

# B-002

## Regarding Procedure to Mill a V-Groove

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Rev B

**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  $45^\circ$  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  $\theta$ , 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  $L$

$$a = b = L \quad (1)$$

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

$$\theta = \frac{180^\circ - 90^\circ}{2} = 45^\circ \quad (2)$$

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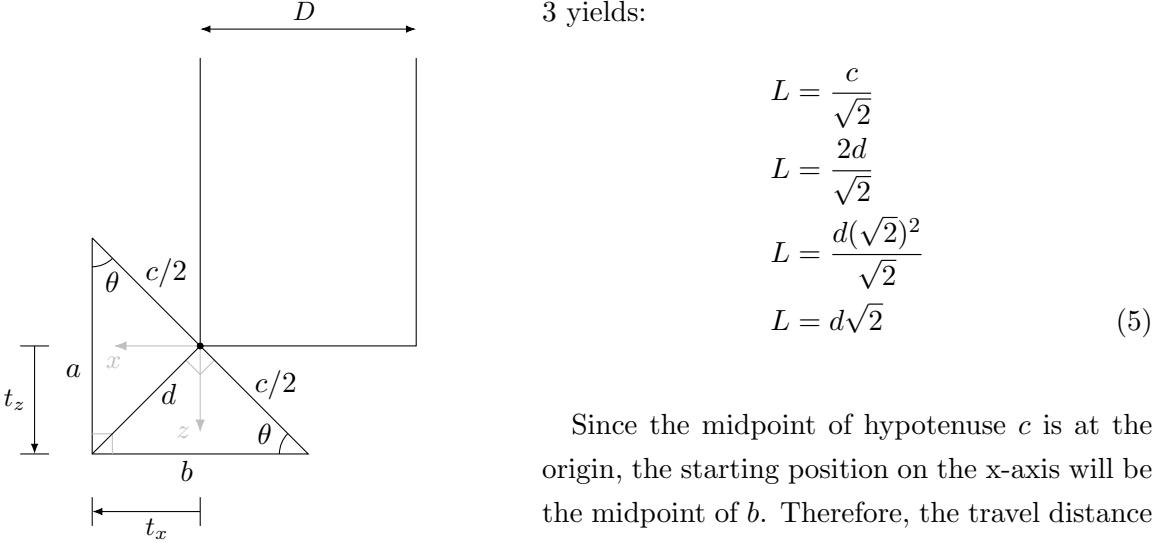


Figure 1: Initial relationship of work object and milling tool. (Note:  $c$  is ENTIRE hypotenuse!)

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.

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

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  $c$ .

$$\begin{aligned} d &= \frac{c}{2} \\ c &= 2d \end{aligned} \quad (4)$$

Substituting  $c$  from equation 4 into equation

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.

$$\begin{aligned} t_x &= \frac{b}{2} \\ t_x &= \frac{L}{2} \end{aligned} \quad (6)$$

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.

$$\begin{aligned} t_z &= \frac{a}{2} \\ t_z &= \frac{L}{2} \end{aligned} \quad (7)$$

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:

$$\begin{aligned} t_x &= t_z = \frac{L}{2} \quad (8) \\ t_x &= t_z = \left(\frac{1}{2}\right) L \\ \boxed{t_x = t_z = 0.5 \cdot L} \quad (9) \end{aligned}$$

Substituting  $L$  from equation 3 into equation

8 yields:

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

$t_x = t_z = 0.353553 \cdot c$

(10)

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

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

$t_x = t_z = 0.707107 \cdot d$

(11)

Symmetry of the initial setup can be used to create a symmetrical v-groove 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-groove will be centered.
8. Mount the work at a  $45^\circ$  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  $D = 0.75 \text{ inches}$

Find: Procedure to mill out a v-groove whose groove “opening” is  $c = 0.825 \text{ inches}$ .

Basic Steps:

1. The value of  $D = 0.75$  and the input variable is  $c = 0.825$ , 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  $c = 0.825 \text{ inches}$  into equation #10.

4. Calculate:

$$t_x = t_z = 0.353553 \cdot 0.825 \text{ inches}$$

$$t_x = t_z = 0.2917 \text{ inches}$$

5. Label Figure 1 with:

$$t_x = t_z = 0.2917 \text{ inches}$$

6. Scribe a line on surface of the work where the v-grove will be centered.
7. Mount the work at a  $45^\circ$  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  $t_x = 0.2917 \text{ inches}$  to the left.
12. Advance the depth of cutter downward along the z-axis until it has sunk a maximum of  $t_x = 0.2917 \text{ inches}$ .
13. Since:

$$D \geq 2 \cdot t_x$$

$$D \geq 2 \cdot 0.2917$$

$$D \geq 0.5834$$

No additional cleanup cuts are needed to removed missed material before the start point.