Measuring Tapers

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Determining the taper of a male shaft or a female socket can be challenging, especially when it must be measured insitu. Sometimes the tapered part can be chucked or mounted between centers in a lathe. Then, a dial indicator and longitudinal DRO (Digital Read Out) can be used to get the taper directly. My task was not so easy. I had a large skid-mounted gas engine with a tapered work shaft attached to the crank as shown in Figure 1. I needed to convert it to a straight keyed shaft by duplicating a female taper in a short length of round bar stock that would slip over the taper.

Now, tapers are designated as the change in diameter per unit length along a shaft. This is twice the value of the trigonometric tangent of the angle between the shaft's sloping side and its axis of rotation. A typical taper might be called out as 3/16 inch per inch or equivalently 1-1/4 inches per foot. Just remember when turning a taper, the angle that the cutting tool's path makes with the lathe's axis of rotation is half the full taper's angle.

Most tapers on commercial machinery are of reasonable value, such as so many sixteenths of an inch per foot. In order to determine my taper, I wrapped and then pasted together a paper pattern around the shaft. The result was a tight fitting conical template as shown in Figure 2.

Figure 1

Figure 2

The paper template was removed from the shaft and flattened by placing it under the weight of a book. Figure 3 shows how I measured the angle between the two edges of the flattened cone. The formula for determining the shaft's taper from the flattened cone angle in degrees is shown in the upper left corner of Figure 3. I measured an angle of 16.7 degrees, The taper was calculated as 0.1864 inch per inch. It is a sure bet that the taper of the engine's shaft is 3/16 inch. per inch = 0.1875.

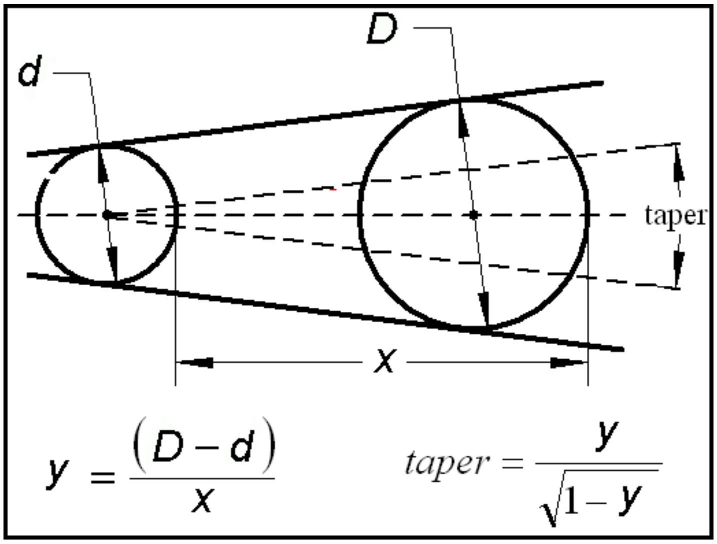
Figure 3

A mating female taper for the engine shaft was on the armature from a close coupled electrical power plant as shown in Figure 4. The two ball method was used to measure this internal taper. Figure 5 shows the measurement of the depth to which a ball penetrated into the tapered hole. Then, a second larger ball's depth was measured and the differences in depth for the two balls was recorded. Make sure the balls are in full contact with the tapered surfaces and not bottomed out in the hole.

Figure 4

Figure 5

Figure 6 shows the equipment needed to measure the ball's depth of penetration into a tapered socket. Drawing 1 illustrates that the taper is calculated from the ratio Y equal to the differences in ball diameter D - d = 0.1565 in. (in my case) to the differences in depth of penetration X = 0.910 in. The calculated taper was 0.1890, nearly the suspected shaft taper of 0.1875.



$$y = \frac{(D-d)}{x} \qquad taper = \frac{y}{\sqrt{1-y}}$$

Drawing 1

Figure 6

Figure 7

Figure 7 shows a taper-to-straight shaft adapter that I made to slip over the engine's shaft. The adapter is secured by a bolt that threads into the end of the engine's shaft (see Figure 1). The female taper was turned at 3/16 inch per inch with the lathe's compound slide. This makes for a full taper angle of about 10 degrees, just right for a self holding taper in steel. The outside of the adapter was turned without rechucking the part. Doing the two operations together insures concentricity of the taper and outer shaft diameter. The keyway was cut with an end mill.

Author's Note: If you're familiar with tin smithing, you'll recognize that the formula shown in Figure 3 relates a cone's angle of revolution to the angular sector of a circle needed to cut out a funnel from a flat sheet of metal. The formula shown in Drawing 1 is just a recasting of the two-disk method for determining a taper as shown in Machinery's Handbook,. There, the separation of the ball centers is used. However, that is not what is measured directly. So, I wrote the formulas in terms of the differences in depth of penetration of the ball's top surfaces into the tapered hole.