The size of the worm grinding wheels in grinding gear

Today many grinding machines use worm grinding wheels for the grinding the gears, because they undoubtedly have a great advantage compared to the form wheels: a smoothing time less in most cases.
At present also, thanks to the great advances that have occurred in the technology of electrolytic deposition, it is possible to construct this type of grinding wheels in CBN also, with a high number of starts.
Given the growing popularity of the grinding process with continuous generation that, it should be spelled out not in opposition but complementary to the form grinding method, it is useful to make some observations on the size of the worm grinding wheels and the influence that the size have on the life of grinding wheels and on the working conditions.
There are two fundamental criteria for estimating the duration of a grinding wheel, ie the number of meters of teeth grindable between two mounting.
The first is to consider the area of the lateral surface of the cylinder on which is formed the grinding wheel and the second is the one that is based on the total length of the screw thread (or of the threads in the case of multiple starts grinding wheels).
In both cases it is evident that all depends on the amount of abrasive involved in the action of cutting. A little deeper into the subject.

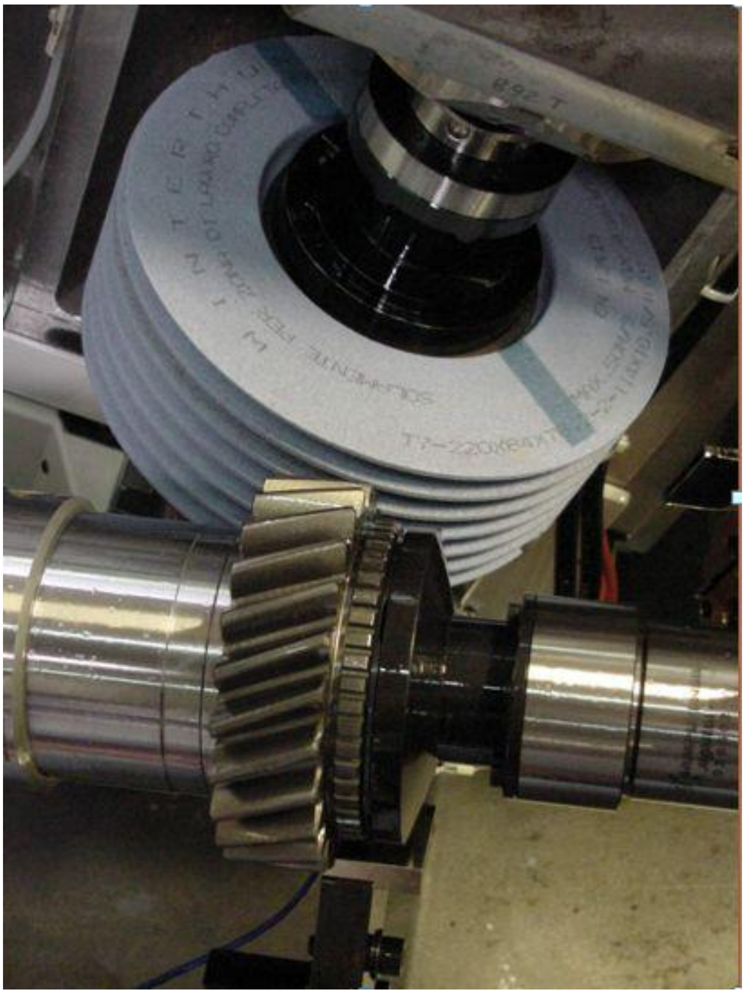

Fig. N°1 – *Grinding with worm wheel*

Area of the side surface of the cylinder
We have to distinguish the total area (At) from the one used (Au), which is the one directly involved in cutting and in the shifting.
In fact, similarly to what happens in the hob, into the ends of inlet and outlet of the grinding wheel must be provided, to complete the profile and to have a certain margin of safety, two unused zones the length of which depends essentially on the module, the pressure angle, the helix angle and the correction factor X of the profile.
Without going into details too fine, it can assume the following values for the part not interested in the shifting (about 10 times the module):

- *for module 2 mm: L_l =20 mm;*
- *for module 5 mm: L_l = 50 mm.*

If we indicate with Lt and Lu, respectively, the total length and the useable length of the grinding wheels you can calculate immediately the lateral area Au.

$$A_u = \frac{\Pi \cdot D^2}{4} \cdot L_u = \frac{\Pi \cdot D^2}{4}(L_t - L_l)$$

The calculated value cannot say how many meters of teeth you may grind, but can only say that if one wheel with a certain lateral area Au performs P meters of teeth between two mounting, a grinding wheel with a lateral area $K \cdot L_u$ can perform approximately $K \cdot P$ meters of teeth.

Thread length

The length of the thread of a worm grinding wheel is, in a certain sense, comparable to the number of cutting edges of a hob.
It is therefore more understandable that the duration of the grinding wheel is directly proportional to the total length of the threads.
The length of the thread of a grinding wheel with one start , calculated on its usable length, is:

$$F_u = \frac{\Pi \cdot D}{\cos\beta} \cdot \frac{L_u}{\Pi \cdot m} = \frac{D \cdot L_u}{m \cdot \cos\beta} = \frac{L_u}{sen\beta}$$

Where : $tg\beta = \frac{\Pi \cdot m}{\Pi \cdot D} = \frac{\Pi}{D}$

Or : $F_u = \frac{L_u \cdot \sqrt{m^2 + D^2}}{m}$

In the multistarts grinding wheel the total length of the threads is slightly different and that is:

$F_u = \frac{i \cdot \Pi \cdot D}{\cos\beta_1} \cdot \frac{L_u}{i \cdot \Pi \cdot m} = \frac{i \cdot L_u}{sen\beta_1}$ with : $tg\beta_1 = \frac{i \cdot m \cdot \Pi}{\Pi \cdot D} = \frac{i \cdot m}{D}$

The difference in length due to different helix angle is, however, absolutely negligible as can be seen from the following example.
Consider a grinding wheel with D = 200 mm and with Lu = 180 mm, module m = 3 mm.
In the case of 1 start we have:

$$tg\beta = \frac{m}{D} = \frac{3}{200} = 0{,}015$$

$$\beta = 0{,}86° \quad ; \quad sen\beta = 0{,}015 \quad ; \quad F_u = \frac{L_u}{sen\beta} = \frac{180}{0{,}015} = 12000mm$$

In the case of 3 starts it has instead:

$$tg\beta_1 = \frac{i \cdot m}{D} = \frac{3 \cdot 3}{200} = 0{,}045$$

$$\beta_1 = 2{,}58° \quad ; \quad sen\beta_1 = 0{,}04495 \quad ; \quad F_u = \frac{i \cdot L_u}{sen\beta_1} = \frac{3 \cdot 180}{0{,}04495} = 12012mm$$

The difference is thus insignificant, indeed it can be completely neglecting the effect of the helix angle of the thread even in the case of grinding wheels with one start .

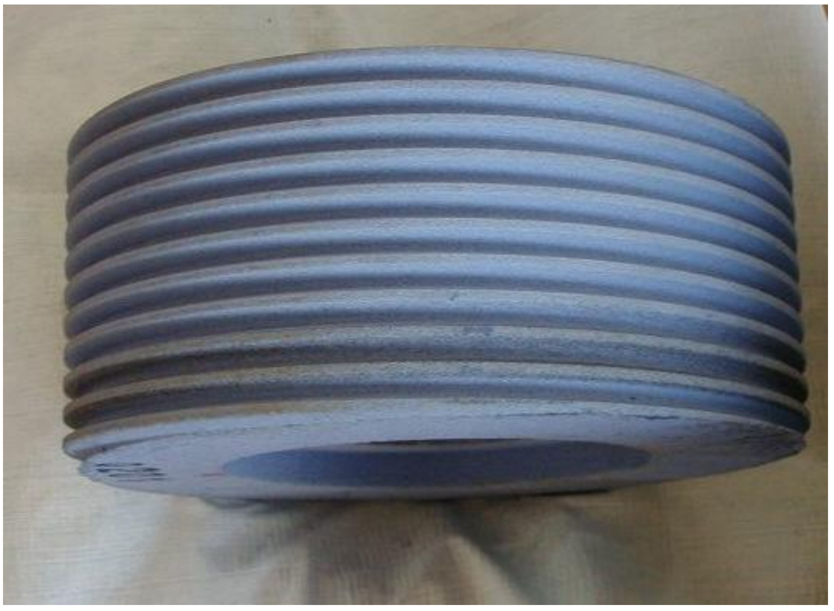

Fig. N°1- *Grinding wheel in aluminum oxide*

As can be seen, the duration of the grinding wheel depends on the diameter and the usable length.
For the usable length of the discourse is analogous to that which can be done about the hobs, that is, that it would be desirable to have the maximum length possible, compatible with the characteristics of the grinding machine and of the possibility of construction of the grinding wheel as well as of its handiness.
To the effects of the life of the grinding wheel, it would also be advisable to use grinding wheels of large diameter, but here we must consider that the grinding time depends significantly on the diameter of the grinding wheel.
With smaller diameters can reduce grinding time.
In fact, at constant cutting speed, the grinding wheel of small diameter becomes more revolutions per minute, and therefore also the piece will rotate faster, then for the same feed of workpiece per revolution you will have higher feed per minute and therefore less time.
The grinding wheels of small diameter have also another advantage: that of being able to work in cutting speed slightly higher than the grinding wheels of larger diameter.
In fact, the arc of contact between the grinding wheel and the workpiece is lower and in this way reduces the thermal stress on the workpiece that is on the grinding wheel, also

about smaller diameters the action cutting oil is more effective because it can reach more easily in proximity of the point of contact between the grinding wheel and workpiece.
But it is obvious that you cannot indefinitely reduce the diameter of the grinding wheel, the more so to find a reasonable compromise between wheel life and grinding time you need to enter another element that might be relevant: the quality of the gear ground.
When reducing the diameter of the grinding wheel, at constant feed per revolution, are obtained of more pronounced grooves on the surface of the tooth ground.
The depth of the grooves can sometimes exceed the limit.
The diameter of the worm grinding wheels in aluminum oxide generally can range from 150 to 300 mm, while those in Electroplated CBN can range from about 80 to 200 mm.

Number of starts
The correct choice of the number of starts of a worm grinding wheel is of fundamental importance for optimizing the grinding time and the desired quality on the gear.
The increase in the number of starts, **i** , of the grinding wheel, implies a proportional increase of rotation speed of the workpiece and then, with the same feed of workpiece per revolution, a reduction of the grinding time.

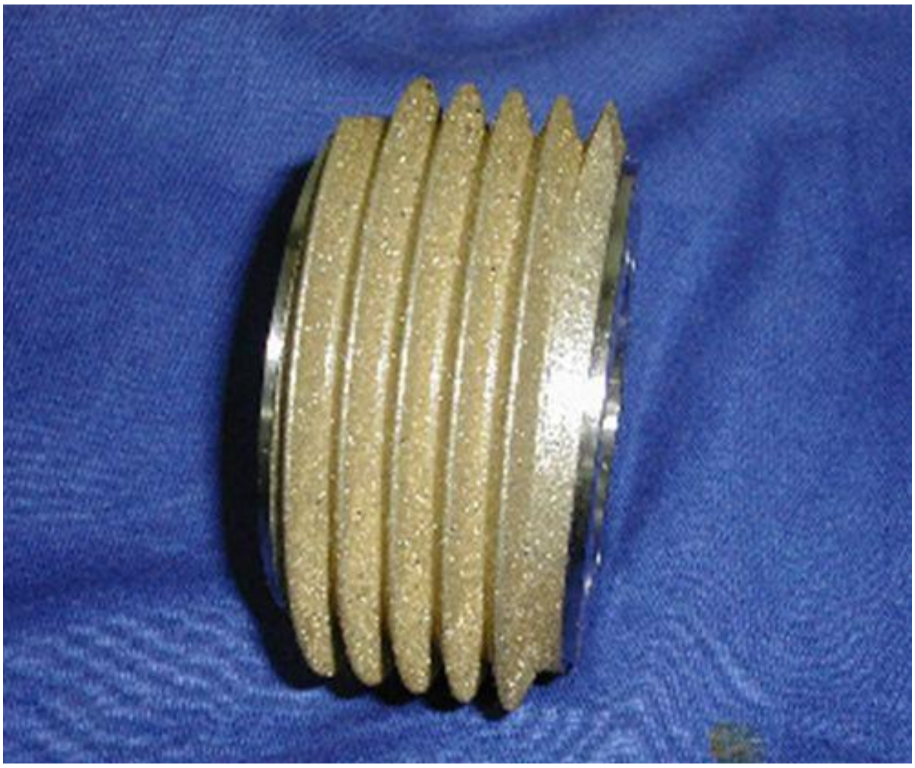

Fig. N°3- *Electroplated CBN worm grinding wheel*

If we indicate with:
N_m = *RPM of grinding wheel*
N_p = *RPM of workpiece*
Z = *Number of teeth of workpiece*
I = *Number of starts of grinding wheel*
A_g = *Feed of the grinding wheel (mm per devolution of workpiece)*
L = *Stroke length*

The situation can be summarized with the following expressions:

$$N_p = \frac{N_m \cdot i}{Z} \quad ; \quad t = \frac{L}{N_p \cdot A_g} = \frac{L \cdot Z}{N_m \cdot i \cdot A_g} \quad \text{(time of one pass)}$$

We must consider, however, that it is not possible to increase indefinitely the number of starts, as the grinding wheel would be increasingly stressed and the quality of the workpiece, the profile especially, would suffer.
Much depends also on the number of teeth of the workpiece and in fact there is a rule, dictated by experience that says that the ratio between the number of teeth of the workpiece and the number of starts of the grinding wheel must be between 8 and 12, also as a function of type of operation (roughing or finishing) and the desired quality.
Another tie is that this ratio should never be an integer; ie the number of teeth must never be a multiple of the number of starts, (possibility of a division error of the gear).
With increasing the number of starts is not possible to keep the same feed per revolution **Ag**, but it is not necessary to reduce it proportionally.
This means that the increase in the number of starts always generates a reduction of the grinding time.
In common practice, the grinding wheels with ceramic can reach a maximum of 7 starts, while the electroplated CBN grinding wheels only in exceptional cases can be up to 5 starts.
The feed per workpiece revolution depends not only on the number of starts, also by the module and the number of gear teeth.
Obviously everything is subject to the desired quality on the workpiece, but in general, for the ceramic grinding wheels, are valid values indicated in the following table.

Axial feed per workpiece revolution

N° of starts	N° of Teeth	Module (mm)			
		2	3	4	5
1	15	0,50	0,40	0,35	0,30
	20	0,55	0,45	0,40	0,35
	30	0,60	0,50	0,45	0,40
	40	0,70	0,60	0,50	0,45
	50	0,75	0,65	0,55	0,50
	60	0,80	0,70	0,60	0,50
	70	0,85	0,70	0,60	0,55
	80	0,90	0,75	0,65	0,60
3	40	0,43	0,35	0,28	0,25
	50	0,48	0,38	0,32	0,28
	60	0,53	0,42	0,35	0,31
	70	0,57	0,45	0,38	0,33
	80	0,62	0,48	0,41	0,35
	90	0,65	0,50	0,44	0,37
5	40	0,32	0,26	0,22	0,19
	50	0,36	0,28	0,24	0,21
	60	0,39	0,30	0,26	0,22
	70	0,41	0,32	0,27	0,23
	80	0,43	0,34	0,28	0,25
	90	0,45	0,36	0,30	0,26
	100	0,47	0,37	0,31	0,27
	110	0,49	0,38	0,32	0,28