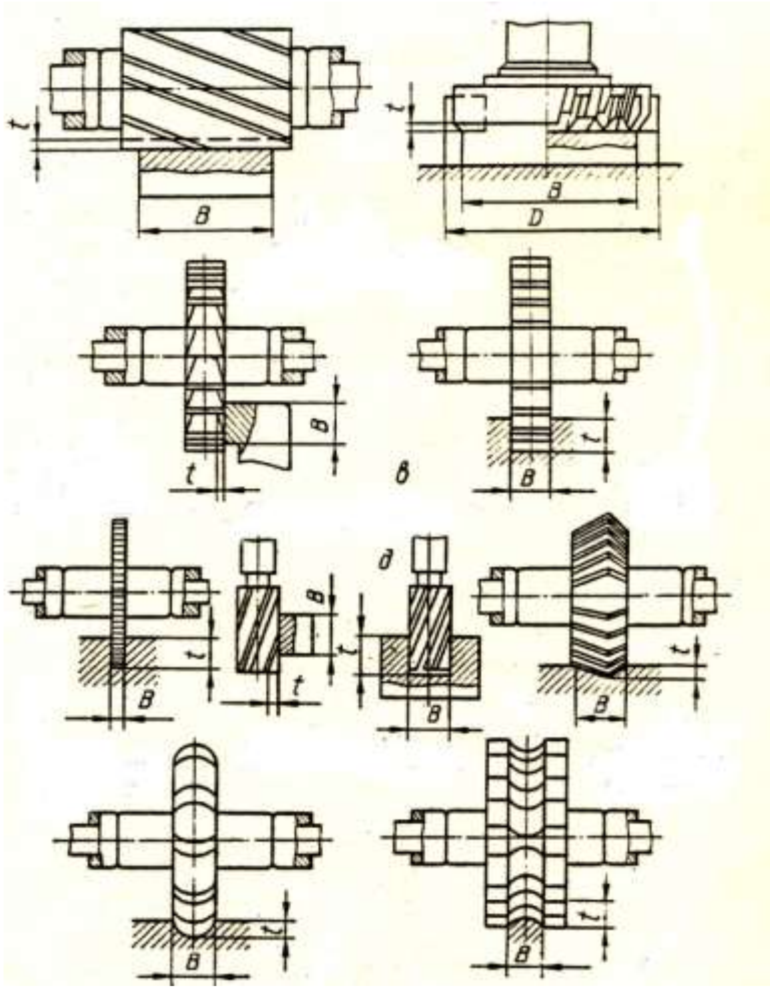

Figure 3. Cutting elements in milling under different machining conditions.

Depth of cut t:

This is the distance between the machined surface and the unmachined surface, measured perpendicular to the machined surface after a single cut.

When milling, the feed rate is classified into 3 types: - Tooth feed rate Sz: the feed rate determined after the cutter rotates a tooth angle θ. Symbol: Sz, mm/tooth. - Rotational feed rate Sv: the feed rate determined after the cutter rotates one revolution. Symbol: Sv, mm/revolution. - Minute feed rate Sph: the feed rate determined after one minute. Symbol: Sph, mm/minute. The following relationship exists between them:

$$S_V = Z \,.\, S_z \qquad (1.1)$$

$$S_{ph} = n \,.\, S_v = n \,.\, Z \,.\, S_z \qquad (1.2)$$

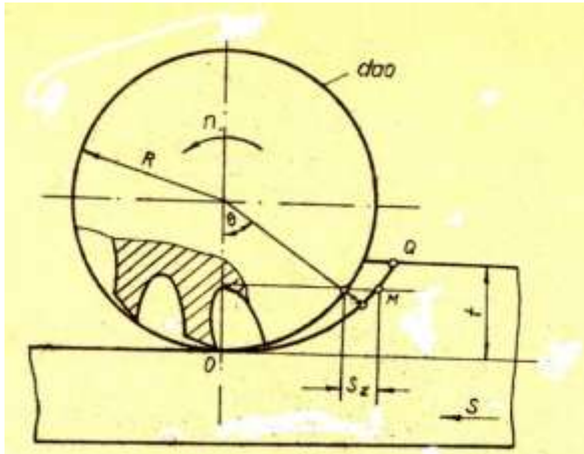

Figure 4. Depth of cut, feed rate during milling.

Cutting speed V: During milling, due to the feed motion of the cutter, the relative cutting trajectory of a point on the cutting edge with respect to the workpiece is an elongated cycloid curve. The cutting speed is determined by the equation:

$$\vec{V}_C = \vec{V}_n + \vec{V}_S \quad (1.3)$$

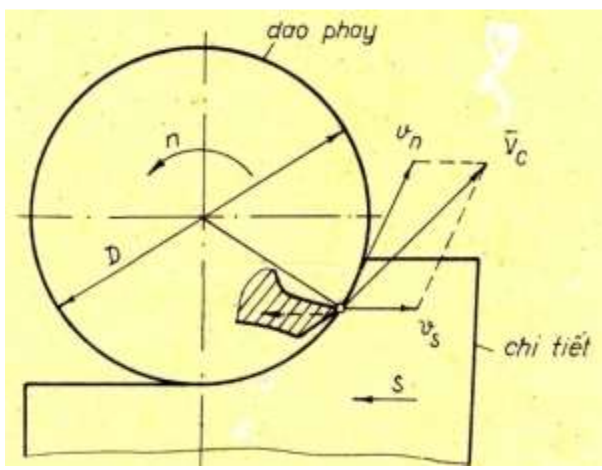

Figure 5. Cutting speed during milling.

In practice, the feed rate of the cutter has a very small value compared to the main cutting speed.

Usually Vs = (0.5 ÷ 1%) Vn. Therefore, when calculating the cutting mode, VS is often ignored. That is, approximately, the relative cutting motion trajectory during milling is considered a circle. Therefore, the cutting speed is calculated as: (m/min) (1.4) Where: D - diameter of the milling cutter, mm. n - number of revolutions of the cutter in one minute, rev/min.

Milling Depth t: This is the size of the metal layer cut, measured perpendicular to the cutter axis, corresponding to the contact angle ψ.

When milling with straight-toothed cylindrical milling cutters, helical milling cutters, disc milling cutters, profile milling cutters, or angle milling cutters, the milling depth t coincides with the cutting depth.

When milling grooves with end milling cutters, the milling depth equals the cutter diameter. When milling perpendicular surfaces, the milling depth t equals the cutting depth.

When milling asymmetrical surfaces with face milling cutters, the milling depth is measured corresponding to the contact angle ψ, while for asymmetrical milling, the milling depth equals the workpiece width.

Milling Width B: The milling width is the size of the metal layer cut, measured along the axial direction of the cutter. When milling with a cylindrical milling cutter, the milling width is equal to the workpiece width. When milling grooves with a disc milling cutter, the milling width is equal to the groove width. When milling grooves with an end milling cutter, the milling width is equal to the groove depth. When milling flat surfaces with a face milling cutter, the milling width is equal to the cutting depth.

Contact Angle ψ This is the angle at the center of the cutter intercepted by the contact arc between the cutter and the workpiece. When milling with cylindrical milling cutters, end milling cutters, disc milling cutters, and profile milling cutters, the contact angle is calculated using the formula:

$$\cos\psi = 1 - \frac{2t}{D}, \quad \sin\frac{\psi}{2} = \sqrt{\frac{t}{D}}$$

$$\sin\frac{\psi}{2} = \frac{t}{D}$$

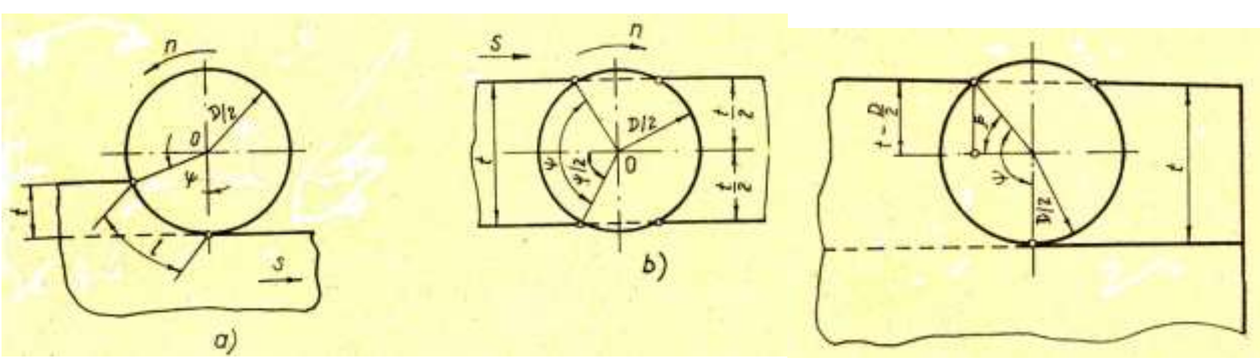

Figure 6. Contact angle during milling

a) Using a cylindrical milling cutter. b and c) Symmetrical and asymmetrical milling using a face milling cutter.

$$\psi = \frac{\pi}{2} + \arcsin\left(\frac{2t}{D} - 1\right)$$

Cutting thickness a: The cutting thickness in milling is the distance between two consecutive positions of the relative cutting motion trajectory of a point on the cutting edge, measured perpendicular to the main cutting edge, corresponding to the tooth feed rate Sz. Since the relative cutting motion trajectory is considered approximately a circle, the cutting thickness in milling is measured in the radial direction of the cutter.

3. RESULTS

Cutting thickness when milling with straight-toothed and helical-toothed cylindrical milling cutters.

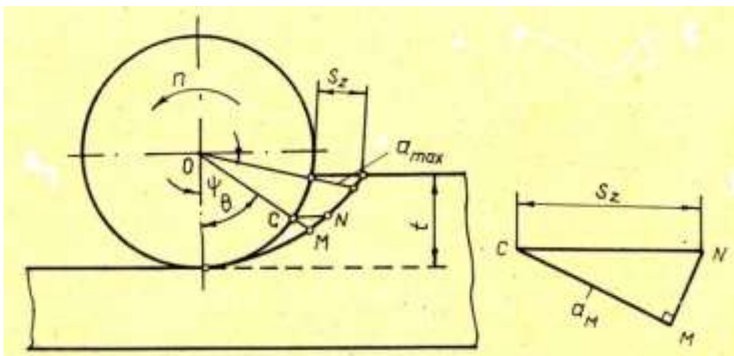

Figure 7. Cutting thickness when milling with a cylindrical milling cutter.

In Figure 7, the thickness of the cut at point M is represented by the segment MC. Approximately, the arc MN can be considered a straight-line segment. Then, triangle CMN will be right-angled at M.

$a_M = S_z.\sin\theta$.

$\theta = 0^o$; $a_{min} = 0$.

$\theta = \psi$; $a_{max} = S_Z.\sin\psi$

The shear thicknesses a is a function of the angle θ, θ varies from 0 to ψ. Therefore:

$$a_{tb} = \frac{1}{\psi}\int_0^{\psi} S_Z.\sin\theta.d\theta$$

$$\cos\psi = 1 - \frac{2t}{D}$$

$$a_{tb} = \frac{2.S_Z.t}{D.\psi}$$

Cutting thickness when milling with a face milling cutter:

When the machine table moves by an amount SZ, the trajectory of the cutting edge will change from position 1 to position 2. The cutter will cut a layer of metal with a thickness aM that changes depending on the position of point M, i.e., depending on the value of angle θ. Approximately, consider ΔDMN as a right triangle at M.

$a_M = MD . \sin\varphi$; $MD = ND . \cos\theta = S_z . \cos\theta$; $a_M = S_Z \sin \varphi \cos \theta$

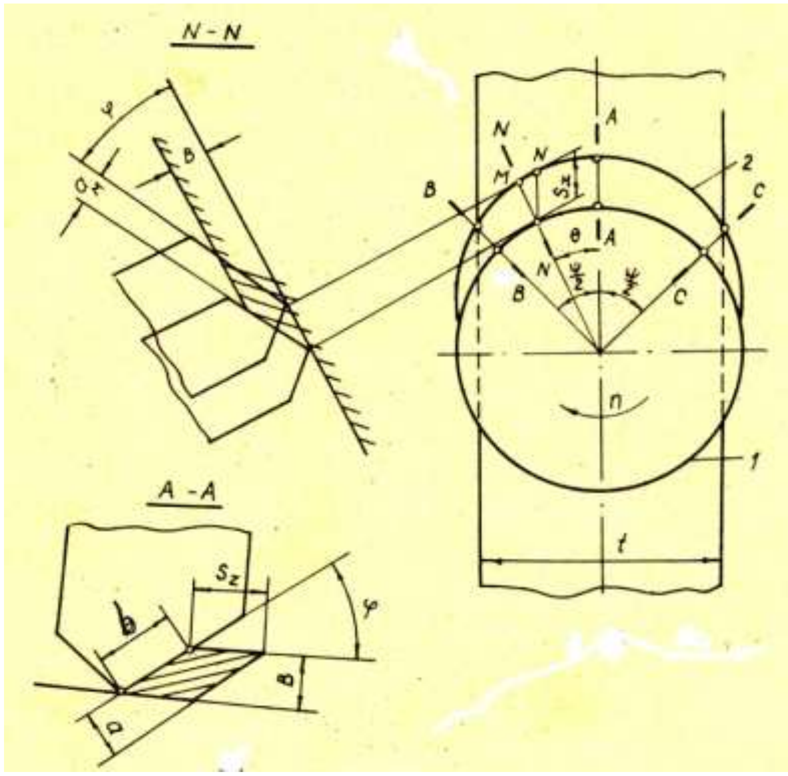

Figure 8. Cutting thickness when milling with a face milling cutter.

In Figure 8, the angle θ = 0 is conventionally defined at cross-section AA. The left side of cross-section AA corresponds to a positive θ value, and the right side corresponds to a negative θ value. With the cutter's rotation direction as shown in the figure, each cutter tooth successively participates in cutting at cross-section BB, corresponding to θ = ψ/2. Then, as the cutting-edge moves, the angle θ gradually decreases to θ = 0 at cross-section AA and then gradually increases again to ψ/2 as the cutter tooth exits the contact area with the workpiece at CC.

4. DISCUSSION

a) When milling with a straight-toothed cylindrical milling cutter:

The cutting area cut by a certain i-th tooth is calculated by:

$f_i = a_i . b_i$; because: $b_i = B$ and $a_i = S_z.\sin\theta_i$. Therefore: $f_i = S_z.B.\sin\theta_i$

The total cutting area due to n teeth simultaneously participating in cutting is calculated by:

The average cutting area is calculated by:

$$F = S_Z .B.\sum_{i=1}^{n} \sin \theta_i$$

And b = B and:

$$a_{tb} = \frac{2.S_Z.t}{D.\psi} \quad F_{tb} = \frac{B.t.S_Z.Z}{\pi.D}$$

ACKNOWLEDGMENTS

From the formulas for calculating the cutting area during milling, we see that the cutting area always changes during milling and depends on the angle θi. Straight-toothed cylindrical milling cutters have a cutting area that changes more during cutting than helical-toothed cylindrical milling cutters. The change in the cutting area changes the cutting force and causes vibrations during cutting, negatively affecting the surface quality, tool life, and reducing machining productivity.

To improve the surface quality of the machined part, it is desired that the cutting area does not change during milling. A milling process where the cutting area does not change is called balanced milling. From the formulas for calculating the cutting area during milling, it can be seen that balanced milling can only occur with helical-toothed cylindrical milling cutters.

REFERENCES

[1]. Petre, I.M.; Găvruş, C. Influence of the Cutting Force upon Machining Process Efficiency. *Mater. Today Proc.* **2023**, *72*, 586–593.

[2]. Hernández-González, L.W.; Curra-Sosa, D.A.; Pérez-Rodríguez, R.; Zambrano-Robledo, P.D. Modeling Cutting Forces in High-Speed Turning Using Artificial Neural Networks. *TecnoLógicas* **2021**, *24*, 43–61.

[3]. Chatterjee, K.; Zhang, J.; Dixit, U.S. Data-driven Framework for the Prediction of Cutting Force in Turning. *IET Collab. Intell. Manuf.* **2020**, *2*, 87–95.

[4]. Velchev, S.; Kolev, I.; Ivanov, K.; Gechevski, S. Empirical Models for Specific Energy Consumption and Optimization of Cutting Parameters for Minimizing Energy Consumption during Turning. *J. Clean. Prod.* **2014**, *80*, 139–149.

[5]. Stephenson, D.A.; Agapiou, J.S. *Metal Cutting Theory and Practice*; CRC Press: Boca Raton, FL, USA, 2018; ISBN 1-315-37311-4.

[6]. Venkatesan, K.; Manivannan, K.; Devendiran, S.; Mathew, A.T.; Ghazaly, N.M.; Benny, S.N. Study of Forces, Surface Finish and Chip Morphology on Machining of Inconel 825. *Procedia Manuf.* **2019**, *30*, 611–618.

[7]. Wyeth, D.J.; Goli, G.; Atkins, A.G. Fracture Toughness, Chip Types and the Mechanics of Cutting Wood. A Review COST Action E35 2004–2008: Wood Machining–Micromechanics and Fracture. *Holzforschung* **2009**, *63*, 2.

[8]. Guo, X.; Li, R.; Cao, P.; Ekevad, M.; Cristóvão, L.; Marklund, B.; Grönlund, A. Effect of Average Chip Thickness and Cutting Speed on Cutting Forces and Surface Roughness during Peripheral up Milling of Wood Flour/Polyvinyl Chloride Composite. *Wood Res* **2015**, *60*, 147–156.

[9]. Marchal, R.; Mothe, F.; Denaud, L.-E.; Thibaut, B.; Bleron, L. Cutting Forces in Wood Machining–Basics and Applications in Industrial Processes. A Review COST Action E35 2004–2008: Wood Machining–Micromechanics and Fracture. *Holzforschung* **2009**, *63*, 2.

[10]. Franz, N.C. *An Analysis of Chip Formation in Wood Machining*; University of Michigan: Ann Arbor, MI, USA, 1958.