

## **Quality obtainable through shaving**

Shaving operation can improve the quality of a hobbed gear of about 2÷3 classes. Anyway the final results depend not only on designing and manufacturing accuracy of the cutter, but also on a series of conditions that influence (with a differential effect) the accuracy of a finished gear.

We can divide such conditions in the following groups:

### **Work piece conditions**

- Gear profile (normal, with protuberance relief, with tip chamfer, with modified profile)
- Quality of gear
- Shaving stock removal
- Workpiece material

### **Shaving method and working conditions**

- We will explain at a later stage the different shaving methods, whose choice depends both on the machines currently available, and on the workpiece main geometry.
- The choice of the cutting speed, feeds, number of passes are decisive for a good performance of the operation. Sometime it is necessary to research the optimum working conditions through practical trials.

### **Shaving machine status and workpiece clamping systems**

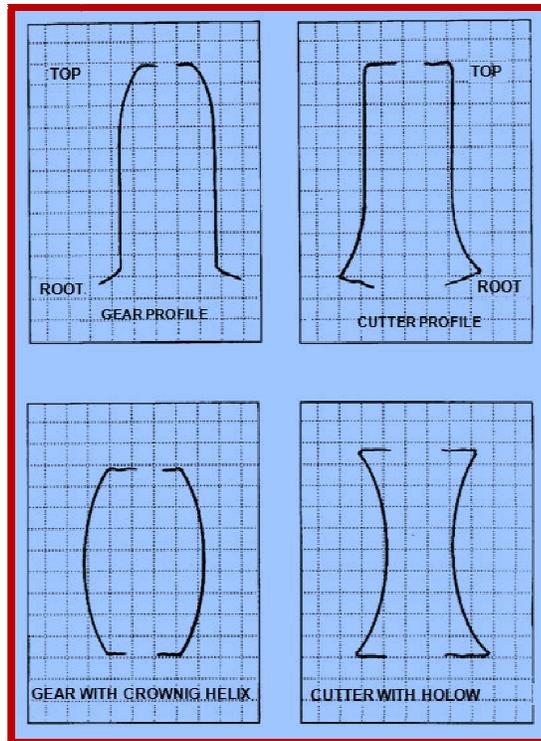
- It is obvious that the shaving machine must be in good operating conditions. No vibrations, flexures, backlash on the spindles, run out on workpiece and cutter rotation must be there, as well as axial fluctuations
- The workpiece must be properly locked with flanges arriving as close as possible to the gear teeth, and through systems and forces that can avoid flexures, sliding and offset rotations.

<b><i>What you can obtain through shaving</i></b>
<ul style="list-style-type: none"><li>❖ Profile improvement of 2÷3 DIN classes</li><li>❖ Helix improvement of 2÷3 DIN classes</li><li>❖ Indexing improvement of 1÷2 DIN classes</li><li>❖ A run out error can be transformed in a cumulative pitch error through shaving</li><li>❖ You can get rid of hobbing scallops and other irregularities left by hobbing operation</li><li>❖ It is possible to obtain a surface with good finish almost as smooth as the surface finish you can obtain by grinding (<math>R_a=0.4\div0.6\ \mu\text{m}</math>)</li><li>❖ You can obtain gears even in class 4 (DIN 3962), but with a properly performed pre-shaving operation, with a lot of care in shaving, long shaving times and main workpiece characteristics favourable to shaving.</li></ul>

Through shaving it is possible to manufacture gears having a modified profile with respect to the theoretical one and also helix is normally modified; you can have the so called crowning, i.e. a convexity along the longitudinal direction.

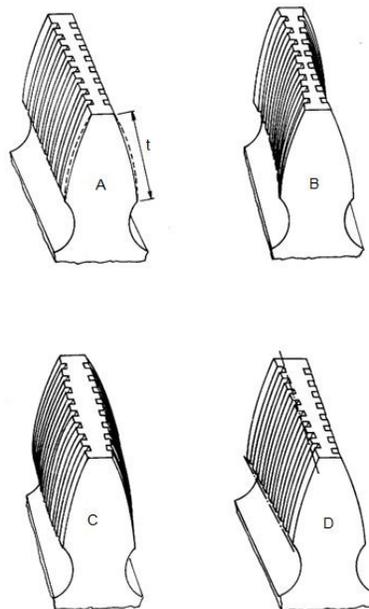
All these corrections of the theoretical parameters are required in the workpiece so as to reduce its noise during the meshing and can be obtained, up to a certain limit, by appropriately shaping the shaving cutter.

Further to that you can obtain slightly taper teeth on a gear starting from a cylindrical hobbed gear.



**Fig.N°3-** Schematics for the gear profile and helix modification and corresponding cutter profile and helix correction

But the possible variations you can obtain on the profile and the helix of a gear are many and they depend upon the type of gear that you want to work.  
In figure no.4 you can find some examples of special applications .



**Fig.N°4-** Examples of special profiles and helix  
 (a) Illustrates involute hollow designed to produce a concave involute gear (crown).  
 ( $t$ =profile working length)  
 (b) Illustrate a hollow helix designed to produce a concave helix gear (crown)  
 (c) Illustrates a concave helix (crown) used to shave internal gears  
 (d) Illustrates a tapered helix designed to produce slightly tapered tothing

Before going into details about what we have just mentioned, we have to see which are the classes of gear accuracy achievable by shaving and the related normal use of such gears.

In table no.1 we have listed the classes of accuracy according to DIN table 3962 and the uses linked to them; we have to clarify, anyway, that there is a high degree of discretion in the choice of gear quality ; let's not forget that the final result, i.e. the noise generated by meshing, depends on many other parameters that have hardly to do with gear accuracy.

Even from these first pages you understand that shaving operation is a delicate matter which requires a peculiar attention to all what it is connected to it, either directly or indirectly.

We are keen on repeating that, above all, the final gear accuracy greatly depends on the deformations due to heat treatment. This last operation can reduce accuracy of 1÷2 Din classes, in function of the type of heat treatment, of the gear shape and the quality of the workpiece steel.

<b>DIN class</b>	<b>Field of application</b>	<b>Comments</b>
3	<i>Accurate master gears for inspection rooms</i>	<i>These are normally ground gears</i>
4	<i>Master gears of common use, checking equipments gearing, aircraft gears subject to high torque, accurate machine tools</i>	<i>In exceptional cases they can be obtained by shaving, but they cannot undergo heat treatment</i>
5	<i>Aircraft gearing, machine tools, high gears for car gearbox, bus, lorries, inspection equipment</i>	<i>An acceptable quality can be achieved through a good shaving, but the good quality is normally lost after heat treatment</i>
6	<i>Automobile and industrial gearbox, machine tools, speed reducers.</i>	<i>This quality can be achieved fairly easily through shaving or after heat treatment starting from a class DIN5</i>
7	<i>Standard accuracy for automobile and industrial gearbox. Normally used in low speed reducers.</i>	<i>Standard quality of a normal shaving. There are no problems to maintain such quality after heat treatment</i>
8	<i>Low gears for automobile and commercial vehicles gearbox, tractors agricultural machines and machine tools</i>	<i>No problems for shaving. Normal heat treatment provided the main geometry of the workpiece is not unbalanced</i>
9÷10	<i>Agricultural tractors, ancillary gearing in machine building, conventional gear reducers</i>	<i>These parts are normally finished hobbled or shaped</i>
11÷12	<i>Agricultural machines in general, low quality kinematics</i>	<i>Same as above</i>

*Table no.1 - Classification according to DIN 3962 table*

As you can see, when gear accuracy is mentioned, DIN specifications are normally stated. This happens because these specifications are universally known, but other important specifications exist and can be found on workpiece drawings.

In table no.2 a comparison is made among the various accuracy specifications foreseen in the main industrial countries.

The correspondence among the various standards is only indicative because it does not exactly cover all the errors.

<b>DIN</b> Germany	<b>UNI</b> Italy	<b>JIS</b> Japan	<b>AGMA</b> USA	<b>BSS</b> England
1	1	-	-	-
2	2	-	-	-
3	3	0	-	-
4	4	1	12	A1
5	5	2	11	A1
6	6	3	10	A2
7	7	4	9	A2
8	8	5	8	B
9	9	6	7	C
10	10	7	6	C
11	11	-	5	D
12	12	8	-	D
-	-	-	-	D

Table no.2 - Comparison among the various accuracy classes pertaining to the different standards

Definition of profile, helix and spacing errors

DIN table 3960 defines the profile, helix and indexing errors and the related symbols that identify the a.m. errors in the pre-printed inspection charts performed by the modern checking equipments.

In order to understand inspection charts it is necessary to know exactly the meaning of these symbols and it is for such reason that we are below listing them.

Profile errors mentioned are schematised in figure no. 5 and need no further comments.

They are :

- $F\alpha$  = total profile error
- $ff\alpha$  = profile shape error
- $fH\alpha$  = profile angular error

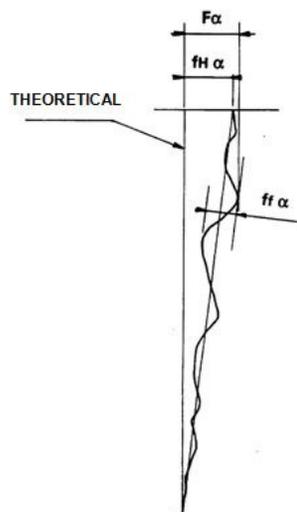


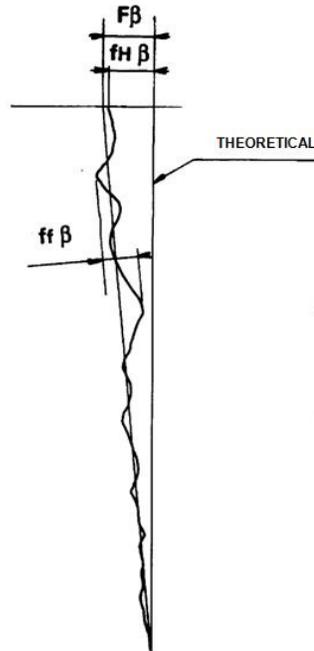
Fig.N°5- Profile error definition

Helix errors are defined in an equivalent way and are clearly defined in figure no.6. They are:

$F\beta$  = total helix error

$ff\beta$  = helix shape error (waviness)

$fH\beta$  = helix angular error



**Fig.N°6-** Helix error definition

Pitch (or indexing) error is more articulated and we can distinguish the following types of errors.

- $f_p$  = Single pitch error. It is the algebraic difference between the effective transversal pitch and its theoretical value. The theoretical transversal pitch is the average of all the effective transversal pitches
- $f_u$  = Pitch error. It is the maximum pitch difference among three consecutive teeth
- $f_{pe}$  = Base pitch error
- $F_p$  = Total pitch error. It is stated without sign and it is the sum of all the absolute values between the maximum negative error and the maximum positive error.
- $F_{pz/8}$  = Cumulative pitch error on 1/8 of revolution (45°). It is the maximum cumulative error measured along approx. 1/8 of the total teeth no.
- $F_r$  = Concentricity error. It is the offset existing between the geometrical axes of the gear and the reference axes of a radial section.

In the modern checking equipments such error is calculated considering the pitch errors surveyed along RH and LH flanks. In other words, the equipment memorises the position (in space) of the single flanks and calculates error  $F_r$ . It corresponds to the eccentricity inspection performed by measuring the differential penetration of a sphere leaning against the teeth spaces.