Lathe Change Gears

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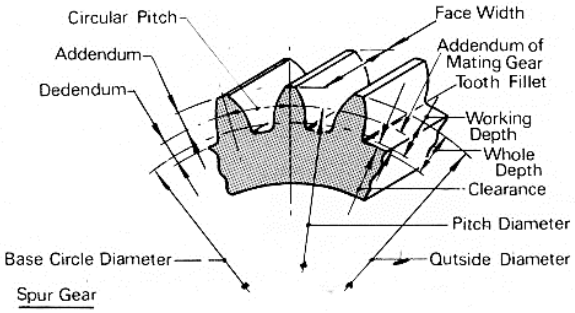
Spur Gears

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form (they are usually of involute form to achieve constant drive ratio), the edge of each tooth is straight and aligned parallel to the axis of rotation.

These gears are used widely on all types of lathes for headstock drives, saddle drive and of course screw cutting via quick-change gearboxes or change gears or a bit of both.

Any spur gear can be defined in terms of its diametral pitch, pressure angle and number of teeth.



What about the DP?

DP is shorthand for *Diametral Pitch* and this is the number of teeth per inch of circumference of the PCD or *Pitch Circle Diameter*.

DP can be calculated using any of the following formulae:

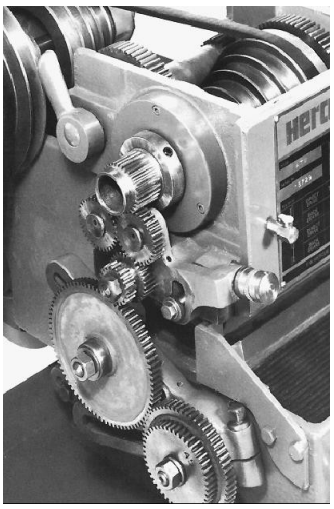
$DP = \frac{\pi}{P}$ *where* ***P*** *= Circular Pitch*

$DP = \frac{N}{PCD}$ *where* ***N*** *= Number of Teeth, and* ***PCD*** *= Pitch Circle Diameter*

$DP = \frac{N+2}{OD}$ *where* ***OD*** *= Outside Diameter*

$DP = \frac{Pb/\cos\Phi}{\pi}$ *where* ***Pb*** *= Base Pitch, and* ***Φ*** *= Pressure Angle*

$DP = \frac{25.4}{m}$ *where* ***m*** *= Module*

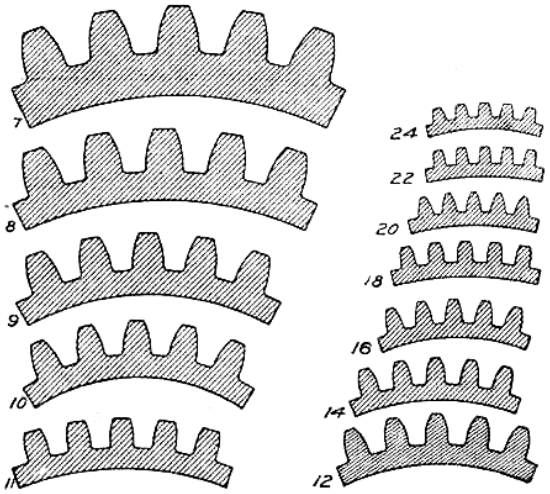


Is the DP is always an even number? Well some will say that there are no odd numbered DPs, but (there's always a BUT) that's not quite true. While it will rarely apply in the case of older lathes spur gears can be specified in diametral pitch, inch module, inch circular pitch, metric module, metric circular pitch, and probably a few others I can't think of at the moment. A given tooth size can be specified in any of these standards and will give a different numerical value depending on which system you use.

There are two main diameters on a gear that the everyday user needs to know; there are many others, but you can effectively forget them for home workshop purposes. These main diameters are:

a) the OD or outside diameter is obvious; and
b) the PCD a theoretical diameter inside the OD.

The pitch circle diameter (PCD) is the distance between the gear centre and the point of contact with a meshing gear. At that point, the teeth and the gaps are the same width. The part of the gear that pokes out beyond the PCD, that is the height from the pitch circle to the tip of the tooth, is the *addendum* of the tooth. The *dedendum* is the distance from the PCD to the root of the tooth or the depth of the tooth space below the pitch circle to the root of the tooth.
It is made bigger than the addendum to allow for some clearance at the root.



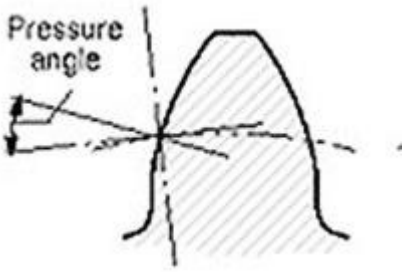
Proportions of gear teeth of different diameter pitches

What PA?

One other necessary detail you need to know about gears is the pressure angle (PA). Most modern gears are cut at 20 degrees, but older gears used a pressure angle of 14.5 degrees. The pressure angle (designated Φ) is the angle between a line tangential to the pitch circle at the tooth profile and a line normal or perpendicular to the surface of the tooth at that point. See the diagram below.
The pressure angle can be calculated as follows:

$$Cos\ \Phi = \frac{Db}{PCD}$$ *where Db = Base Diameter, and PCD = Pitch Circle Diameter*

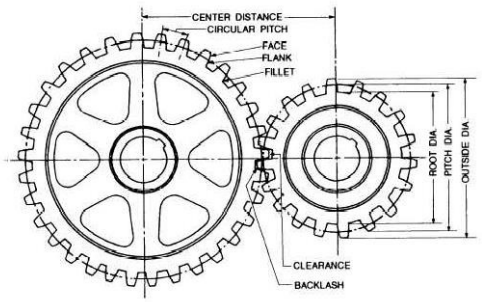
$$Cos\ \Phi = \frac{Pb}{\pi / DP}$$ *where Pb = Base Pitch, and DP = Diametral Pitch*



The pressure angle is also known as the *angle of obliquity*. Earlier gears with pressure angle 14.5 were more commonly used because for a given pressure angle the cosine would be larger for a smaller angle, thus resulting in more power transmission and less pressure on the bearing.
But for a given material, smaller pressure angles produce a weaker tooth. To run gears together properly one must match pressure angles.

Strictly speaking an *involute* spur gear cannot be said to have a definite PA or PCD until it has actually been assembled in mesh with its mating gear because the PA is related to the *actual* centre distance. If the centre distance is altered this does not prevent the transmission of motion at constant angular velocity. This is one of the advantages of the system.
Now a bit more on the technical side - the 20 degree PA is the stronger, but the 14.5 degree PA the quieter. It's always a trade-off. Also spur gears are noisier than any other type of gear.
Extensive use of non-metallic gears (e.g. nylon or *Tufnol*) has played a major role in overcoming noise in gear assemblies.

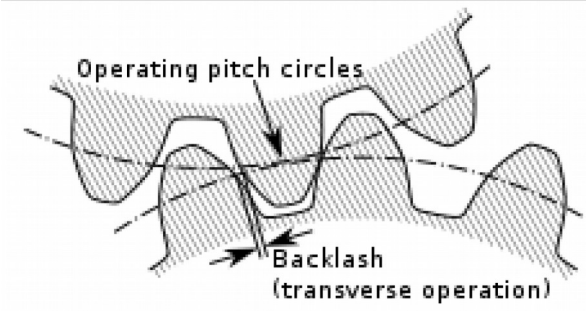
Spur gears also wear more readily and so can tend to develop excessive backlash. It's not all bad though as spur gears are relatively easy to manufacture and have high mechanical efficiency in the order of 96-98%.



It is really hard to measure a PA in the home shop without specialist equipment. But the good news is that most machine tool makers used 14.5 and generally stick to it because of legacy issues.
To sum up, DP is tooth size, the bigger the number the finer the teeth, the smaller the number the coarser the teeth. PA is narrow slimmer teeth or chunky blocky teeth.

Backlash

Backlash is the error in motion that occurs when gears change direction. In other words it is the total free movement at the pitch circle of one gear, when the other gear in the pair is fixed, and the bearing clearances are eliminated. It exists because there is always some gap between the trailing face of the driving tooth and the leading face of the tooth behind it on the driven gear, and that gap must be closed before force can be transferred in the new direction.



The term "*backlash*" can also be used to refer to the size of the gap, not just the phenomenon it causes; thus, one could speak of a pair of gears as having, for example, "0.007 inch of backlash."

A pair of gears could be designed to have zero backlash, but this would presuppose perfection in manufacturing, uniform thermal expansion characteristics throughout the system, and no lubricant. Therefore, gear pairs are designed to have some backlash. It is usually provided by reducing the tooth thickness of each gear by half the desired gap distance. In the case of a large gear and a small pinion, however, the backlash is usually taken entirely off the gear and the pinion is given full sized teeth.

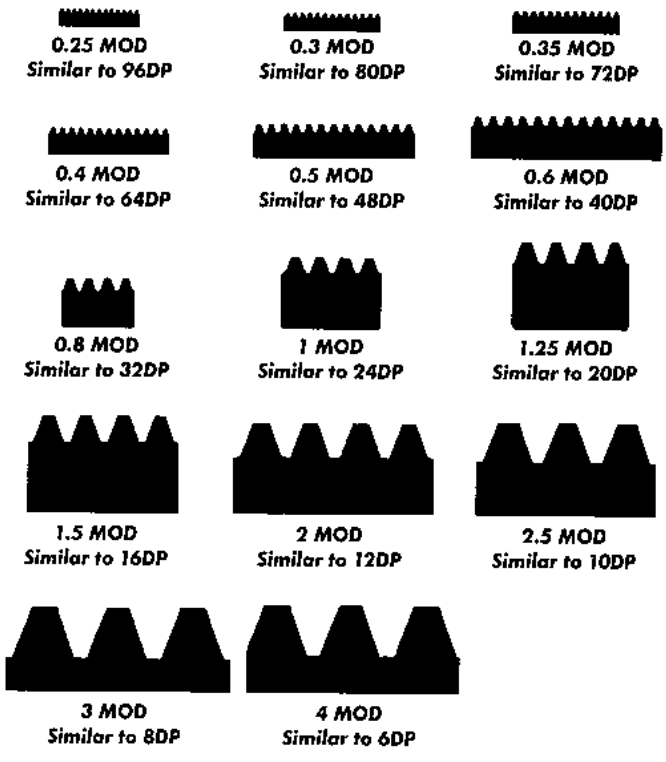
Backlash can also be provided by moving the gears further apart.

What about module gears?

The Module (MOD) is the pitch circle divided by the number of teeth; it is the reciprocal of the DP. It may be expressed in any unit of length and hence the unit must be stated. Metric gears are referred to by the Module in millimetres.

The chart (to the right) gives an idea of what the most commonly used modules look like in linear representation (rack gearing) compared to the nearest equivalent DP.

As you can see some metric module gears are similar to **but are not the same as** DP gears.



Matching gears and DP to particular lathes

Below is a brief, and unfortunately incomplete, guide to some of the change and other gears found on lathes that you may come across if you live in Australia.

24DP Gears

- **Smart & Brown** '1024 VSL' lathe change gears are 24DP with a 20PA.
- **Atlas** 6 inch lathes change gears are 24DP with 14.5PA. The gears are 3/8" (0.375") wide with a ½" (0.500") bore and two opposed 1/8" (0.125") keyways.

20DP Gears

- **Atlas** the back gears on the 'Model 618' are 20DP.
- **Myford** change gears of all years are 20DP with a 14.5 PA. The gears are 3/8" wide (0.375") with a 5/8" bore (0.625") and 1/8" (0.125") keyway. A standard ML7 or Super 7 changewheel set is: 20(2), 25, 30, 35, 38, 40, 45, 50, 55, 60, 65, 70 and 75. Note that the tumbler reverse gears on the SOUTH BEND, BOXFORD and HERCUS '9 inch' lathes are 20DP with 14.5 PA. These tumbler reverse gears are 7/16" (0.4375") wide with a 5/8" (0.625") bore. Pictured below is a Hercus lathe with tumbler reverse – if you look closely you can spot the different DP of the gears.

18DP Gears (the Clones)

- **Boxford** – these lathes use 18DP gears of 14.5PA.
- **South Bend** - the '9 inch' and 'Light 10' (10K) lathes both use 18DP gears. These are 14.5PA though some of the later South Bend lathes used a 20PA. The gears are 3/8" (0.375") wide with a 9/16" (0.5625") bore. Note that the tumbler change gears on the South Bend 'Heavy 10' are also 18DP gears. South Bend lathe publication 903E (the 9/10K Parts List dated 1964) gives the complete change gear set as: 16, 24, 32 (2), 36, 40, 44, 46, 48, 52, 54, 56, 60, 80 plus an 80 idler, and a 42 for cutting 27tpi was an extra-cost accessory. Note that due to the small size the 16T gear has a shallower key seat (see the picture below).
- **South Bend** - 9" Workshop change gear lathes use 18 DP gears. These have a 1/8" key slot, a 3/8" face and a 9/16" bore.

- **Sheraton** – the 9 inch and 'Conquest' 10 inch use 18DP gears with a 14.5PA. The gears are 3/8" (0.375") wide with a 9/16" (0.5625") bore and 1/8 (0.125") keyway.
- **Hercus** - 9 inch and Model 260 lathes use 18DP gears with a 14.5PA. The gears are 7/16" (0.4375") wide with a 9/16" (0.5625") bore and 1/8" (0.125") keyway.

16DP Gears

- **Barnes** – the Model '4.1/2' lathe uses 16DP gears with 14.5PA. The gears have a bore of 19/32" (0.594"). Barnes gears rise by 4s and a standard change gear set for the Model 4.1/2 is: 16 (2), 20, 24, 28, 32, 36, 40, 44, 48, 52, 56 and 88.

- **Barker** – the 5 x 24 lathe uses 16DP gears. A standard change gear set is: 20, 24, 32, 36, 38, 40, 44, 48, 52, 54, 56, 60 and 80.
- **Atlas** – the ‘Craftsman Model 101’ and lathes of 9, 10 and 12" swing use 16DP gears with 14.5 PA. Face width has varied a little but is mostly 3/8” (0.375"). The bore is ¾” (0.750") with a double keyway 3/16” (0.1875") wide. The gears are interchangeable across the three Atlas lathes although on the 9 inch the central boss is thinner.
- **Denham** – the ‘Junior MK2’ lathe uses 16DP change wheels. The gears are 3/8" (0.375) wide with a 3/4" (0.750) bore.
- **Logan** – these lathes use change gears of 16DP and 14.5 PA. The gears are 7/16” (0.4375") or 5/8” (0.625) wide with a 5/8” (0.625") or a 15/16” (0.9375”) bore.
- **Colchester** - the early Colchester lathes used 16DP gears with a 14.5 PA. Later models went to module pitch.
- **South Bend** – the ‘Heavy 10’ (10L) lathe uses 16DP gears of 14.5 PA.
- **Craftsman** – the 10 and 12 inch lathes use 16DP gears with 14.5 PA and ¾” (0.750”) bore

14DP Gears

- **Drummond** – these lathes use 14DP gears. The early Drummond round bed rise in 4s (10tpi lead screw) the standard set being, 20, 20, 24, 28, 32, 36, 40, 44 and 64 with the extras for metric threads being 25, 35, 45, 50 and 63. The gears for other Drummonds, later round bed, "B" type flat bed and "M" type rise by 5s from 20 to 50 or 65 with additional intermediate gears to give the metric threads (26, 38, 63, 66 and 73 depending on lathe model)