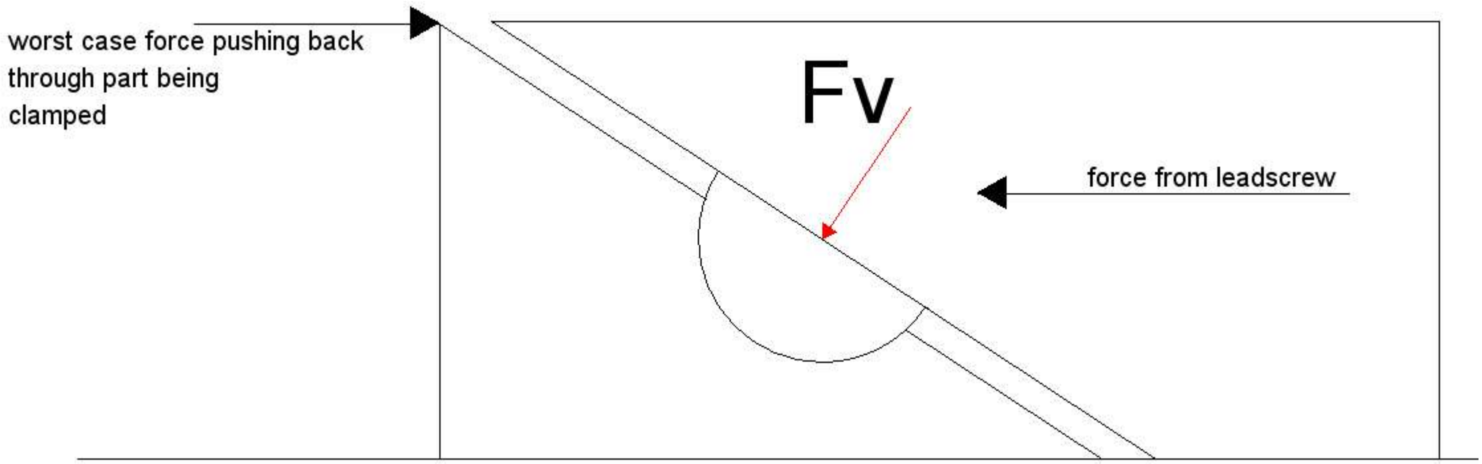
How a Lock-down Vise Works, and Doesn't

By R. G. Sparber

In theory, a lock-down vise clamps and forces the part down on the vise ways with a single turn of the vise handle. Ever thought about how this works? I did as I was trying to duplicate the function. Along the way I learned how these vises also don't work (perfectly) and why the fix works.

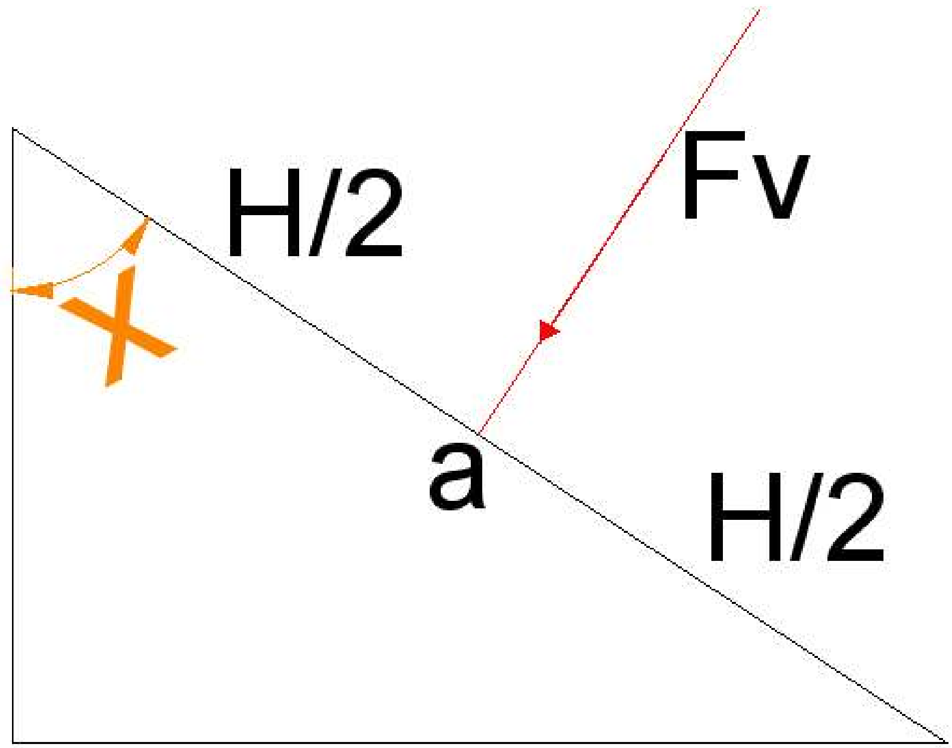


The key elements of a lock-down vise are a sliding block, call it the pusher block, driven by a leadscrew, a sloped face on this sliding block, a pivot point, and a second block with the opposite slope which actually does the clamping. Call this second block the movable jaw.

The movable jaw has a right triangle cross section. The worst place for a clamping force to be applied is at the very top. This will have the maximum tendency to rotate the movable jaw. If this jaw rotates, the part will rise up which causes error.

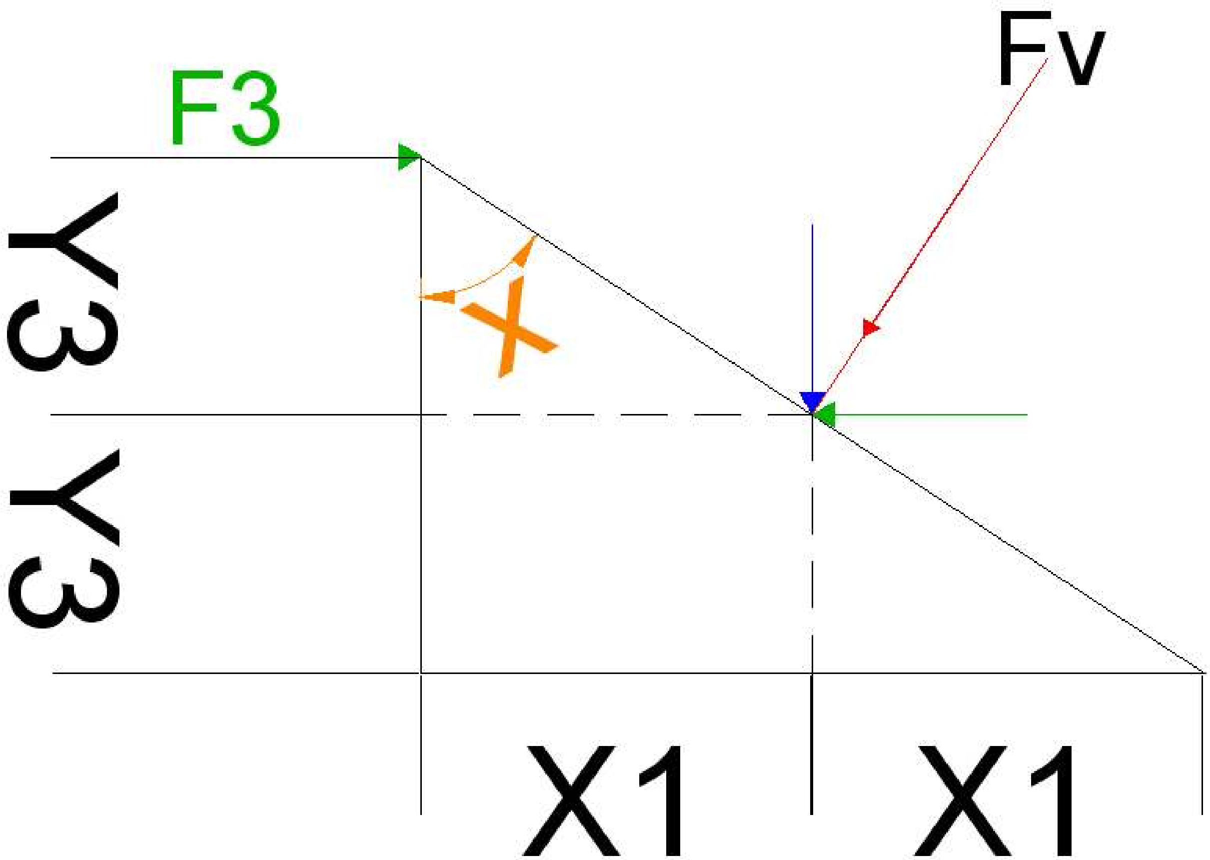
Although the force from the leadscrew is horizontal, the sloped face on the pusher block causes a force, F_v, to be applied as shown. The pivot is free to turn so its flat is always in contact with the sloped surface.

For the lock-down to work, the movable jaw must always stay down flat. So, how does that happen?



Let me assume that I have placed my pivot point such that, F_v, is applied at point "a" which is at the halfway point of the sloped surface of our triangle block. This means that half of the length of our hypotenuse is above it and half is below it.

I will also assume that I know an angle, "x". Note that if x=0°, my slope would be vertical. If x=90°, the slope would be horizontal.



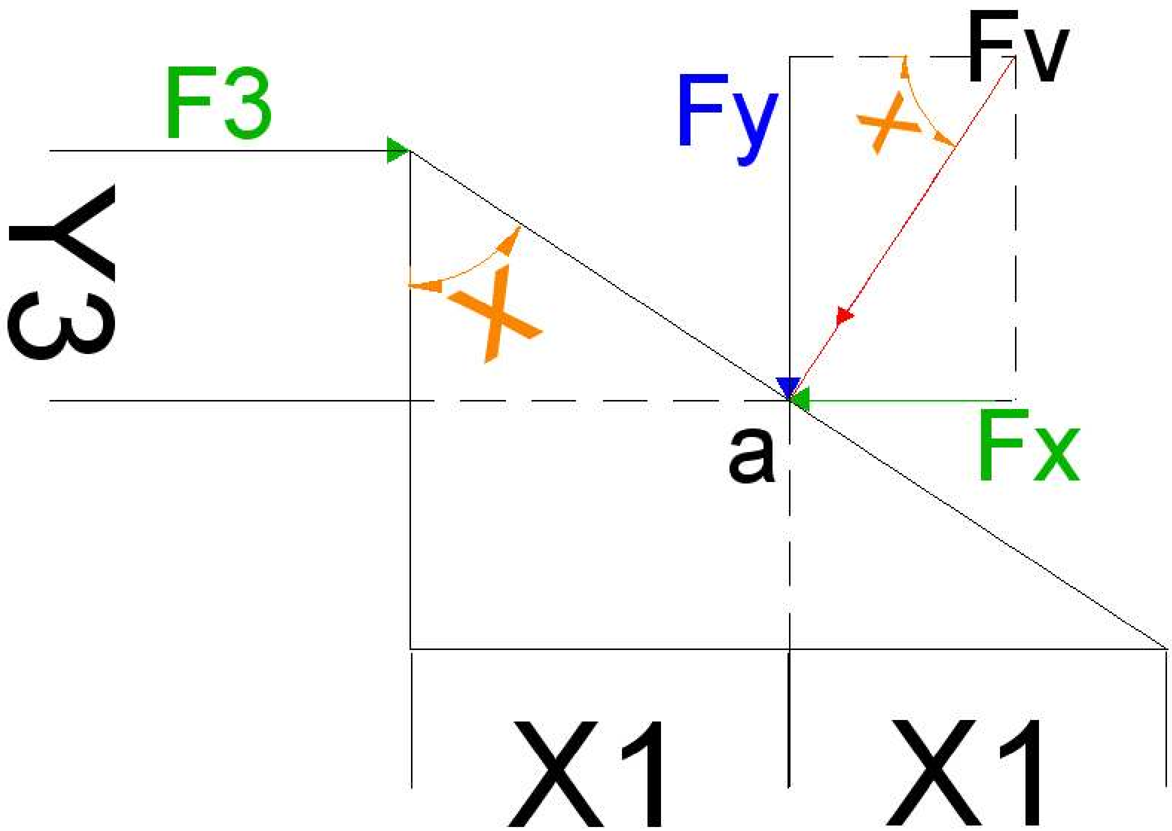
Since point “a” is at my half way point on the hypotenuse, I can also say that this is at the half way point both vertically and horizontally. In other words, I can define a distance X1 and Y3 as shown.

Note that

$$\tan x = \frac{x1}{y3}$$

or we can say

$$Y_3 = \frac{X_1}{\tan x} \quad \text{(equation 1).}$$



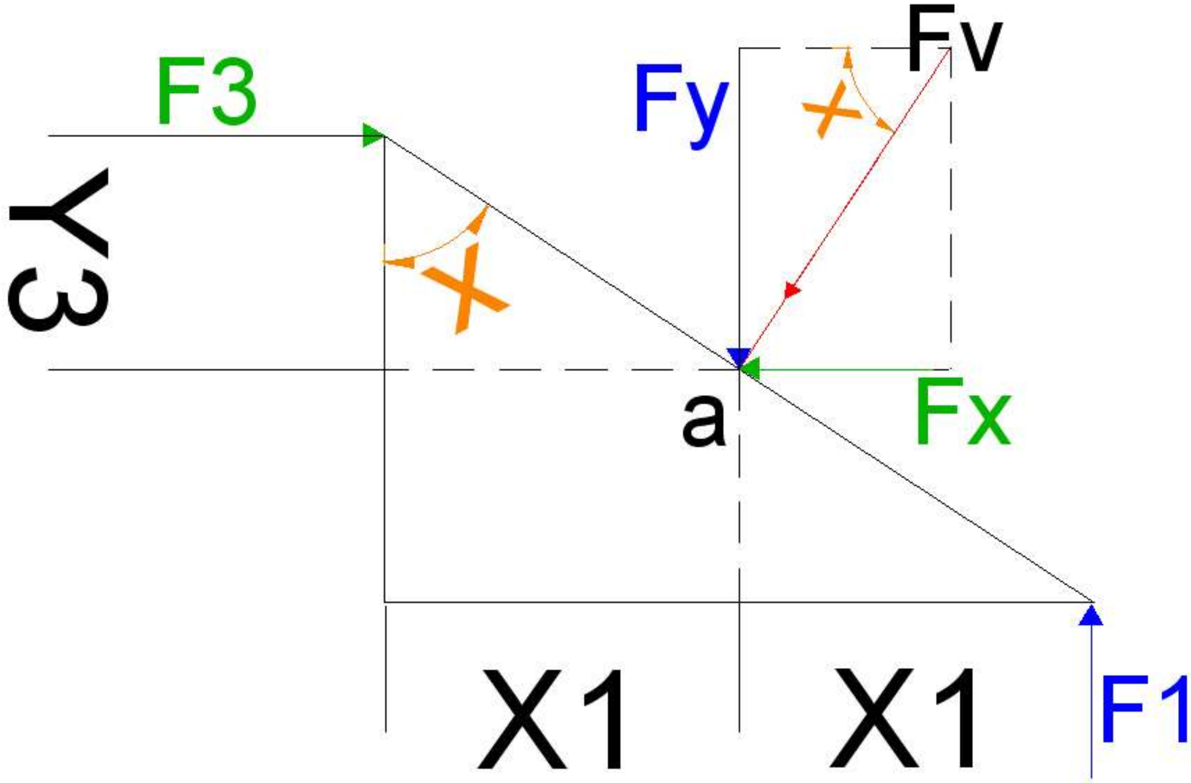
My force, F_v, can be represented by two forces, F_x and F_y because we know the angle, x.

Then I know that

$$\tan x = \frac{Fy}{Fx}$$

or I can say

$$F_y = F_x \tan x \quad \text{(equation 2).}$$



Now comes a series of critical observations that may not be intuitively obvious.

We are trying to determine what it takes to cause the movable jaw to rotate clockwise. It turns out that we are free to define any point as the center of our rotation as long as the movable jaw does not actually turn. So we will pick point "a". We will then sum the torque at this point. Note that Fx and Fy pass through point "a" so their force times distance will be zero.

We do have a clockwise torque equal to F3 times Y3 that will tend to lift up the movable jaw.

Countering this clockwise torque we have a counterclockwise torque. To see it, we must assume that the movable jaw is just about to lift up. This means that the bottom of the movable jaw is barely in contact with the vise ways except at right most end. This means that I must have an upward force, F1, at this tiny contact point. We then get a counterclockwise torque equal to F1 times X1.

In order to insure that the movable jaw does stay down on the ways, we must have

$$(X_1 \; x \; F_1) > (Y_3 \; x \; F_3) \quad \text{(equation 3).}$$

As we look at the horizontal forces, we see F3 pushing to the right and Fx pushing to the left. Since the movable jaw is not moving, these two forces must be equal. We can therefore write

$$F_3 = F_x \quad \text{(equation 4).}$$

There is one more critical observation. Since the movable jaw is just about to lift up, we know that the total upward force is F1. Looking at the above figure we see that the only downward force is Fy. So these forces must be equal and we can say

$$F_1 = F_y \quad \text{(equation 5).}$$

We now have all of the pieces to solve the puzzle.

$$Y_3 = \frac{X_1}{\tan X} \quad \text{(equation 1)}$$

$$F_y = F_x \tan X \quad \text{(equation 2)}$$

$$(X_1 \; x \; F_1) > (Y_3 \; x \; F_3) \quad \text{(equation 3)}$$

$$F_3 = F_x \quad \text{(equation 4).}$$

$$F_1 = F_y \quad \text{(equation 5).}$$

First we put equation 1 into equation 3 and get

$$(X_1 \; x \; F_1) > \left(\frac{X_1}{\tan X} \; x \; F_3\right).$$

Then we toss in equation 5 and get

$$\left(X_1 \; x \; F_y\right) > \left(\frac{X_1}{\tan X} \; x \; F_3\right).$$

Next we use equation 4

$$\left(X_1 \; x \; F_y\right) > \left(\frac{X_1}{\tan X} \; x \; F_x\right).$$

Equation 2 ($F_y = F_x \tan X$) comes next and we get

$$(X_1 \ x \ F_x \tan X) \ ) > ((\frac{X_1}{\tan X}) \ x \ F_x).$$

We can now divide both sides by X_1 and also divide by F_x which leaves us with

$$(\tan X \ ) > (\frac{1}{\tan X}).$$

Multiplying both sides by tan x gives us

$$(\tan x)^2 > 1$$

And lastly, we take the square root of both sides and get

$$\tan x > 1.$$

The values of x that give us a tangent greater than 1 are those greater than 45°. We can increase this angle up to 90° at which point our movable jaw has been squished down flat.

Let's play with a few values for this angle and see what it gives us. We have

$$F_y = F_x \tan X \quad \text{(equation 2)}$$

Where F_x is our horizontal force applied to the movable jaw and F_y is our downward force trying to keep the movable jaw in contact with the vise ways.

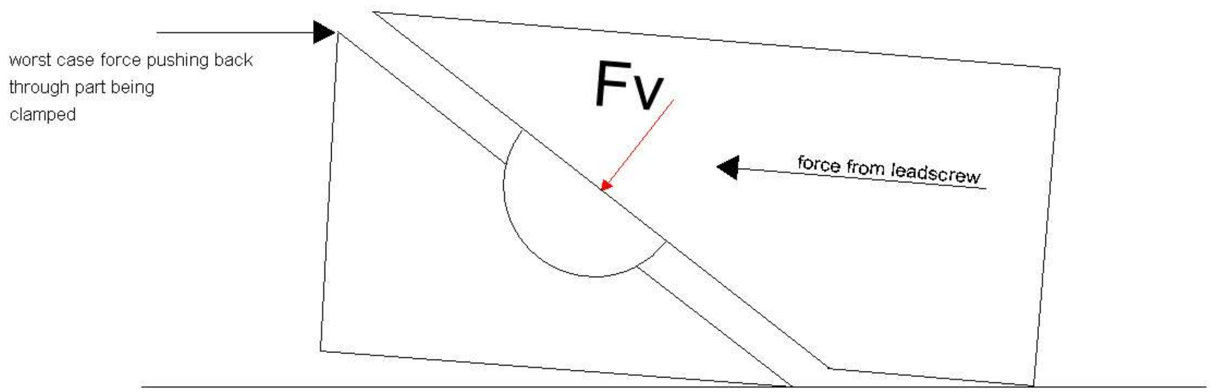
At 45°, our downward force equals our horizontal force. If you figured the clockwise and counterclockwise torques you would see that they were just balance. This doesn't give any margin for keeping the movable jaw seated.

At 50° we have tan 50° = 1.19. So our downward force is 1.19 times the horizontal force. That sure helps.

At 60°, which is what a Kurt® vise is supposed to have, we get a factor of 1.73. So for every pound of horizontal force we get 1.73 pounds of downward force.

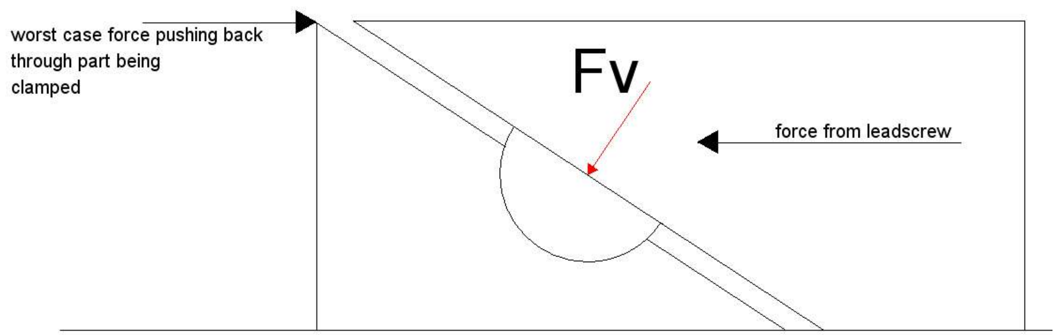
One subtle point exists here. The horizontal force experienced by the part being clamped is not equal to the force applied by the leadscrew. This should sort of make sense since we took the leadscrew force and split it so some pushed down while the rest pushed horizontally. With all of that downward force, you can see why these vises have massive bases.

So why doesn't this work perfectly? The answer comes from the fact that the pusher block must slide on the vise ways.



This means that as force is applied to the movable jaw, the pusher block will rise up. It will, in fact, pivot on its back corner. With the movable jaw in contact with the pusher block, it too will rise up and pivot on its rear corner. The amount of movement here is a few thousandths of an inch but that is a lot in machining. The fix is to tap the part being clamped back down. But note that it isn't the part that rose up with respect to the movable jaw. It was the movable jaw that rose up with respect to the vise ways.

Once tapped down, we are back to the ideal case of



Acknowledgements
Thanks to Brian Lamb of Valley Metal for helping me understand why a lock-down vise works. Thanks to Professor Tim Frank of South Mountain Community College, Phoenix, AZ, for helping me understand the force diagrams.

I welcome your comments and questions.

Rick Sparber
Rgsparber@aol.com