Gear milling cutters for cylindrical gears

The direct cutting of cylindrical gears is the most old and at the same time, more intuitive system, because the space between two teeth is directly obtained by a milling cutter with a constant profile shaped exactly like the space of the tooth itself.
Of course we get a space at a time and most times you must perform roughing and finishing passes.
The result is an obvious slowness of this process of gearing, which strongly limits the diffusion.
The gear milling cutter is in fact used only for very small series or individual pieces, for the construction of spare parts or other special productions. Its cost, in terms of time, would be prohibitive for mass production.

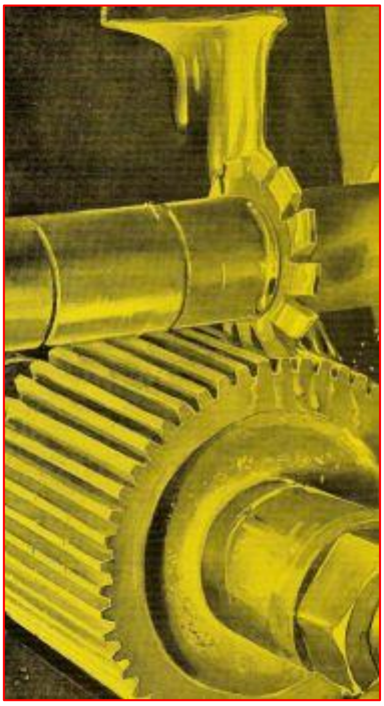

Fig. N°1- *Direct cut of a gear with a gear milling cutter*

This system in theory would require a gear milling cutter for each type of gear. Would be necessary to provide a cutter for each module, for each pressure angle and for each number of teeth.
In order to limit this vast number of different cutters you give up accuracy using a single type of cutter for each group of gears with the same module and pressure angle whose number of teeth is contained in determined limits.
The gear milling cutter are generally an unground profile and are used for cutting wheels at the final size.
It is useless to build a milling cutter with ground profile where the cost is higher in order to have greater accuracy when construction errors are inherent in the concept of this work.
However this may not be true if you plan to make a milling cutter for a specific gear.
In this case the profile of the cutter will be designed based on the characteristics of the teeth to perform and then you can get good accuracy and then it is correct to grind the profile of the tool.
You can even have "*semitopping*" cutters, ie cutters having a profile that can also make a chamfer at the top of the teeth of the gear.
But if we stay on the standard gear milling cutters up to module 9 mm are provided set consisting of 8 cutters, and from module 10 to module 20 mm sets are composed by 15 cutters. The table N ° 1 shows the numbers of teeth of the gears that each milling cutter of the set can be cut.

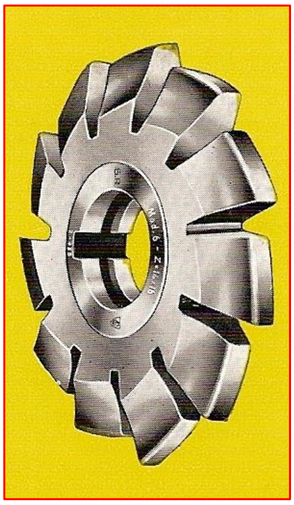

Fig. N°2 -.*Gear milling cutter for finish*

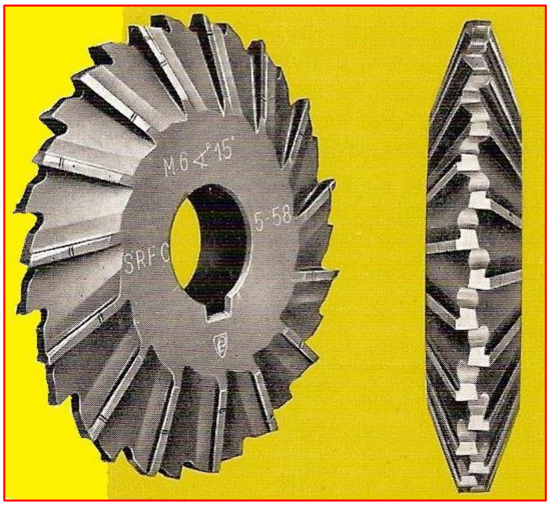

Fig. N°3*- Gear milling cutter for roughing*

The last milling cutter of each set can be used for cutting racks, although this process would be more accurate to use cutters with straight flanks.
The profile of a specific milling cutter corresponds exactly to the shape of space between two teeth of the gear with the smallest number of teeth of the range.
The gear milling cutter listed in the table N°1 are for finish operations ; roughing milling cutters, sometimes adopted to relieve the work of the finishers cutters, or cutting gears in a shorter time, have a lower level of precision and is usually made with an only straight flanks cutter for each module and pressure angle, regardless of the number of teeth on the gear.
In order to increase the efficiency of cutters for roughing operations they can be sharpened with a positive rake angle in accordance with the workpiece material and on the cutting edge you can also make the chip breaker grooves that increase the efficiency of these tools.
The gear milling cutters for finish are usually sharpened with rake angle of zero degree so as not to change the profile in successive sharpening.

Tab. N°1- Composition of gear milling cutters

Set of 8 gear milling cutters up to module 9 mm		*Set of 15 gear milling cutters for module from 10 to 20 mm*			
Cutter number	*N° of teeth of gear*	*Cutter number*	*N° of teeth of gear*	*Cutter number*	*N° of teeth of gear*
1	*12 – 13*	*1*	*12*	*5*	*26 – 29*
2	*14 – 16*	*1 1/2*	*13*	*5 1/2*	*30 – 34*
3	*17 – 20*	*2*	*14*	*6*	*35 – 41*
4	*21 – 25*	*2 1/2*	*15 - 16*	*6 1/2*	*42 – 54*
5	*26 – 34*	*3*	*17 – 18*	*7*	*55 – 79*
6	*35 – 54*	*3 1/2*	*19 – 20*	*7 1/2*	*80 - 134*
7	*55 – 134*	*4*	*21 – 22*	*8*	*≥ 135*
8	*≥ 135*	*4 1/2*	*23 - 25*	*--*	*--*

The table N ° 2 shows the dimensions of commercial gear milling cutters that are designed normally for pressure angle of 14° 30', 15° and 20°.

Tab. N°2- Size of comemrcial gear milling cutters

Module	Outside diameter	Bore diameter	Module	Outside diameter	Bore diameter
0,5	40	16	5	90	32
0.75	40	16	5,5	95	32
1	50	16	6	100	32
1,25	50	16	6,5	105	32
1,5	60	22	7	105	32
1,75	60	22	8	110	32
2	60	22	9	115	32
2,25	60	22	10	120	32
2,5	65	22	11	135	40
2,75	70	27	12	145	40
3	70	27	13	155	40
3,25	75	27	14	160	40
3,5	75	27	15	165	40
3,75	80	27	16	170	40
4	80	27	17	180	50
4,25	85	27	18	190	50
4,5	85	27	19	195	50
4,75	90	32	20	205	50

Cutting of cylindrical helical gears with gear milling cutters

It's possible to use gear milling cutter for cutting cylindrical gears with helical teeth but you can properly choose the cutter to be used. The choice of the cutter must be done taking into account the following considerations.

In figure N°4 can be seen that the pitch cylinder with radius R is cut obliquely by a plane AB through the cutter axis. The milling cutter is inclined from the axis of the gear as the helix angle.

This plan creates an ellipse, which overturned on the plane of the figure comes in ADBH. The circle with radius R_1 is the osculating circle of the ellipse and its center C_1 can be found from the rectangle ACDE by drawing the line E-C_1 normal to AD.

The choice of the milling cutter should be done as if you must to cut a fictitious gear with radius R_1 f instead of R.

With reference to figure N°4 we have:

$$\overline{ED} = \frac{R}{\cos\beta} \qquad \overline{EA} = R \qquad \tan\varphi = \frac{\overline{EA}}{\overline{ED}} = \cos\beta$$

$$R_1 = \overline{C_1D} = \frac{R}{\cos\beta\cdot\tan\varphi} = \frac{R}{(\cos\beta)^2} \qquad z = \frac{2\cdot\pi\cdot R}{P_a}$$

$$Z_1 = \frac{2\cdot\pi\cdot R_1}{P_n} = \frac{2\cdot\pi\cdot R_1}{P_a\cdot\cos\beta} = \frac{2\cdot\pi\cdot R}{P_a\cdot(\cos\beta)^3}$$

$$\frac{Z_1}{Z} = \frac{1}{(\cos\beta)^3} \qquad Z_1 = \frac{Z}{(\cos\beta)^3}$$

In this way, however, slight imperfections resulting mainly because a disk of revolution which is the cutter cannot fit into a helical groove having its same section. The groove so created is not exactly the theoretical one.

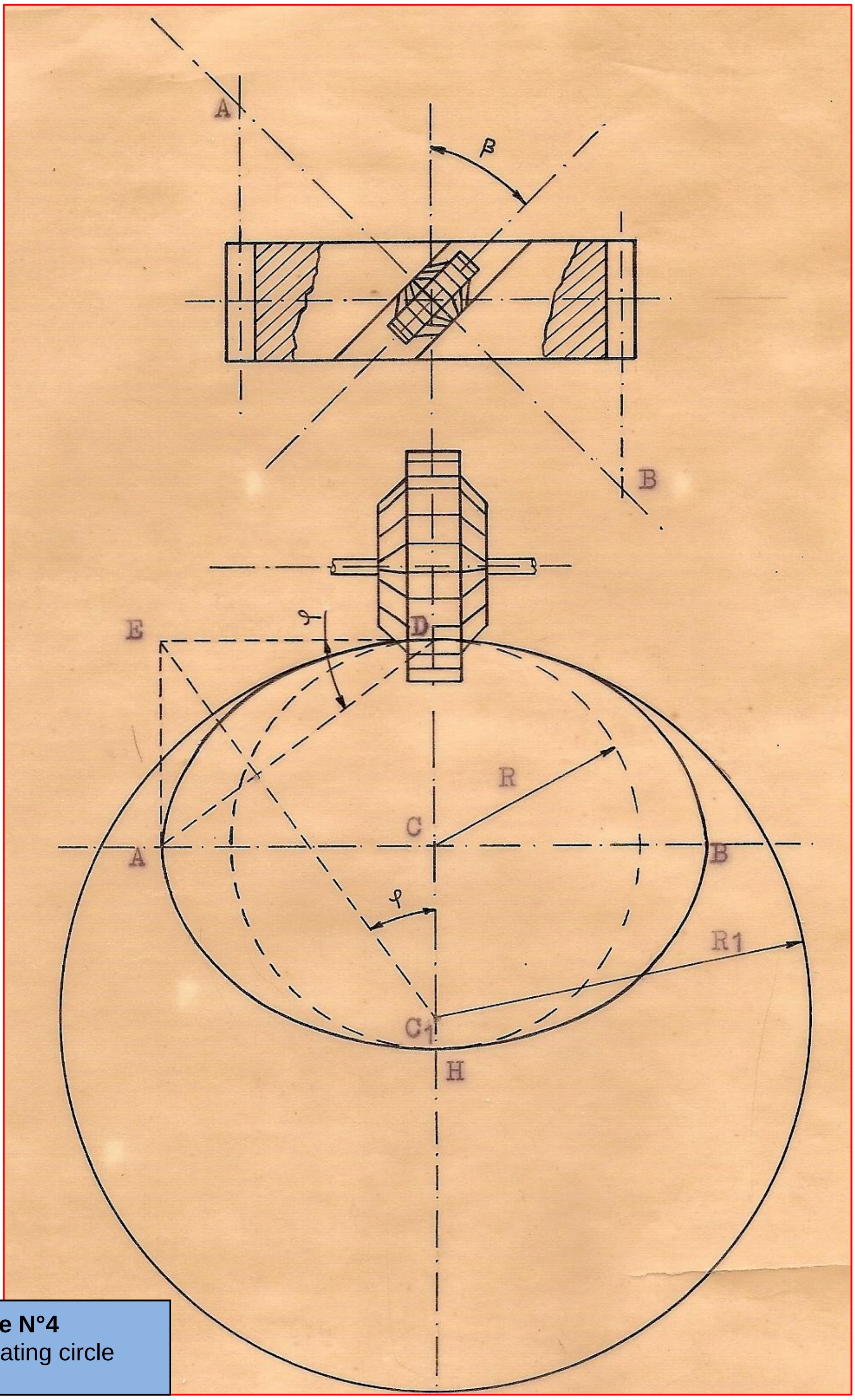

Figure N°4
Osculating circle

in the table N°3 are the values of the ratio $\frac{1}{(\cos\beta)^3}$ for the calculation of the number of fictitious teeth.

Tab. N°3- Values of the ratio $\frac{1}{(\cos\beta)^3}$ *for calculation of the fictitious number of teeth*

β	$\frac{1}{(\cos\beta)^3}$	β	$\frac{1}{(\cos\beta)^3}$	β	$\frac{1}{(\cos\beta)^3}$	β	$\frac{1}{(\cos\beta)^3}$
5°	1,0115	19°	1,1830	33°	1,6952	47°	3,1525
6°	1,0166	20°	1,2052	34°	1,7550	48°	3,3379
7°	1,0227	21°	1,2290	35°	1,8193	49°	3,5414
8°	1,0298	22°	1,2546	36°	1,8885	50°	3,7653
9°	1,0379	23°	1,2821	37°	1,9632	51°	4,0122
10°	1,0470	24°	1,3116	38°	2,0436	52°	4,2852
11°	1,0572	25°	1,3433	39°	2,1363	53°	4,5879
12°	1,0685	26°	1,3773	40°	2,2245	54°	4,9243
13°	1,0810	27°	1,4137	41°	2,3263	55°	5,2994
14°	1,0947	28°	1,4528	42°	2,4366	56°	5,7189
15°	1,1096	29°	1,4947	42°	2,045563	57°	6,1898
16°	1,1258	30°	1,5396	44°	2,6866	58°	6,7200
17°	1,1434	31°	1,5878	45°	2,8284	59°	7,3195
18°	1,1625	3°	1,6396	46°	2,9832	60°	8.0000