CUTTING INVOLUTE GEARS WITH FORM TOOLS

by John Stevenson

I am proposing to write two articles about gear cutting, this the first will be about making and using form tools and the second will be about making and using hobs. Firstly a few notes about tools required. As I realise that not everybody has a well-equipped workshop so these notes will be written with a lathe and milling machine in mind, however a miller is not completely necessary and with a little forethought all the work can be done on a lathe with a vertical slide fitted.

Secondly a note on the contents of these articles. As I lot of this material has been collected over the years from a lot of sources I am bound to be repeating pieces that have been published before. I make no claim that all of this is my own work only that I have pieced together the relevant details from many sources. Some of this work is what I would state was mine but when like minds ponder on a problem there is often duplication of ideas, all that matters is the information is readily available to others. Enough drivel, now to work!

A lot of books have been written on gears and gear cutting and it will serve the reader good to read up on the overall principles before getting stuck in to practical work. The involute form is now the presently accepted form of gear tooth is general use. The shape of the tooth form can be best described as the path taken by a point on a piece of string, as it is unwound of the circumference of a circle.

The geometrical build up of the involute is quite complex but for our use it can be simplified into a single radius. Most of the early work on form tools was done by Brown and Sharp where a lot of this information has come from. If one looks at a gear with 12 teeth and two others with say 25 and 60 teeth it will be obvious that the shape of the involute changes from a small radius on smaller gears up to straight sides on a rack. To cut gears with different number of teeth a different cutter is required for each gear. As this is undesirable a standard was introduced using a series of eight cutters to cover the range. These are listed in Table 1.

Number of Cutter	Will cut Gears from	Number of Cutter	Will cut Gears from
1	135 to a Rack	5	21 to 25
2	55 to 134	6	17 to 20
3	35 to 54	7	14 to16
4	26 to 34	8	12 to 13

Table 1

Because of the differences in shape the lower number in the range is correct for that gear, the other numbers are a compromise i.e. Number 5 cutter 21 to 25 teeth is only accurate for 21 teeth.

The main principle behind the form tool is to adapt the radius of the involute to the form tool. Looking at one tooth on a gear it is obvious that it has the same radius both sides to form the tooth. So if we take two disks of known radius and present them to the tooth so that they fit snug all we need to know is the distance apart and the distance fed in to duplicate the tooth. All this information is in Table 2.

Involute Cutter Proportions 20 deg. Pressure Angle For 1 DP or 1 Module					
Cutter No.	**Range of Teeth**	**Pin Dia. D**	**Pin Centres C**	**Feed in F**	**Blank Width W**
1	135 - Rack	46.17	44.80	3.934	4.0
2	55 - 134	18.81	19.07	3.415	4.0
3	35 - 54	11.97	12.64	3.098	4.0
4	26 - 34	8.89	9.75	2.875	4.0
5	21 - 25	7.18	8.147	2.710	4.0
6	17 - 20	5.81	6.864	2.543	4.0
7	14 - 16	4.788	5.905	2.387	4.0
8	12 -13	4.10	5.267	2.251	4.0

Some Useful Formulae

TO FIND METRIC IMPERIAL

PCD Number of teeth x Mod No of teeth / DP

O/D [No of teeth + 2] x Mod [No of teeth + 2] / DP

DP 25.4 / Mod Pi [3.1416] / CP

MODULE mm CP / Pi 25.4 / CP

NO TEETH PCD [mm] - Mod PCD x DP

CP Mod x Pi Pi / DP

Pi can be taken as 3.1412.

A quick note here on the difference between DP CP and module. DP which stands for Diametrical pitch is the number of teeth per inch measured on the pitch diameter. CP which stands for Circular Pitch is the distance measured between two teeth measured on the pitch diameter. The module is the metric equivalent of the circular pitch and is the distance between two teeth measured on the pitch diameter in millimeters.

DP gear data is found by dividing the figures in Table 2 by the DP and the results will be in inches. Module gear data is found by multiplying the figures by the module and the results will be in millimeters.

Using the diagram in Figure 1 and Table 2 we will lay out an example for a 24 DP gear with 20 teeth.

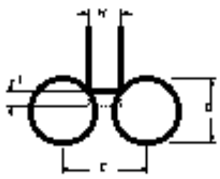

Fig 1

From the table we need to make a No 6 cutter to cover 17 - 20 teeth, the diameter of the pins [D] needs to be 5.81 divided by 24 =0.242" dia. The distance apart [C] will be 6.864 / 24 = 0.286". The infeed distance [F] will be 2.543 / 24 =0.106" given that the blank [W] is 4.0 / 24 = 0.167".

To make the cutter first of all decide what bore size you will need to fit your machine. To economise on material if you select a bore size of 3/4" then the cutters can be made out of 1 1/2" silver steel or drill rod. Sizes above this are hard to find. To make these cutters you will need an arbor. Make up an arbor that can be used in the lathe as well as the miller.

To make the form tool turn up two pins in drill rod or silver steel as shown in Figure 2 and mount them in a holder to fit your lathe toolpost.

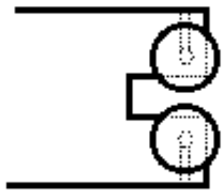

Fig 2

These pins must be hardened and tempered after turning. The top face then needs grinding flat to give a cutting edge. The distance apart [C] is critical and is best don with the holder mounted in the toolpost at an angle of 5 degrees and the distance measured using the crossslide dial.

The cutter is the next job. Turn up a blank of drill rod with a bore of 3/4" and a width of 0.167" [W]. Mount this on the arbor and present the form tool to it as laid out in Fig1. Using a slow speed and lots of coolant wind the form tool in to 0.106" [F]. this will then give you a disk cutter with the right shape but no cutting edges or clearance, also called form relief.

Remove the cutter from the arbor and mark eight equal radial lines on it, mark four lines 'A' and the other four lines 'B'. Refit the cutter to the arbor and mount in four jaw chuck and set to run 1/4" offset. Set the cutter so that one radial line, A, is on the centre at the point where the eccentric is nearest the tool, See Fig3.

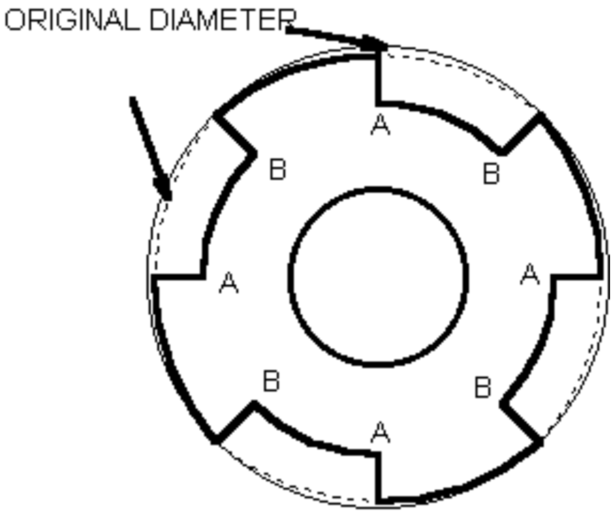

FIG 3.

Bring the cutter in and clean up the form until the cut extends between one pair of 'B' lines. Note the crosslide reading. Rotate the blank to the next 'A' line and repeat. Do this four times and you will have a blank with four equal lobes. Remove from the arbor and mill the four spaces out between 'A' and 'B'. mark the cutter details on one side. You will need the cutter number , the DP and the depth to cut. This is not the feed in depth from table 2 but the full depth plus clearance. This will have to be obtained either from a hand book or from the formulae 2.25 divided by the DP.

Harden and temper the cutter to light straw. To harden tools made in silver steel or drill rod, heat up evenly to a cherry red and quench in water vertically. Clean one face and put it on a steel plate with the clean face up. Heat the plate from underneath and watch the colour of the cutter, when it reaches light stray colour remove and requench as quickly as possible. Clean up and grind the four cutting faces taking care to keep the faces radial. Provided that the cutter is reground equally and radially it can be reused until it is worn away.

To make a cutter for a one off job or to make a quick job, the cutter blank can be mounted on the arbor and offset an 1/8" as described above and the form turned on in one go. Instead of rotating round and repeating the process, remove from the arbor and cut one gash in at the point of maximum eccentricity. Harden and temper as above and this will give you a serviceable fly cutter that is able to be reground many times.

The set out for a module gear is exactly the same the only difference is the working out of the form tool sizes.

As an example we will take a 1.5Mod pitch gear with 13 Teeth.

From table 2 we need a number 8 cutter. The pin diameter [D] is 4.100 x 1.5 = 6.15mm. The distance [C] is 5.267 x 1.5 = 7.90mm. The feed in [F] is 2.251 x 1.5 = 3.37mm and the blank width is 6.0mm. The cutting depth to be marked on the cutter is worked out from the formulae 2.25 x mod which in this case is 2.25 x 1.5 = 3.38 mm.

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Rev: 03/17/97