

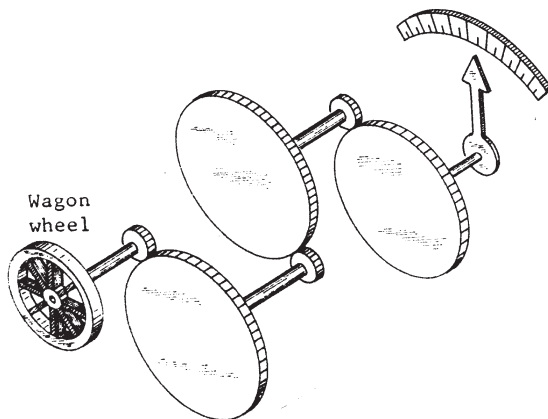
4. Worm Gearing

Heron of Alexandria

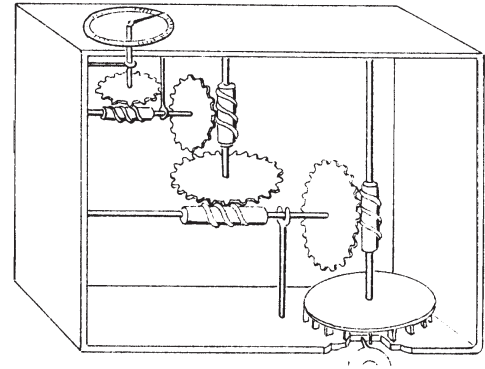
The word teamster today means a truck driver, but originally it meant a wagon driver, someone who drives a team of horses, mules or oxen.

Over 2000 years ago teamsters in the Roman Empire needed a way to measure how far they had traveled, so they could charge more for a longer haul.

A Greek scientist, Heron of Alexandria, invented a device to measure and indicate distance traveled - similar to the odometer (mileage meter) in today's cars. Heron had the idea of driving a tiny gear from the wagon wheels, meshing that gear with others in a very high reduction ratio, and driving an indicating needle. How far the indicating needle rotated would indicate the distance traveled by the wagon.

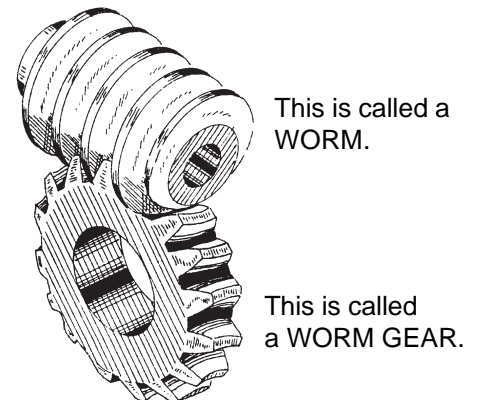


To make it work in practice he needed gears that would give a very high reduction ratio in a very small space. The kind of gears he used are still used today for the very same reason - high reduction ratio in a small space. They are called worm gears. Heron's sketch of his odometer using worm gears was preserved for us through the Dark Ages by Arab scientists. Here's what it looks like.



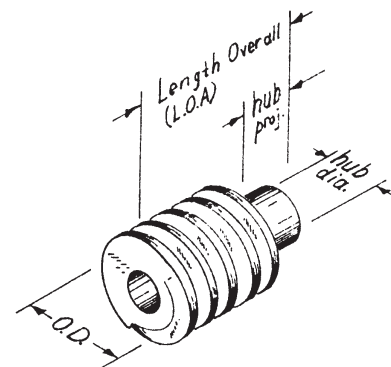
Worm Gearing

Worm gearing today looks like this.

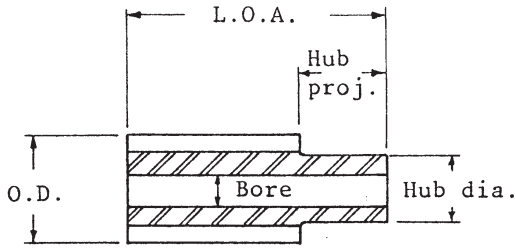


Worms

A worm is dimensioned like this.



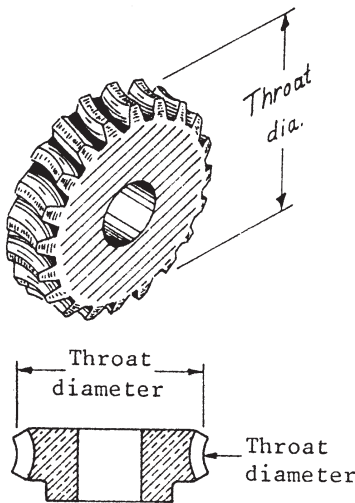
In section it looks like this.



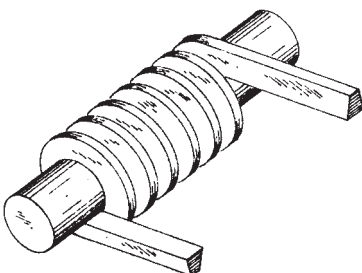
Bore, keyway and set screw work the same as in spur gears.

Worm Gear

A **worm gear** has parts similar to a spur gear except for one, which is called throat diameter. The worm gear usually wraps slightly around the worm, making its face curve slightly. Diameter in the center is called throat diameter.



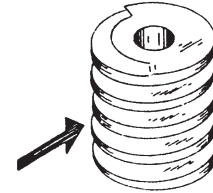
Worm gears can be plain, web, spoked or ring type, same as spur gears. The action of worm gearing in mesh is a little different from spur gears. Think of a worm as a cylinder with a ridge wrapped in a spiral around it, like a barber pole.



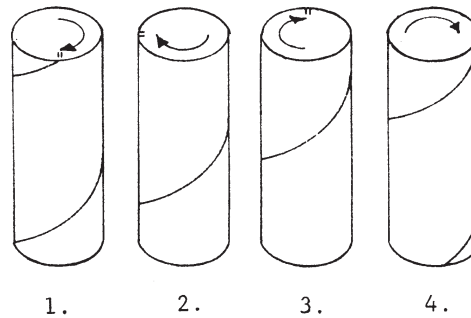
Thread

The ridge is called a **thread**. In practice worms are not made of a thread wrapped around a bar, but are cut from one piece of steel. The shape is a spiral, however, just as if it was wrapped.

Picture a worm with an arrow floating in a fixed place in air, and pointing at the worm.

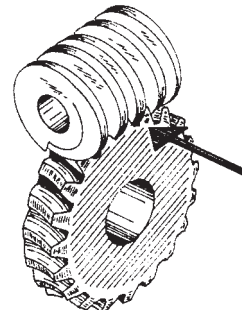


When a single thread worm rotates through exactly one revolution, exactly one pitch (tooth plus space) passes the arrow - the same way a stripe moves up or down a barber pole.



In this sketch, as the worm rotates clockwise, the thread moves continually up.

Worm gear teeth are in mesh with the thread of the worm. The endwise movement of the thread moves the gear teeth past the floating arrow.



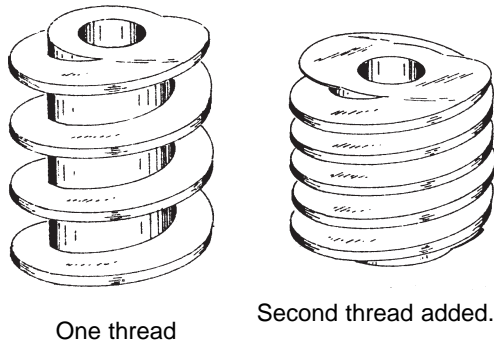
If the gear has 60 teeth, it takes 60 revolutions of the worm to rotate the gear once around.

Speed ratio is 60:1.

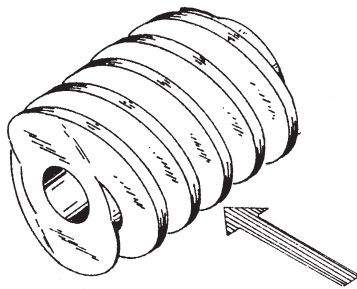
If the gear has 40 teeth, speed ratio is 40:1.

Double Threads

It's possible to have two threads wrapped around a worm.



When you rotate a double thread worm once around, two pitches pass the arrow.



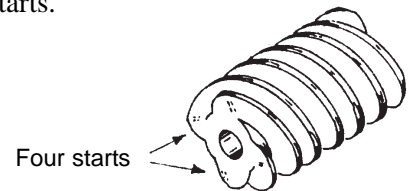
When in mesh, one revolution of the worm moves two pitches of the gear past the arrow.

If there are, for example, 60 teeth in the worm gear, it takes 30 revolutions of a double thread worm to turn the gear one complete revolution.

Speed ratio is $60:2 = 30:1$

If we think of the worm as a pinion with one or two teeth (threads) we see that the formulas and calculations for worm gears are the same as for spurs.

In practice worms are made with as many as four threads (and in some cases up to 5 or 6 threads). You can quickly see the number of threads on a worm by looking at the end and counting the thread starts.

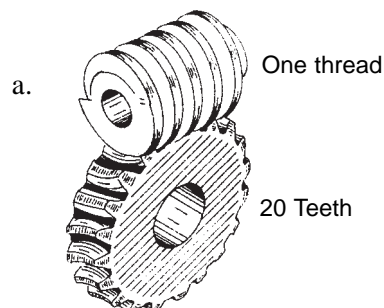


Remember, the worm always goes faster than the gear.

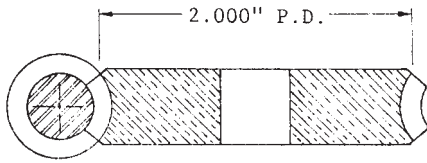
Study Questions A.

Write your answers in the spaces allowed after each question.

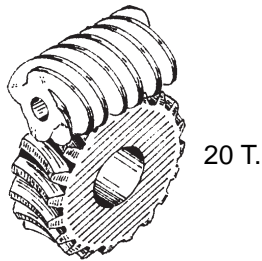
- In a., b., and c. below the worm goes 1750 RPM. What is worm gear speed in each case?



b. Worm 16 D.P., Double thread.



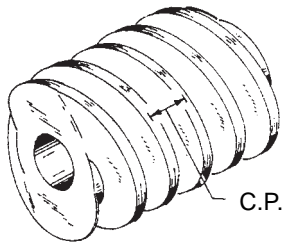
c.



2. If you want a conveyor drive shaft to turn at about 58 RPM, and you have a motor running at 1750 RPM, what worm gear ratio do you need?

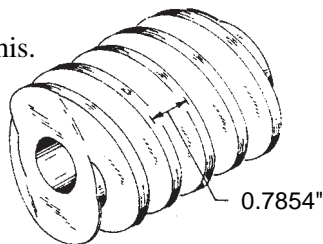
Lead Angle

Worm threads are made in even D.P. sizes, measured parallel to worm centerline.

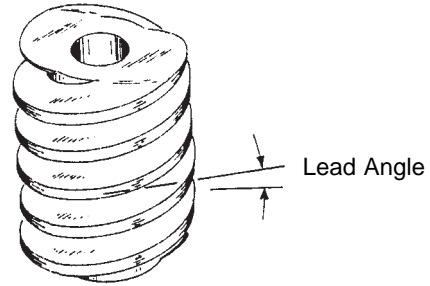


For example, a 4 D.P. worm measures like this.

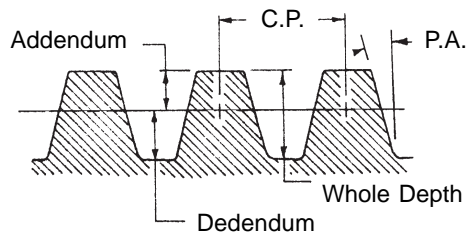
$C.P. = \frac{\pi}{4} = 0.7854"$



The angle of the thread is called **lead angle** or **helix angle**. (Lead rhymes with reed.)

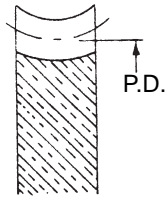


Tooth parts are the same as spur gears.

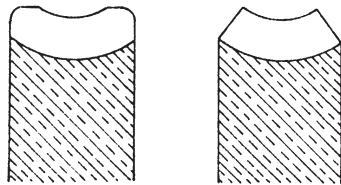


Worm Gears

Worm gears have a pitch diameter at the center point of the wrap-around curve.



Teeth are usually chamfered or rounded off at the corners to keep them from breaking, and for appearance.

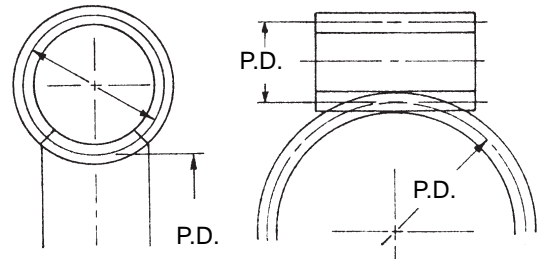


Pitch diameter is calculated the same as for spur gears. $P.D. = \frac{\text{Number of teeth}}{D.P.}$

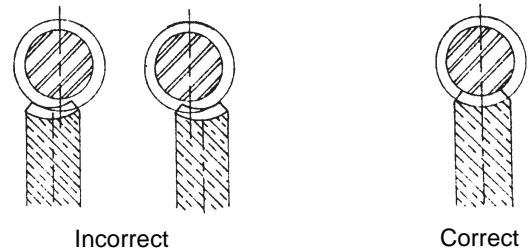
For example, a 50 T., 4 D.P worm gear has a 12.500" P.D.

$$\frac{50}{4} = 12.500''$$

Worm P.D. and worm gear P.D. just touch when in mesh.



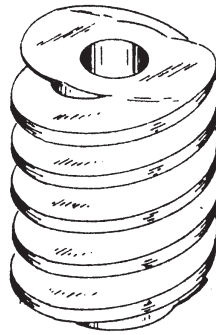
It is important for the worm and worm gear to be lined up properly side to side because of the wrap-around curve of the gear teeth.



Study Questions B.

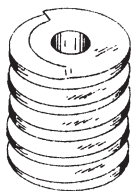
1. What is P.D. of a 60 T., 5 D.P. worm gear?
2. A worm gear set has these specifications:
6 D.P., Worm P.D. = 2.000", Gear 36 T., 1 1/2" bore in gear.
What is the center distance?

- 3. A worm is 8 D.P.
Show its circular pitch
as a dimension
on this sketch.



Left and Right Hand

The direction of slant of the threads on a worm is called hand. A worm can be either **Right Hand** or **Left Hand**.



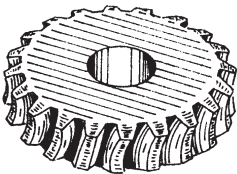
R.H.



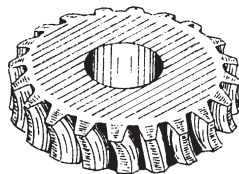
L.H.

Teeth on a worm gear are also slanted across the face of the gear.

The gear can also be either Right Hand or Left Hand.



R.H.



L.H.

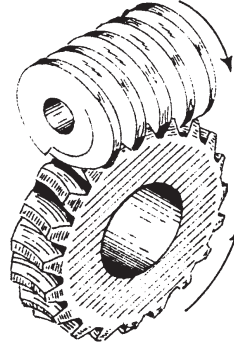
For a worm and gear to fit in mesh, the hand of the worm must be the same as the hand of the gear.

R.H. worm runs with R.H. gear.

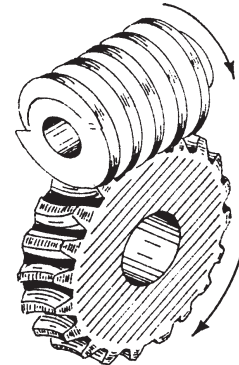
L.H. worm runs with L.H. gear.

The hand of the gear set affects direction of rotation.

For the same direction of worm rotation, opposite hands give opposite gear rotation.

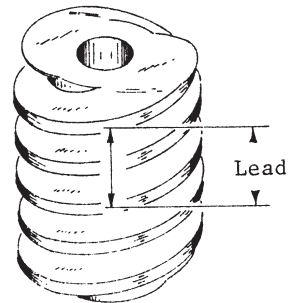


R.H.



L.H.

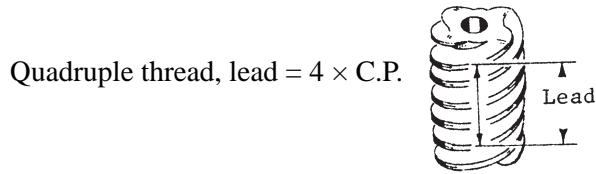
The axial distance that one thread moves for one worm revolution is called **lead** (Rhymes with reed).



For a single thread worm, lead equals circular pitch.

For a double thread, lead = 2 × C.P.

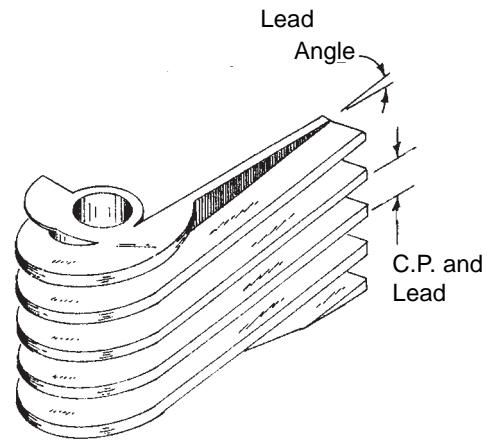
Triple thread, lead = 3 × C.P.



The more threads or starts on a worm, the higher the lead, and the higher the lead angle.

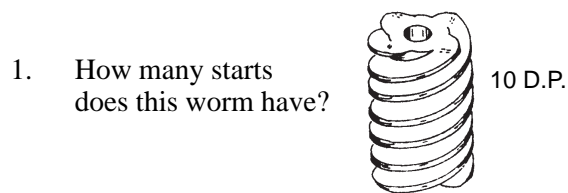
It's sometimes helpful to picture a worm to be made with an imaginary wrapping or lamination on the outside, with the thread attached to the lamination.

Imagine you unwrap the lamination, and stretch it out flat.

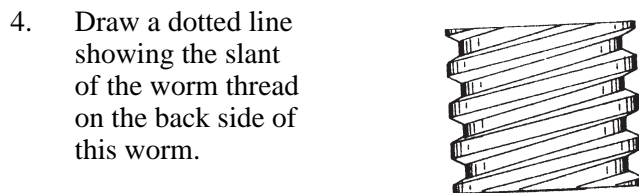


You can then easily visualize helix or lead angle, circular pitch, and lead.

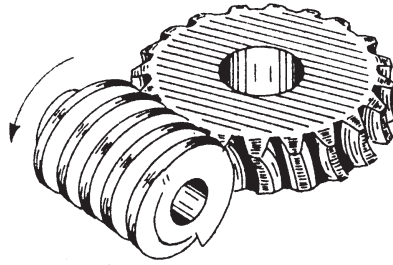
Study Questions C.



2. What hand is the worm in question 1?
3. What is the lead of the worm in question 1?



5. What direction will the worm gear rotate? Indicate with an arrow.



6. What is the lead of a triple, 8 D.P. 20° P.A., 2.000" P.D. worm?

Bronze Worm Gears

When a worm and worm gear run together, the high amount of sliding friction tends to make the surfaces stick together and gall each other. This is especially true if the material of the worm and gear are the same. For this reason a worm should always be made of different material than the worm gear.

The most common combination of materials is a steel worm and a bronze gear. Bronze is an expensive alloy of copper and tin, with other alloys such as aluminum and manganese sometimes added. It is commonly furnished in the form of a casting, or as bar stock or forged parts. The steel worm is often heat treated for greater hardness and wear capacity.

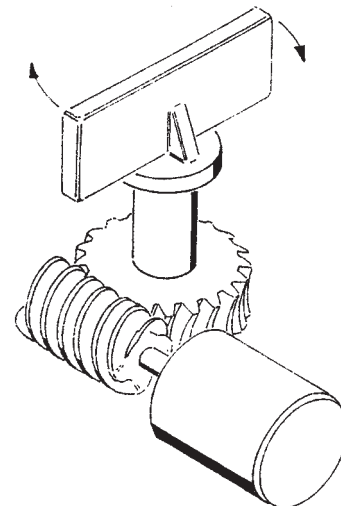
Almost all worm gears are made of bronze.

Study Questions D.

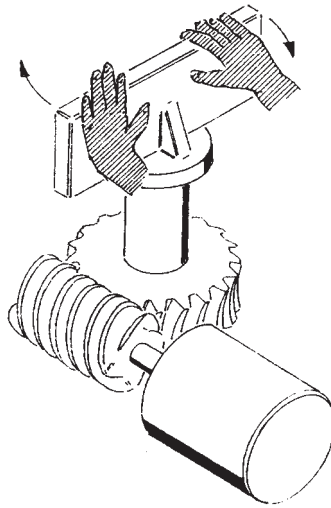
1. A steel worm with a cast iron gear is acceptable, true or false?
2. The main reason bronze is used in worm gearing is because it is tough, true or false?

Back Driving

Picture an electric motor driving a worm and worm gear, 5:1 ratio, which rotates a small display sign.



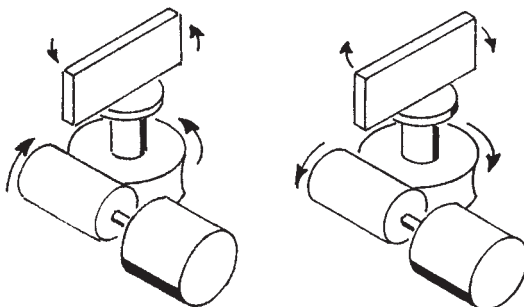
Turn the motor off; the sign stops rotating. Now try and rotate the sign by hand.



Turning the sign by hand rotates the worm gear, which in turn rotates the worm (five times faster). This is called **backdriving**.

Instead of the motor driving the sign, now the sign is driving the motor. Power is not flowing forward, from the motor to the sign; it's flowing backward from the sign to the motor.

Notice this is **not** the same as reversing direction. Reversing just means you make the motor go clockwise or counter clockwise, and in turn the sign goes CW or CCW.



Backdriving is reversing the flow of power, not the direction of rotation. There are four possible cases:

1. Forward direction - Forward power
2. Reverse direction - Forward power
3. Forward direction - Reverse power
4. Reverse direction - Reverse power

Self Locking

Imagine the gear ratio in the previous sign drive is 60:1 instead of 5:1. If you turn off the motor and try to drive the sign by hand, you'll find it's locked in place. It won't rotate.

The worm and gear mesh locks when you try to back drive it. You can only rotate the sign by turning the worm shaft. This is called a **self-locking** gear set. Self-locking is caused by normal friction in the gear set in high ratio worm gearing.

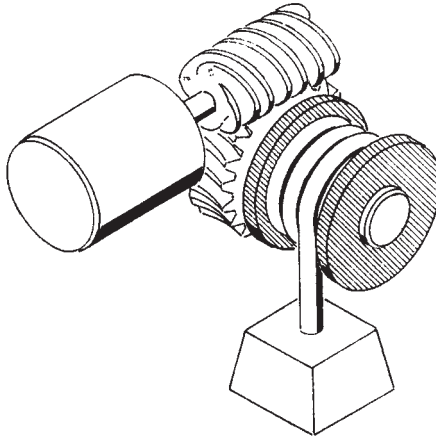
As a rule of thumb, worm gear ratios over about 30:1 will probably be self-locking. Spur, helical and bevel gears are not usually self-locking.

You should **not** depend on worm gears, even in ratios over 30:1, to be self-locking, especially if safety is affected. Vibration, lubrication, temperature and the details of the gear mesh design and manufacture will change its ability to self-lock. If you must hold something locked in place, use a brake.

Study Questions E.

1. A worm gear mesh, driving a drum and cable is used to lift a weight.

When you stop the motor, even with no brake applied, the weight will not go down since the worm gear mesh is self-locking. How do you lower the weight?



2. A 50:1 worm gear set connects an electric motor to a belt conveyor.

With the electric motor turned off, somebody decides to pull on the conveyor belt in order to move it a short distance. What happens? How can you move the conveyor by hand?

Section Summary

In this section you were introduced to **worm gearing**, and saw how to calculate worm gear ratios. You learned to recognize **right hand and left hand** worms and gears. You learned what **lead** is, what single, double, triple, quadruple, and **helix angle** mean, and what **throat diameter** is. You saw how the hand of worm gears affects direction of rotation. Lead is measured parallel to worm centerline.

Backdriving is reversal of power flow. It's not the same as reversing direction of rotation. **Self-locking** is the refusal of a worm gear mesh to backdrive. The most common worm gear materials are a steel worm and a **bronze** gear. Bronze is an alloy of copper and tin.

The next section is about bevel gears. You will see how the shape of bevel gears change when their ratios change. You will learn what pitch angles and mounting distance are, and what miter gears are.

Proceed to the next section.