## Multi-start hobs

We have already briefly seen that this special kind of hob, which is widely used in gear manufacturing, may be compared to a multi-threaded milling cutter. The first observation that we must therefore make is that if the number of revolutions of the hob per minute is constant, the gear will have higher angular speed, that is double if the hob has two starts, triple if the hob has three starts and so on.
In other words each time the hob revolves, the workpiece will revolve by an angle that corresponds to as many teeth as there are threads.
This means that if the cutting conditions are constant, the time needed to cut the gear with a hob that has two starts will be half that of a single-start hob.
Unfortunately, however, it is not quite so straight-forward.
To get things clear, let us take the example of a two-start hob. During one revolution it will cut two gear teeth which means that it will be strained twice as much as a single-start hob and this is clear if we consider that the volume of chips removed in one revolution of the hob is double.
In short the feed per workpiece revolution $\mathbf{f_a}$ cannot be the same as that which would be used with a single-start hob; it must be lower. In any case its value must allow for a considerable reduction in hobbing time especially if the number of teeth is increased.
This is not the only aspect to keep in mind. The fact that it takes half of the hob teeth to form a gear tooth means that the tooth profile is enveloped by only half the enveloping lines and therefore it comes less closely to the theoretical profile. In other words the profile is less accurate.
With reference to figure N°1 and **f'** being the number of enveloping lines that envelope the gear tooth profile, the following applies:

$$f' = \frac{e \cdot i}{t_g \cdot f} \qquad \text{where:}$$

*e = length of the meshing line*
*$t_g$ = Base pitch*
*i = Number of gashes*
*f = Number of hob's starts*
*$d_k$ = Outside diameter of gear*
*$d_f$ = Root diameter of gear*

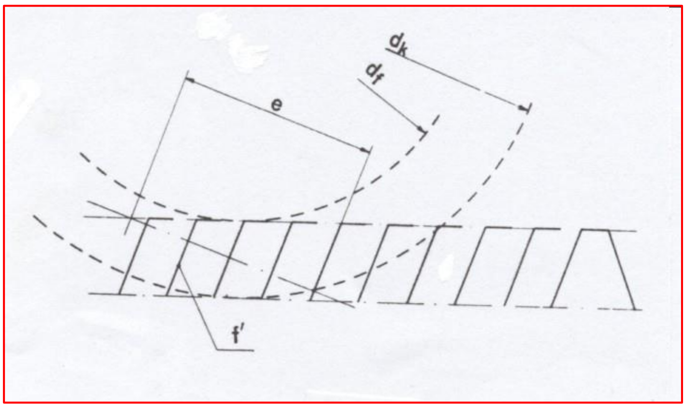


**Fig. N°1**

Consequently multi-start hobs should have a higher number of gashes.
Also with multi-start hobs there may be indexing errors between the starts and this is not the only accuracy limitation as there is also a larger tooth to tooth error which is caused by the lead error. (see figure N°2).

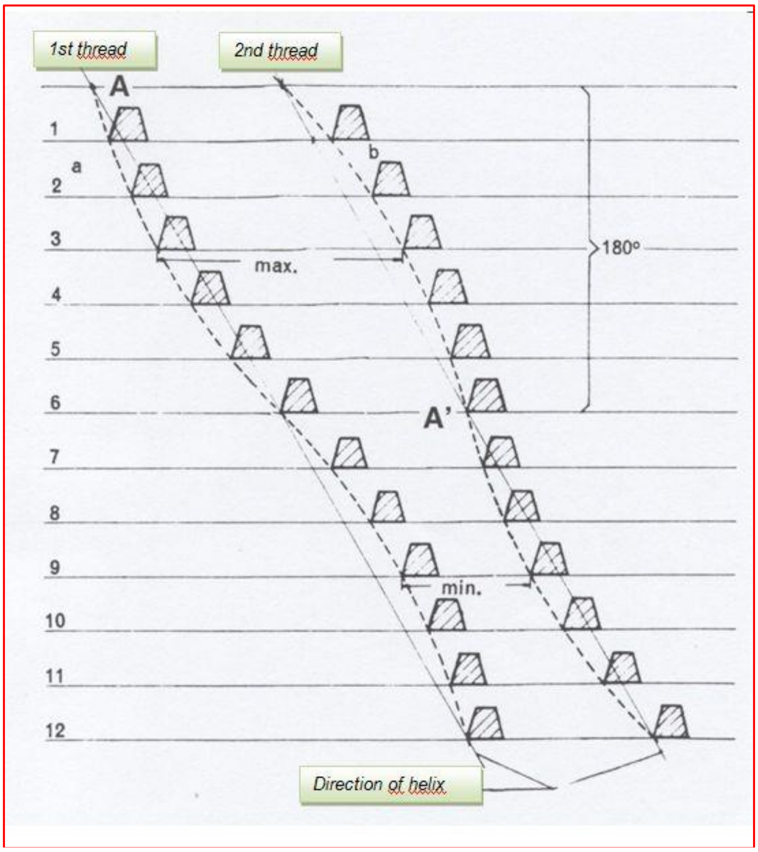


**Fig.N°2**

Figure N°2 illustrates a two-start hob with 12 gashes. If we imagine developing the pitch cylinder on a plane, the tooth section would appear as in this figure.
If when grinding the first thread, the lead error (due to errors of the grinding machine) is the one indicated by the dotted line (a), the same error will also be generated when grinding the second thread (b).

To grind the second thread the hob is rotated by 180°, while the machine is idle, and so the grinding wheel which was in contact with the first thread at point A will come into contact with the 6$^{th}$ tooth of the second thread after this rotation at point A'. The lead errors will therefore be staggered by 180° compared to those on the first thread and therefore the pitch error is amplified as is clearly shown in the figure.
This problem is easily overcome, however, if the profile is ground by a Numeric Control machine. The indexing errors between the threads and the lead error are reduced to such an extent that they are negligible.
With hobs that have an even number of starts, more profile errors are generated by the run out that occurs arises when mounting the hob on the machine. If the hob has an odd number of starts, this error tends to compensate itself and is less significant.
As regards the divisibility between the number of gear teeth and the number of hob starts the following three ratios are possible:

1) *an even ratio (the number of gear teeth is exactly divisible by the number of starts)*
2) *a common divisor*
3) *a prime ratio*

In the first case, the same thread of the hob always enters into the same tooth vane so the thread indexing error of the hob generates a pitch error on the gear. For example, with a two-start hob, the first start always cuts the even teeth and the second cuts the odd teeth.

In the third case, that is when there is a prime ratio between **Z** and **f,** all the threads enter into all of the tooth vanes which means that indexing errors are spread between the threads but these errors generate bigger profile errors.
Lastly in the second case, a number of the threads will generate each vane so as regards error distribution, the results are halfway between the other two types described.
In general it is preferable to have a prime ratio between the number of gear teeth and the number of starts as a profile error can be easily eliminated by shaving.
The use of modern numeric control relief grinding machines has reduced many indexing errors between the various threads and lead errors are also usually very low.
The above considerations have therefore become less significant to a certain extent even though such difficulties have not been resolved completely.

When error distribution on the surface of a tooth is examined, it will become clear that profile accuracy depends on the number of gashes that contribute to cutting a tooth, as mentioned above, and that the helix error depends predominantly on the feed per workpiece revolution of the hob.
This last type of error on the helix is much larger than that on the profile and with multi-start hobs it tends to be smaller due to the lower feed per piece revolution applied.
In some cases the concept of increasing the number of starts is taken to extremes and the feed per revolution is practically reduced proportionally.
In this way the helix errors on the gear are very limited and if these errors are distributed opportunely, the profile errors will also be low.

To be able to do this it is essential to have a hobbing machine that can withstand very high workpiece table speeds, even 2 – 3 times faster than the hob spindle.
The following two examples are very indicative.
The feed speed (mm/min) is equivalent to that which would be obtained with a single start hob and a feed per workpiece revolution of respectively 4,8 and 4,5 mm, but with the advantage that the depth of the helix error is extremely limited, so much so that the workpiece does not require further finishing operations.
It is worth noting that the number of starts in the second example is divisible by the number of teeth. This is not of any particular significance but it means that each gear tooth is always cut by the same three starts.

*Table No.4 – Examples of manufacturing with a large number of starts*

| | Example N°1 | Example N°2 |
|---|---|---|
| Hob diameter (mm) | 101 | 100 |
| Module (mm) | 2,5 | 2,5 |
| N° of gashes | 35 | 38 |
| N° of starts | 16 | 15 |
| N° of gear teeth | 7 | 5 |
| N° of hob revolutions (rpm) | 347 | 318 |
| Cutting speed | 110 | 100 |
| N° of workpiece revolutions | 793 | 954 |
| Feed (mm/workpiece revolution) | 0,3 | 0,3 |
| Feed (mm/min) | 327,9 | 286,2 |