B-002
Regarding Procedure to Mill a V-Groove

Vincent W. Finley*

July 2025
Rev C

Abstract: Cutting a long v-groove in a part is a frequent operation in machining. This article presents a procedure to mill a v-groove by locating the desired groove center on the part work surface.

1 Problem

Given:

- An object with a planar (flat) surface mounted 45° to the horizontal,
- *and* a right-hand coordinate system drawn from some arbitrary starting location on the object's surface plane, with +x axis to the left, +y axis into the page, and +z axis downward,
- *and* a right triangle with angles θ, and sides a, b of equal length L and a hypotenuse c,
- *and* a hypotenuse midpoint that coincides with the coordinate system origin,
- *and* a distance d from the origin to the vertex of the right angle $\angle ab$,
- *and* a milling cutter tool (endmill) with diameter D whose bottom-left corner is at the coordinate origin.

Find:

- The distance t_x along the x-axis, and t_z along the z-axis, the milling tool must travel to remove a v-groove in the planar surface for some arbitrary value of c.
- The distance t_x along the x-axis, and t_z along the z-axis, the milling tool must travel to remove a v-groove in the planar surface for some arbitrary distance d.

2 Solution

The right triangle shown in Figure 1 has equal sides a and b of some length L

$$a = b = L \tag{1}$$

Since lengths of a and b are equal, $\triangle abc$ is an isosceles triangle. Furthermore, angles θ will be:

$$\theta = \frac{180^\circ - 90^\circ}{2} = 45^\circ \tag{2}$$

* ©2025: Bear, DE, USA: CC BY 4.0 license
https://creativecommons.org/licenses/by/4.0/legalcode

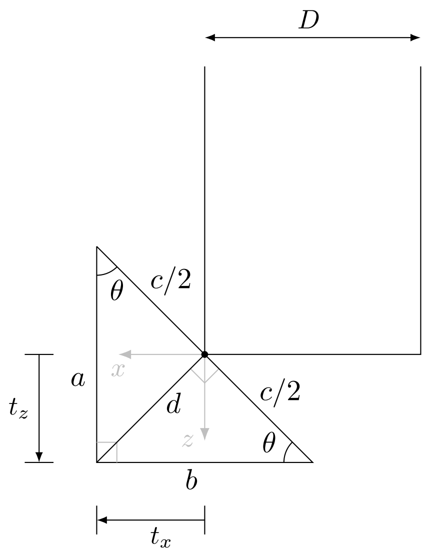

Figure 1: Initial relationship of work object and milling tool. (Note: c is ENTIRE hypotenuse!)

For a right triangle, side c (the ENTIRE hypotenuse!) is related to a and b by the Pythagorean theorem. By substituting $L = a = b$ from equation 1 into the theorem, L is found to be.

$$\begin{aligned} c^2 &= a^2 + b^2 \\ c^2 &= L^2 + L^2 \\ c^2 &= 2L^2 \\ \sqrt{c^2} &= \sqrt{2L^2} \\ c &= L\sqrt{2} \\ L &= \frac{c}{\sqrt{2}} \end{aligned} \tag{3}$$

A second smaller right isosceles triangle is formed by d and $c/2$, with hypotenuse b. Since d bisects c, the length of d will be equal to half of c.

$$\begin{aligned} d &= \frac{c}{2} \\ c &= 2d \end{aligned} \tag{4}$$

Substituting c from equation 4 into equation 3 yields:

$$\begin{aligned} L &= \frac{c}{\sqrt{2}} \\ L &= \frac{2d}{\sqrt{2}} \\ L &= \frac{d(\sqrt{2})^2}{\sqrt{2}} \\ L &= d\sqrt{2} \end{aligned} \tag{5}$$

Since the midpoint of hypotenuse c is at the origin, the starting position on the x-axis will be the midpoint of b. Therefore, the travel distance t_x will be half the length of b. Substituting $b = L$ from equation 1, it is found.

$$\begin{aligned} t_x &= \frac{b}{2} \\ t_x &= \frac{L}{2} \end{aligned} \tag{6}$$

Likewise, the midpoint of hypotenuse c is at the origin, so the starting position on the z-axis will be the midpoint of a. Therefore, the travel distance t_z will be half the length of a: Substituting $a = L$ from equation 1, it is found.

$$\begin{aligned} t_z &= \frac{a}{2} \\ t_z &= \frac{L}{2} \end{aligned} \tag{7}$$

From equations 6 and 7 it can be seen that t_x and t_z are equal to $L/2$, and are therefore equal to each other. We can write:

$$t_x = t_z = \frac{L}{2} \tag{8}$$

$$t_x = t_z = \left(\frac{1}{2}\right) L$$

$$\boxed{t_x = t_z = 0.5 \cdot L} \tag{9}$$

Substituting L from equation 3 into equation

8 yields:

$$t_x = t_z = \frac{L}{2}$$
$$t_x = t_z = \frac{\frac{c}{\sqrt{2}}}{2}$$
$$t_x = t_z = \frac{c}{2\sqrt{2}}$$
$$t_x = t_z = \left(\frac{1}{2\sqrt{2}}\right) c$$

$$\boxed{t_x = t_z = 0.353553 \cdot c} \tag{10}$$

Furthermore, substituting L from equation 5 into equation 8 yields:

$$t_x = t_z = \frac{L}{2}$$
$$t_x = t_z = \frac{d\sqrt{2}}{2}$$
$$t_x = t_z = \left(\frac{\sqrt{2}}{2}\right) d$$

$$\boxed{t_x = t_z = 0.707107 \cdot d} \tag{11}$$

Symmetry of the initial setup can be used to create a symmetrical v-grove in the work by passing the rotating cutter tool along the y-axis.

After each pass, the tool should be stepped slightly leftward until the tool has traveled a distance t_x along the y-axis. Then the tool should be advanced downward after each pass, along the z-axis, until distance t_z has been traveled. Thus the groove is formed.

The machinist should be advised that the diameter D of the cutting tool is relatively unimportant. However if $D \leq 2 \cdot t_x$ then some leftover material may need to be cleaned up before the start point.

3 Procedure

To begin, review Figure 1 and design the v-groove by assigning a length for either $a = b = L$, c or d. This will be the single input variable that will be used to calculate t_x and t_z. You should examine your personal project blueprints to help you choose the input variable and its length.

Input Variable	Use Equation #
$a = b = L$	9
c	10
d	11

Table 1: Input variables and equations

Now do the following:

1. Choose your single input variable and its length.

2. Label Figure 1 with values for D and your selected input variable (remember c spans ENTIRE hypotenuse!)

3. From Table 1 above, find the equation corresponding to the input variable.

4. Substitute the length value of the input variable into the corresponding equation.

5. Use the corresponding equation to calculate t_x and t_z.

6. Record the values of the input variable and calculated values for t_x and t_z onto Figure 1.

7. Locate and scribe the place on surface of the work where the v-grove will be centered.

8. Mount the work at a 45° angle in a vise in the milling machine, with the scribed line parallel to the y-axis.

9. Mount the cutting tool in the milling machine spindle.

10. Position the milling machine table so that the scribed line touches the bottom-left corner of the cutting tool.

11. Zero out any Digital Readouts or dial indicators.

12. Turn on the milling machine, make an initial pass along the y-axis.

13. On subsequent passes, advance the cutter leftward in the x-axis until it has traveled a maximum of t_x to the left.

14. Advance the cutter downward along z-axis until it has sunk a maximum of t_z.

15. If the diameter of the cutter is $D \leq 2 \cdot t_x$, make additional passes to remove missed material before the start point.

4 Example

Given:

- A piece of flat steel bar stock.
- An endmill (cutting tool) whose diameter $D = 0.5\,inches$

Find: Procedure to mill out a v-groove whose groove "opening" is $c = 0.75\,inches$.

Basic Steps:

1. The value of $D = 0.5$ and the input variable is $c = 0.75$, label Figure 1 with the values of D and c (remember c spans the ENTIRE hypotenuse!).

2. From Table 1 find the corresponding equation for input variable c (it is equation #10).

3. Input $c = 0.75\,inches$ into equation #10.

4. Calculate:

$$t_x = t_z = 0.353553 \cdot 0.75\,inches$$
$$t_x = t_z = 0.2652\,inches$$

5. Label Figure 1 with:

$$t_x = t_z = 0.2652\,inches$$

6. Scribe a line on surface of the work where the v-grove will be centered.

7. Mount the work at a 45° angle in a vise, with the scribed line parallel to the y-axis.

8. Position the work so that the scribed line touches the bottom-left corner of endmill.

9. Zero out and Digital Readouts or dial indicators.

10. Turn on the milling machine, make an initial pass along the y-axis.

11. On subsequent passes, advance the cutter leftward along the x-axis until it has traveled a maximum of $t_x = 0.2652\,inches$ to the left.

12. Advance the depth of cutter downward along the z-axis until it has sunk a maximum of $t_x = 0.2652\,inches$.

13. Since:

$$D \leq 2 \cdot t_x$$
$$D \leq 2 \cdot 0.2652$$
$$D \leq 0.5303$$

Additional cleanup cuts will be needed to removed missed material before the start point.