LAWRENCE COOPER
Mechanical Engineering Technician
3D CAD Modeling Design & Drafting

Telephone - (03) 981 3029
Mobile - 022 3811 031

cooper.lawrence.jo@gmail.com

Gear Basics Part 1

An introduction to the basic terms and there interaction required to design simple gear assemblies. There are many requests posted to the Questions Forum asking questions relating to basic gear theory so I have put together this quick tutorial on the basic knowledge to design simple gear trains.

Part of an engineer's tool kit, is a good library of technical books. In my part of the world, some of the common books an engineer would possess are, Machinery's Handbook, Chapman's Workshop Technology parts 1, 2 & 3, these books and many other machine design texts provided the basic theory and calculations required to design workable gears and many other mechanical components.

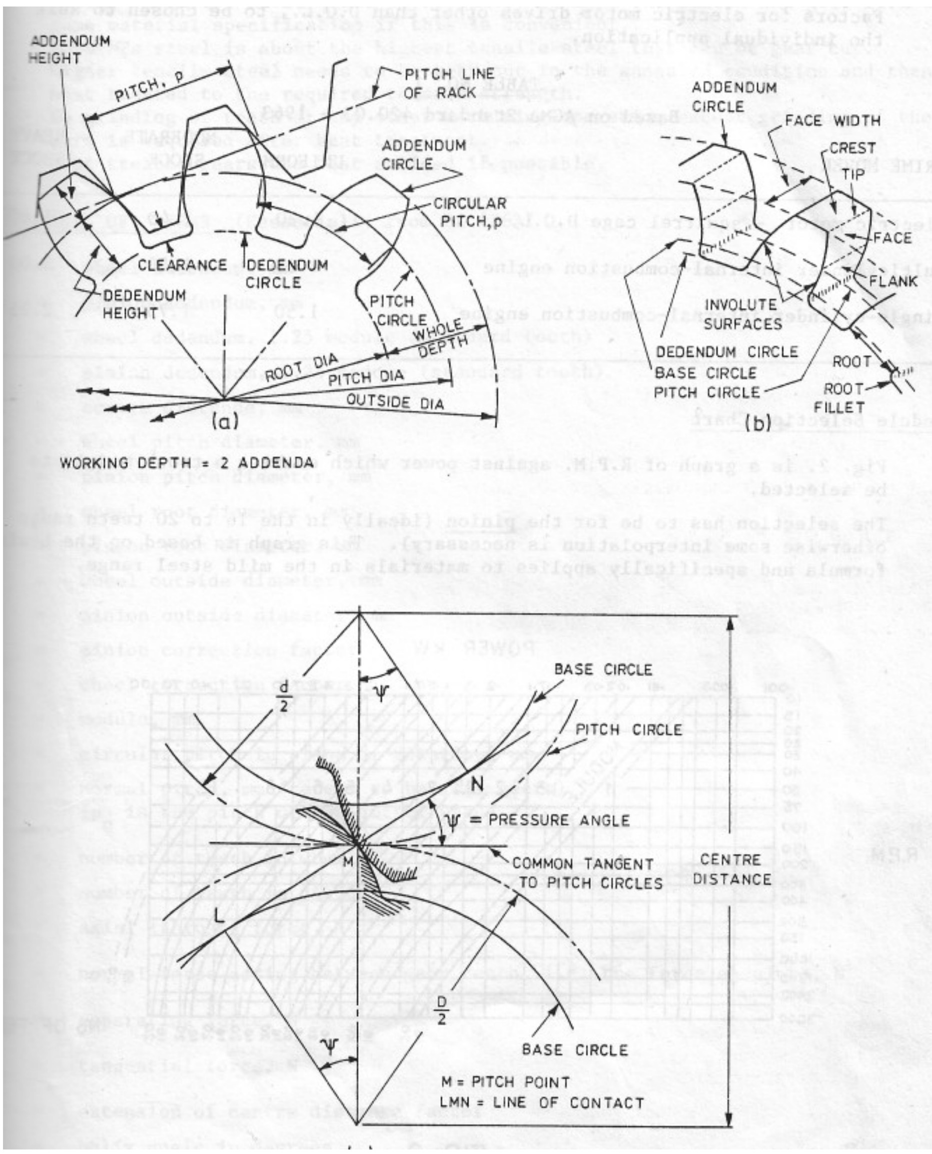


Diagram 1

An excellent textbook "Applied Mechanical Design" by A. K. Hosking & M. R. Harris 2nd edition has been used as the main reference for this document, This has proved to be a very useful text over the years for mechanical design. It covers all the main components of mechanical design, shafts, gears, springs, belts, chain drives, bearings, keys couplings and more, being an Australian publication all the design data complies with ISO and Australian/ NZ standards, the standards in use in this part of the world. I have made good use of the 1st edition of this text and as this is worn a bit and falling apart after many years of use so I located a copy of the 2nd edition

These images, from the textbook "Applied Mechanical Design" show the common terms we use to name the parts of simple gears.

We will be looking at modern involute toothed gearing with a pressure angle of 20 deg. We will be looking at gear design in conjunction with the ISO Standard 54 and AS 2938. In this document we will only be looking at simple straight cut spur gears.

Tooth Module (M)

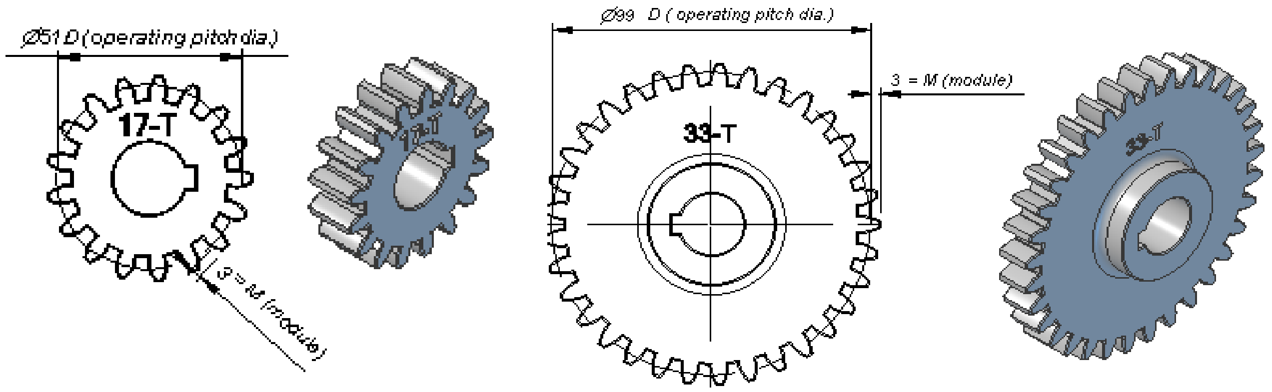
This is the heigh of the addendum in mm (see Diagram 1). Also module M can be defined as the number of mm in the pitch circle diameter for each tooth in the gear. This takes us to our first gear calculation formula

$M=\frac{D}{N}$ *where M = the gear module, D = operating pitch diameter of the gear, N = the number of teeth the gear has.*

Example

A gear has D (operating pitch dia.) = 99 : N (no. of teeth) = 33 then $M=\frac{99}{33}$ *= 3*

If we need to design real gears that can be easily manufactured using standard tooling and machine tools we need to take a precise approach to our gear design, this is where ISO 54 comes in. The Tooth Module defines the size of the gear teeth. For gears to mesh correctly they must have the same sized teeth, that is the same module. Also, these teeth must be able to be cut using standard tooling.



Example Gears

The textbook. " Chapman's Workshop Technology part 3" details standard gear manufacture methods, also so does the " Machinery's Handbook ", worth having a look if you have access to a copy of these texts.

We need to start off our gear design from the tooth modules defined in ISO 54. The standard modules according to ISO 54 are:

1.00	1.125	1.25	1.375	1.50	1.75	2.00	2.25	2.50	2.75
3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	8.00
9.00	10.00	11.00	12.00	14.00	16.00	18.00	20.00	22.00	25.00
28.00	32.00	36.00	40,00	45.00	50.00				

The highlighted values are non-preferred and should only be used if there is no choice. This is because each different module requires different tooling the preferred sizes are more likely to be *available in most machine shops. When designing gears in accordance with ISO 54 as the size of the gear teeth are precisely defined in this document the tooth size is our starting point. The module we select to use for our gears is influenced by there purpose, with the smaller modules our gear train will take up less physical volume, if we are dealing with larger power and torque in our gear design we need larger teeth for strength.*

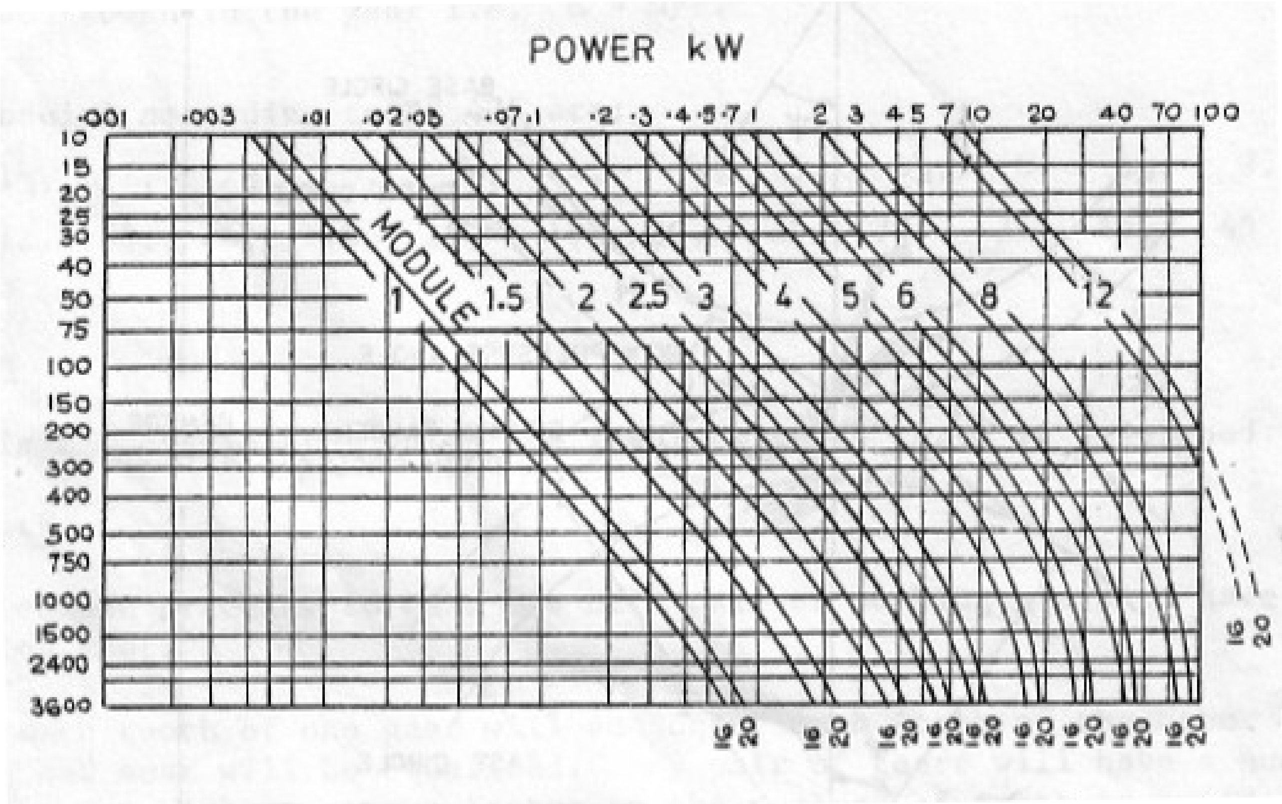


Diagram 2

This chart, from the book "Applied Mechanical Design" , is a guide to help in the selection of a suitable module for your gear design.

Base Circle

This is the circle from which the involute curve is developed. Gears can also be generated using a cycloidal curve. This is often used with the gears used in clocks, the reason being that gears with less number of teeth can be cut before we get severe undercutting problems. An involute curve is a special version of a cycloidal curve. If you wish to learn more about cycloidal gears for clocks a place to start is Here*.*

Operating pitch diameter.

If we had a pair of cylinders rotating about there centers touching each other so that one of them was driving the other the diameters of these cylinders would be the wheel pitch diameter. As we have already decided the module M we require and from the velocity ratio of the drive we can work out the number of teeth required for the pinion and for the driven gear this formula which defines the relationship is what we use to determine the basic dimensions for our gears.

D (pitch dia. gear) = N(no. of teeth gear) x M (tooth module) – this is for the driven gear

d (pitch dia. Pinion) = n (no. of teeth pinion) x M (tooth module) – for the pinion gear we use the same basic formula but change to lower case to indicate this is pinion calculation

the next formula us used to calculate the center distance required between gear and pinion

$$Center\ Dist = \frac{(D+d)}{2}$$

Example

Gear 33 teeth, pinion 17 teeth module 3

d = n x M → 17 x 3 = 51

D = N x M → 33 x 3 = 99

From this it is simple to calculate the basic dimensions we need to design a gear / pinion drive, the required center distance between the gears.

$$Center\ Dist = \frac{(D+d)}{2} \quad \rightarrow \quad Center\ Dist = \frac{(99+51)}{2} = 75$$

These calculations along with the module we selected and a suitable number of teeth on the pinion and driven gear will give us the basic information for us to start out designing a pair of gears that can be manufactured and will work in our application.

Hunting Tooth.

When designing a pair of gears a good practice is to have a "hunting tooth", that is to equalize wear each in the first gear will encounter each tooth of the second gear equally. This is achieved when the highest common factor is unity or when the numbers are prime to each other.

Examples : 21 and 41, 30 and 61, - prime, 21 and 39, 30 and 62, - not prime

Minimum Number of Gear Teeth.

With a 20 deg. Pressure angle gear if the gear has less than 17 teeth undercutting will occur as shown in Diagram 3. The smaller the number of teeth the more of a problem this will become. A gear with less than 12 teeth is not desirable.

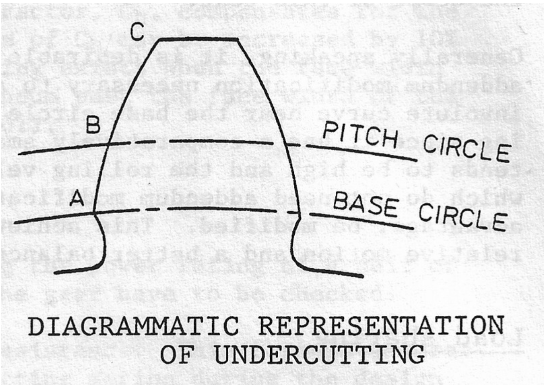


Diagram 3

This completes this first basic gear tutorial, it is just a starting point for acquiring a basic understanding of how to design usable and manufacturable gear assemblies. Laying out a proper involute gear tooth profile is not too difficult but can be quite time consuming so most of us will make use of a gear generation tool. I have found the gear generation tools available in the no cost free cad application FreeCad to have quite good gear generation workspace. As it develops FreeCad is becoming a useful cad tool but as it is a community developed application bits of it function differently, it is like using several different cad applications at the same time. If you only require an approximation and not a true involute tooth profile this tutorial on GrabCad is simple to use.

In the next Gears tutorial we will look further into the process of gear design looking at how we determine how to calculate stress on a gear and working out the width required for our gear.