## The master for the control of the gears

The master gear is a special gear that is coupled with the gear to be checked in order to highlight the construction errors or serious imperfections that may compromise the finishing operations.
The master gear is used to control a wide range of gears, one need only consider that there are also master for micro teeth, with module of 0.1 mm.
Can also be considered master gears the sample that is used to set up the rolling gear testers or other equipment.
These latter types of master gear are also called, especially in the Far East, "*monitor gear*".
The double flank rolling gear testers are monitoring equipment normally used to highlight three errors on the gears: the error of eccentricity, the error center distance and dents present on the teeth.
Unlike earlier, the single flank rolling gear testers are more sophisticated units because they allow the determination of errors on each side of the gear teeth.
The contact between the master and gear takes place with backlash, reproducing in a certain way mating conditions that have in gearbox.
One can still distinguish the single flank rolling gear testers that operate without load to be those in which a load is applied to simulate even more the conditions of use. These last rolling gear testers are primarily used in the laboratory.
Returning to the double flank gear tester, which is the one commonly used in the workshops for the control of mass production can be said that the classical represented by diagram of meshing is represented in the figure N°1, which indicates clearly the errors of eccentricity, the center distance and the presence of dents on the teeth.

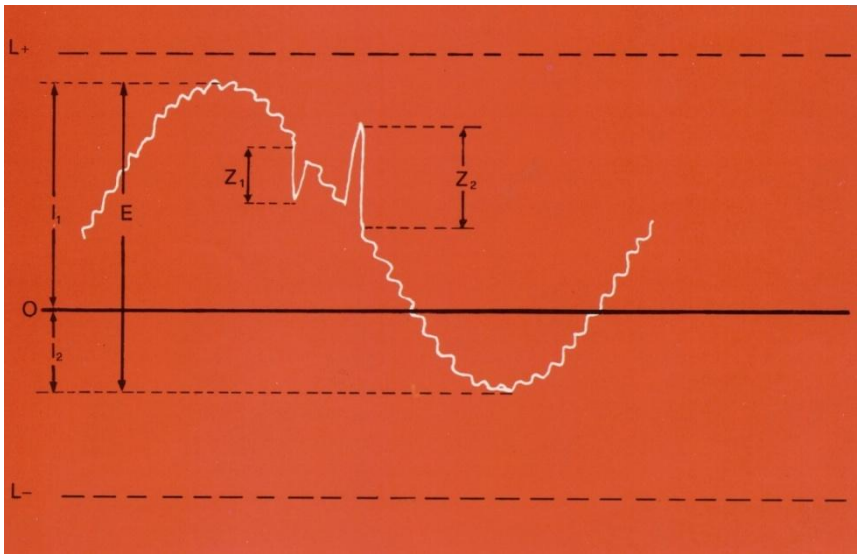


**Figure N°1-** *Diagram of meshing of a single flank rolling gear tester*

- *E = Eccentricity*
- *(1 – 2) = Deviation from theoretical center distance*
- *$Z_1$ e $Z_2$ = Nicks*

As will be mentioned shortly, the rolling gear testers most modern of this type can highlight other errors in addition to those listed above.
The control is carried out by analyzing the rotational irregularities of the master when it meshes with the gear; these irregularities, usually manifest as a shift in the radial direction of the slide of the master.

The displacements of the slide are detected by a sensor and sent to an electronic device which will processing them.
As mentioned above, however, this is not the only case in which it is used a master.
The simplest case is that of control which is carried out after an operation of toothing with a hob or with shaper cutter and before starting a finishing operation with grinding or shaving.
In this case it is extremely important that the gear that must be finished has not serious errors, such , for example, a tooth or a radius on the bottom tooth too large, because in this case could cause breakage of the teeth of the shaving cutter or serious damage to the grinding wheel.
These large errors can be caused, not very rarely, by broken teeth of the shaper cutter or abnormal wear on the teeth of the cutter or hob.
The master gear for this control, applied in a simple device at the entrance of the finishing machine, has no special requirements for precision, but should be so designed that during rotation it arrives to touch the entire profile of the gear to be inspected, until the beginning of the active profile at the bottom of the tooth.
Another case of master gear that does not require a great precision of construction is what is used for the set-up of the gear testers. In this case for the truth it is a true sample gear, built with the same geometrical characteristics of the gear to be checked.
The only warning is to do everything possible to have the thickness of the tooth of the gear in the middle of tolerance of the checked gear, but in any case it is important to know what is actually this value, in order to properly calibrate the equipment.
For the rest of the tolerances should be about the same as those of the gear or a little less.
The master gear real, what is used in the rolling gear testers is instead a very precise gear which meshes with the gear to be checked. Unfortunately, however, even if it is very precise, it will never be error free.
These errors overlap with those of the gear, introducing a margin of uncertainty in the measurement, uncertainty that is greater the less accurate is the master gear. Leaving aside the errors of profile and helix that in the master are usually extremely limited and virtually no influence on the measurement errors of eccentricity and spacing, you must linger attention to what happens when the eccentricity of the master and the gear are combined.
The precision of the gears and therefore also of the master gear is defined by the table DIN 3962 and the errors depend on the module, the diameter and precision class that is considered.
The following table shows the errors of eccentricity allowed for classes interesting the master. Meanwhile, you can see immediately that the class DIN 2 has errors that are 50% of the class DIN 4, but as has been said, with modern grinding machines is not very difficult to obtain a master gear class 2 DIN.

*Eccentricity according to DIN 3962 (micrometers)*

| ***Module mm*** | ***Diameter mm*** | ***Class DIN 2*** | ***Class DIN 3*** | ***Class DIN 4*** |
|---|---|---|---|---|
| *1 - 2* | *50 - 125* | *4* | *6* | *8* |
| | *125 - 280* | *5* | *7* | *9* |
| *2 - 3,55* | *50 - 125* | *5* | *7* | *10* |
| | *125 - 280* | *5,5* | *8* | *11* |
| *3,55 - 6* | *50 -125* | *5,5* | *8* | *11* |
| | *125 - 280* | *6* | *9* | *12* |

It may be noted that errors are not completely negligible if compared with the corresponding errors on the gears.
If you think that if it should be checked, for example, a gear class DIN 6, which has an error of eccentricity of 20-22 micrometers (for modules from 2 to 3.55 mm), it is seen that a master class DIN 4, with an error of 10 micrometers, in practice covers 50% of the error that must be checked.
The errors of eccentricity of the master and of the gear follow a sinusoidal law, of the type indicated in figure N°1, with an amplitude equal to the error admitted and with a period that depends on the number of teeth.
If, as it must be, the number of teeth of the gear is different from that of the master, the two sinusoids, with different amplitude and period are added or subtracted with a causal law, making it very uncertain the control result.
Until a few years ago the master standard was of DIN class 4 and class of DIN 3 was considered a master of precision.
Today the situation has changed. The master are ground with numerical control machines, with both the method: generation and form, that ensure, for all parameters, but especially for the division, directly connected to the eccentricity, a very high accuracies.
That is why today the standard is considered the master in class DIN 3, while the precision master gear is in class 2 DIN.
In addition to the precision of the teeth, ie the profile, helix and the division, in the master is very important to the parallelism of the flat surfaces and their perpendicularity to the axis of the master. Errors of this type of course would cause irregularities in the rotation with consequent uncertainty on the accuracy of control.
But even with this increase in the quality of the master, the problem, though slightly reduced, remains.
But we must immediately point out that a good solution has been found by using a computer dedicated to the analysis of the data collected.
There are in fact a special software that allow you to separate the errors of eccentricity due to master, from those of the gear.
The first condition for making this possible is that the number of teeth of the gear must not be divisible by number of teeth of the master, condition easily obtainable during the design of the master.
The second is that one must rotate the gear for at least two revolutions during the acquisition of data, therefore there is a small increase in the time of control.
This software is very important, because in case two gears are coupled in the gear tester, you can find the errors of eccentricity of both.
It is clear that this particular software has allowed to make a remarkable improvement in the reliability of the controls of eccentricity with zero backlash gear testers.
In the absence of this software, when it is necessary to determine the reliability of the checking equipment, that is, its repeatability, it is necessary to start with the control taking care to mount the master and the gear always in the same position. This is easily done by marking the teeth.
Has some importance also the fact that the master has or has not the convexity of the helix.
Normally the gears have the helix convex what has already sufficient to guarantee a correct contact also if the master have the theoretical helix; in fact practically all masters are constructed with theoretical profile and helix.
It may, however, be born any inconvenience if the gear to be checked not had crowning, in this case, the contact between the teeth could be only at one end of the tooth itself with possible errors in the control (Figure N°2).

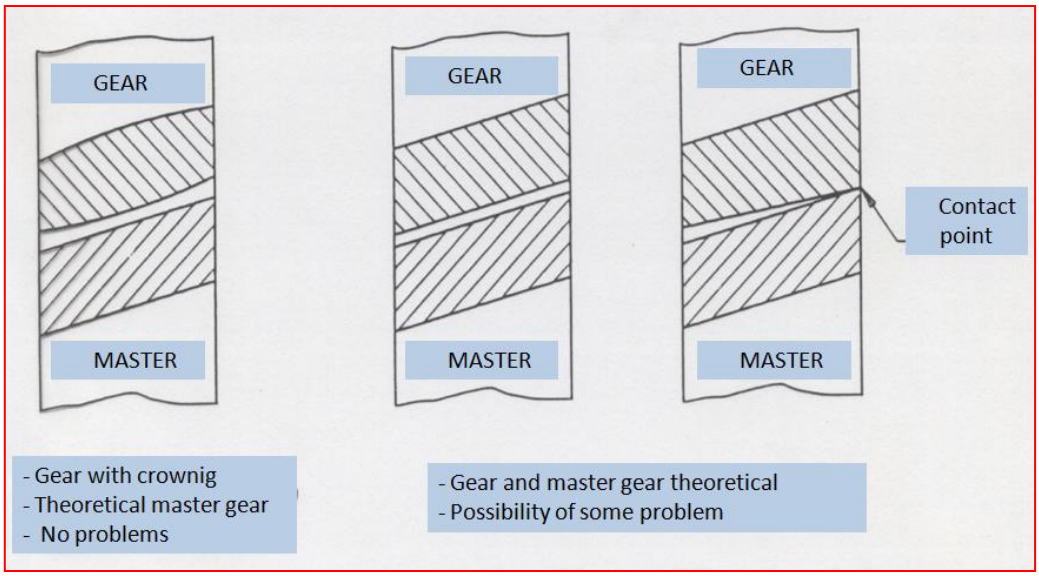


**Figure N°2-** *Master with theoretical helix and with crowning*

Another important news relative to zero-backlash gear testers, introduced very recently, is the possibility to detect possible errors of the inclination of helix and the taper of the teeth. This is made possible by the fact that the master holder can be tilted in two directions indicated schematically in figure N°3.

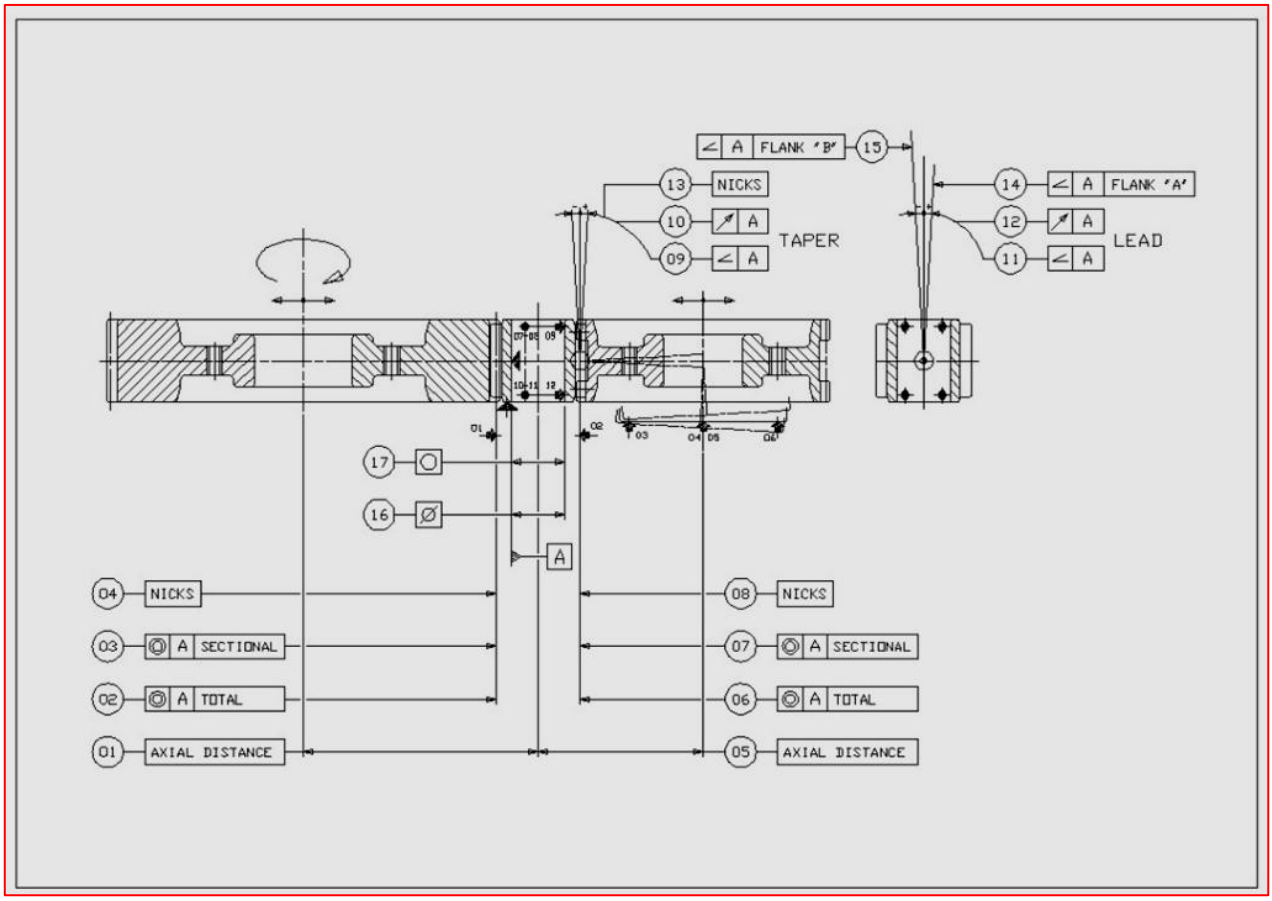


**Figure N°3-** *Schematic representation of the head for control of inclination and tapering of the teeth (tilting master gear)*

Since the master is pressed against the gear, its teeth are housed between the gear teeth, that is, they follow the direction of the teeth of the gear itself.
In the synoptic scheme of Figure # 3 it can be observed that the rotation is given by a dedicated gear (on the left). In fact, it is not possible to assign this function to the gear to be controlled as you measure the parameters of the hole, and even the master cannot be driven as it must be able to move freely in both directions indicated.
It is sufficient to measure the inclination of the master in both directions in order to know how the teeth are conical or how the helix deviates from the theoretical one.
It is also possible, by analyzing the values of taper and of helix, understand the error of helix of each tooth flank of the gear.
It is clear that this will not be a real relief of helix, but the determination of its average inclination, but it's a big step forward in the automatic control of the gears.
In this type of control is necessary to use a master modified so that it comes into contact with the flanks of the gear teeth at the ends of the teeth themselves, must therefore be discharged to the center.
In fact, if the master was theoretical and gear convex, the contact would be at the center of the teeth and the master would not be able to follow the trend of the helix.
This type of control has recently successfully passed the stage of development and testing and has entered in the marketing phase.
Two more words on the master gears produced today, to say that in addition to the higher precision of the parameters of the teeth, they also have a duration much higher because are coated with TiN.
The steel normally used for the construction of the master is a category M2 , with a hardness of about 62-64 HRC, this feature combined with the coating gives, as is known, a greater resistance to wear and therefore a greater dimensional constancy .

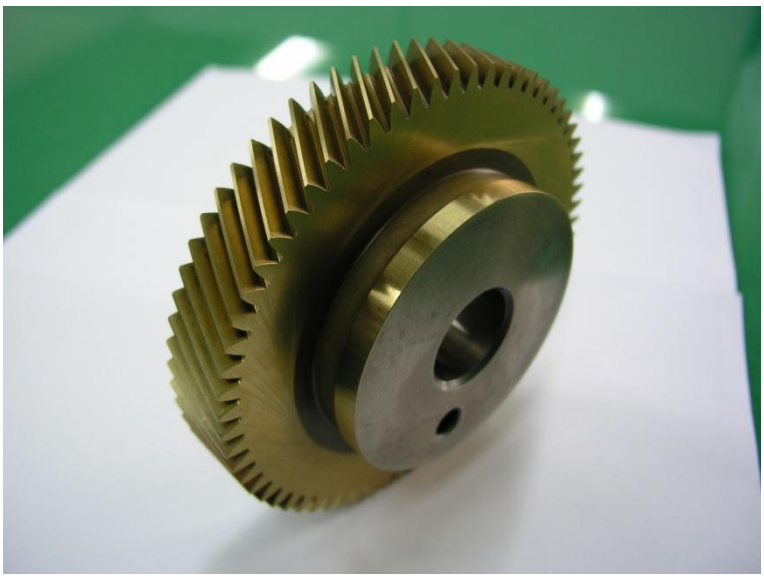

**Figure N°4**- *Cylindrical and helical master gears coated with TIN*

Today there may be cases of masters that are also replaced after a million pieces checked, especially if the pressure of the master on the workpiece is not very high.
In this regard the modern gear testers provide devices for adjusting the pressure as a function of the characteristics of the piece to be checked, for example, the pressure may vary from 5 to 35 N.
It should be noted that the lower the pressure the lower the wear of the gear and the greater will be its sensitivity.

The worn master gears will be ground and coated with TiN and can be used again taking care to recalibrate the center distance in according to the  value detected.
This recovery operation of the master can, in theory, be repeated several times.
After sharpening the profile of the master is no longer the original one, in fact changes the diameter of the pitch diameter and thus also the operating pressure angle .
All this does not have any influence on the precision of the control, apart the necessary to recalibration of  the equipment as regards the center distance.