

## Helical Gear Design

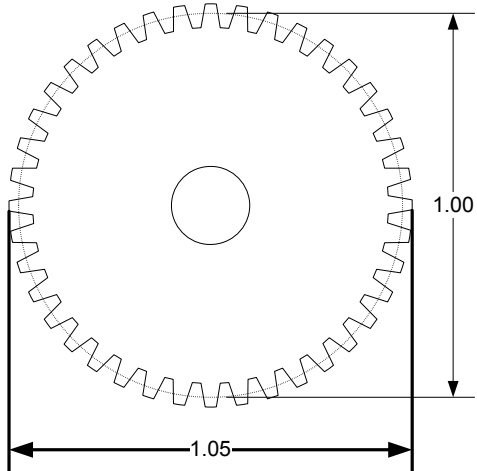
This is a treatise on how I calculate basic dimensions and angles in making helical or skew gears for model engines. I can't assure you that this information is exactly correct, but I the gears that I have made mate and work flawlessly, so I have to think it's pretty much right on.

### Spur Gear Basics

I'll start with just the fundamentals of spur gears since most of the terms are the same for both helical and straight gears. Straight spur gears are, after all, helical gears with a 0 degree helix angle. I won't get in to gear tooth cutter design since I use commerical gear cutters and don't understand enough about tooth shapes to be schooling anyone. You can skip to the next section if you're already pretty familiar with straight spur gears.

**Pitch Diameter** –This is the diameter of a circle, called the pitch circle, as measured a little bit over half way between the tips and valleys of the gear teeth. When calculating the gear dimensions, you first calculate the pitch diameter. From there, you can calculate the outside diameter and finally, the depth of cut for each tooth.

**Diametral Pitch** – This describes the number of teeth in a gear with a 1" pitch diameter.



The circle with the dotted line in the gear to the left describes the pitch circle and its diameter is the pitch diameter, which is 1 inch. Since the gear has 40 teeth, this gear has a DP (diametral pitch) of 40.

The pitch diameter is determined by dividing the number of teeth in the gear you are designing by the diametral pitch. So a 60 tooth gear would be 1.5" ( $60 / 40$ ).  $PD = N / DP$ .

The distance from the Pitch Circle to the tip of the gear tooth is  $1 / \text{Diametral Pitch}$  or  $1 / 40$  in this case. Therefore, the outside diameter of the gear is determined by adding  $2 \times 1 / 40$  to the Pitch Diameter. So, in the example to the left,  $OD = 1 + (2 \times 1 / 40) = 1.050$  inches.

## Helical Gear Calculations

The Pitch Diameter of a helical gear is determined much the same as a spur gear:

$$PD = N / (DP * \cos A)$$

The difference is that the Diametral Pitch must be multiplied by the Cosine of helix angle, as measured from the axis of the gear. As the helix angle increases, the COS decreases so the corresponding Pitch Diameter gets larger. Here is a list of Cosines for angles from 10 degrees to 80 degrees:

$$\cos 10^\circ = 0.985$$

$$\cos 20^\circ = 0.940$$

$$\cos 30^\circ = 0.866$$

$$\cos 40^\circ = 0.766$$

$$\cos 50^\circ = 0.643$$

$$\cos 60^\circ = 0.500$$

$$\cos 70^\circ = 0.342$$

$$\cos 80^\circ = 0.174$$

Using the example from the previous page, a straight spur gear of Diametral Pitch 40 having 40 teeth has a Pitch Diameter of 1 inch. If you change the helix angle to 10 degrees, the Pitch Diameter =  $40 \text{ (teeth)} / (40 \text{ (Diametral Pitch)} * .985 \text{ (Cos } 10^\circ))$ . This yields a Pitch Diameter of 1.015. Changing the helix angle to 40 degrees, the formula becomes  $40 \text{ (teeth)} / (40 \text{ (Diametral Pitch)} * .766)$ . This gives a pitch diameter of 1.305 inches. Here are the formulas with values for each of the helix angles listed above:

$$10^\circ: 40 / (40 \times .985) = 1.015"$$

$$20^\circ: 40 / (40 \times .940) = 1.064"$$

$$30^\circ: 40 / (40 \times .866) = 1.155"$$

$$40^\circ: 40 / (40 \times .766) = 1.305"$$

$$50^\circ: 40 / (40 \times .643) = 1.556"$$

$$60^\circ: 40 / (40 \times .600) = 2.000"$$

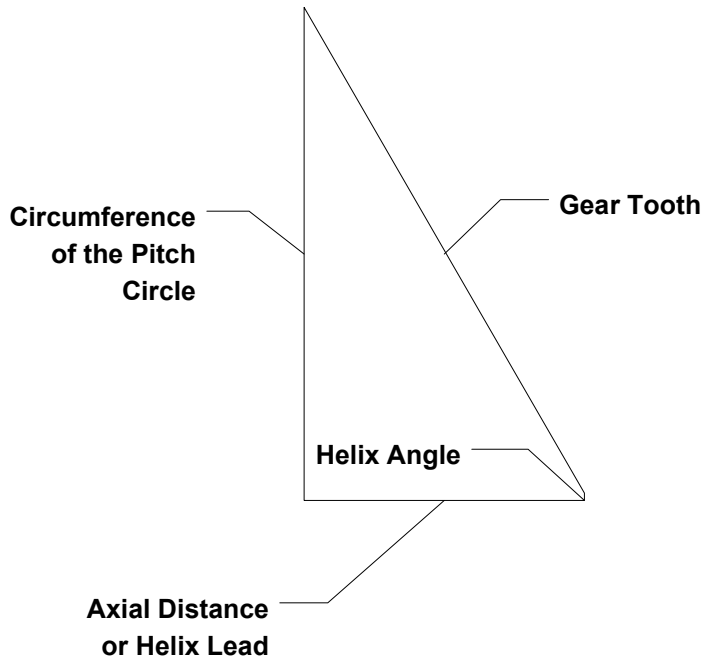
$$70^\circ: 40 / (40 \times .342) = 2.924"$$

$$80^\circ: 40 / (40 \times .174) = 5.759"$$

Each of the above examples yields the Pitch Diameter of the gear. In every case, the outside diameter of the gear (and the gear blank) is determined by adding  $2 \times 1 / 40$  where 40 is the Diametral Pitch of the gear.

## Cutting a Helical Gear

When cutting a helical gear, you need to know the axial distance to move the gear as you are cutting the tooth around the pitch circle. This is easier to understand if you imagine a right triangle which would be formed by unwrapping 1 gear tooth from the helical gear and laying it out flat.



The left leg of the right triangle is the circumference on the Pitch Circle and is found by multiplying the Pitch Diameter by PI which is 3.14. The bottom leg of the triangle is the Helix Lead or the axial offset of the tooth for one full revolution of the gear. This distance can be calculated by dividing the Pitch Circle circumference by the Tangent of the Helix Angle.

Example: DP = 40, Helix Angle = 80 Deg, Number of Teeth = 6

Pitch Diameter =  $6 / (40 * .174) = .862"$

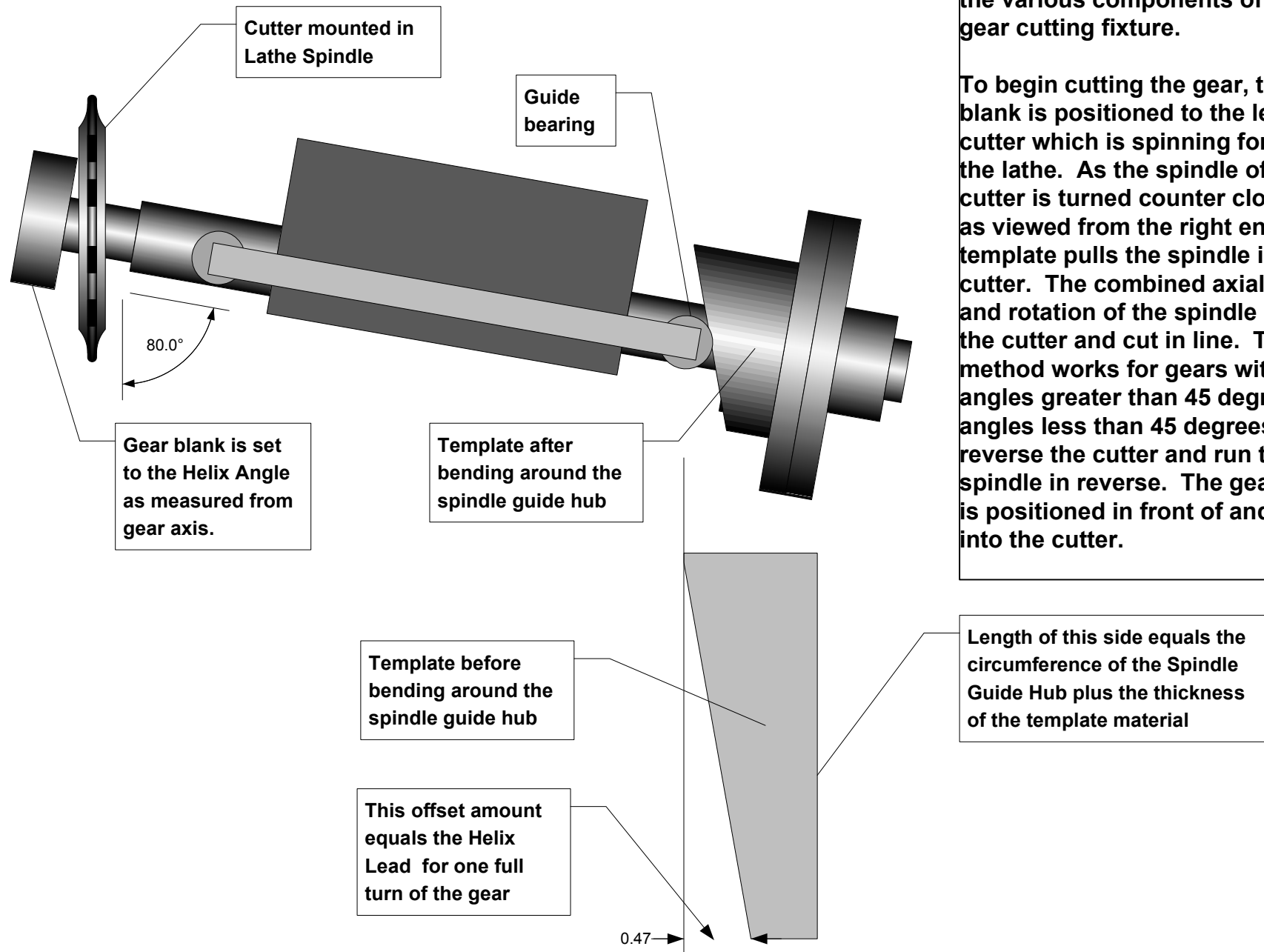
Circumference =  $0.862 * 3.14 = 2.707"$

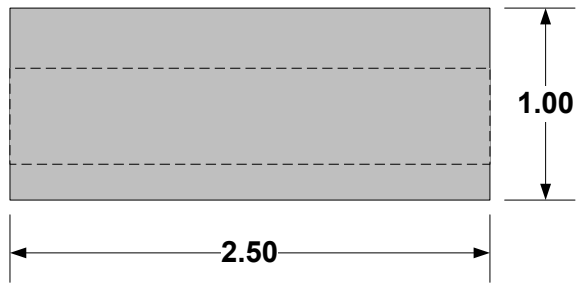
Helix Lead =  $2.707 / 5.671 (\tan 80 \text{ Deg}) = 0.477"$

So, when cutting a tooth, for each full revolution of the gear blank, the cutter must move .477" axially across the face of the gear blank.

This drawing is meant to illustrate the various components of the helix gear cutting fixture.

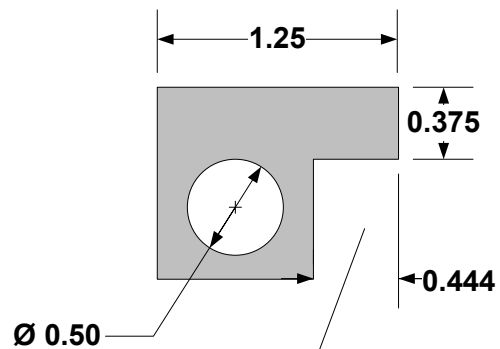
To begin cutting the gear, the gear blank is positioned to the left of the cutter which is spinning forward in the lathe. As the spindle of the gear cutter is turned counter clockwise, as viewed from the right end, the template pulls the spindle into the cutter. The combined axial motion and rotation of the spindle keeps the cutter and cut in line. This method works for gears with helix angles greater than 45 degrees. For angles less than 45 degrees, I reverse the cutter and run the lathe spindle in reverse. The gear blank is positioned in front of and pushed into the cutter.



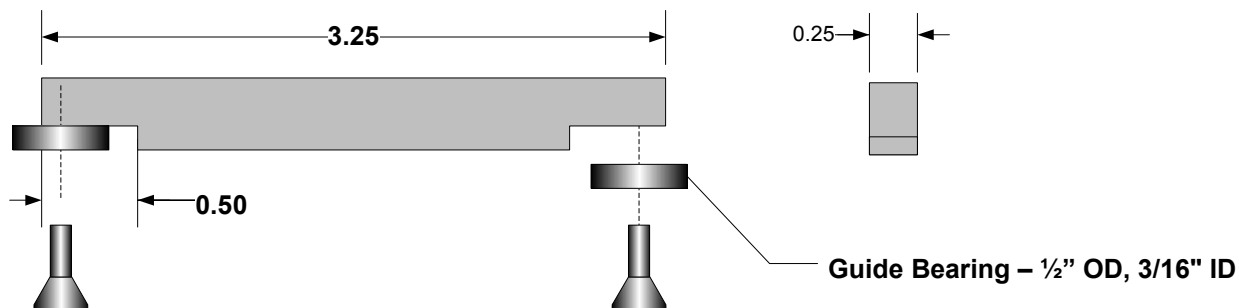


The spindle block is made from a piece of cold rolled steel I had on hand and was made to fit the milling vise on my 11" Logan Lathe. The size isn't critical. The gear blank will be positioned so that the teeth are cut in the top as it moves under the cutter.

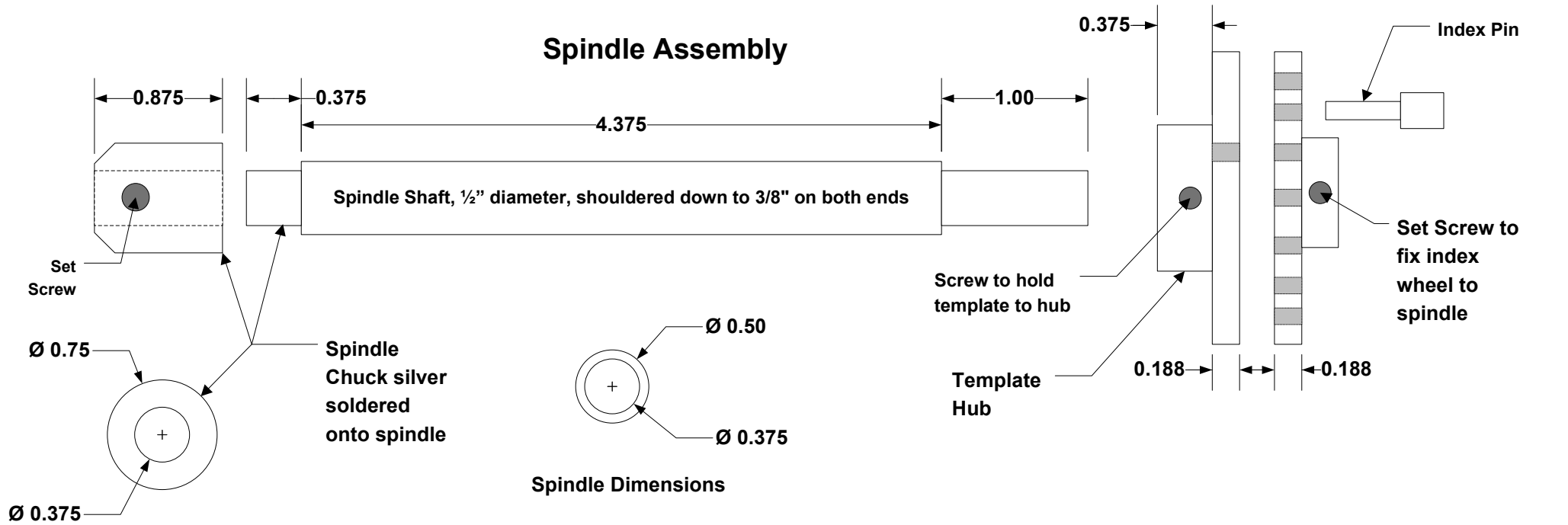
The hole is reamed so the spindle will be a close fit but should slide and rotate freely.



I milled this piece out leaving the .375" tang to fit in my lathe saddle milling vice. This may not be needed for other lathe mountings



## Spindle Assembly



Template wheel holds curved aluminum template around the hub. This wheel spins freely on the shaft and is locked to the indexing wheel with the index pin.

Index wheel is fixed to spindle shaft with a set screw.

1/8" Holes, 24 total, evenly spaced around index wheel

