Flexible controls of gear and shaft

The equipment actually available on the market for control of middle and big series of gears are very flexible with respect to the old ones.
They consist of standard modules that can be quickly assembled and adjusted in a manner to check also other gear types, without any specialized intervention.
The equipment described in this article are manufactured by Metrel (Cornate d'Adda – Milan) and are rolling gear testers for single toothed gears or shafts.
To call them simply rolling gear testers is an inadequate definition, because they are capable of controlling a series of dimensions of the gear's body or shaft, actually many applications in these gearbox production lines concern only the control of diameters, planes and shims position without inscribe tooting. Besides, with the same basic structure, they can control the (OBD) over ball diameter i.e. the diameter on balls of any single tooth supplying, through a polar diagram, the error of the tooting radial run out and measure the splined section. As we can see in picture N° 1, the base structure of shaft equipment is made of a series of horizontal bars and the control devices are fixed to them, i.e. probes for control of diameters and shims, the slides with the master gears or OBD control device.
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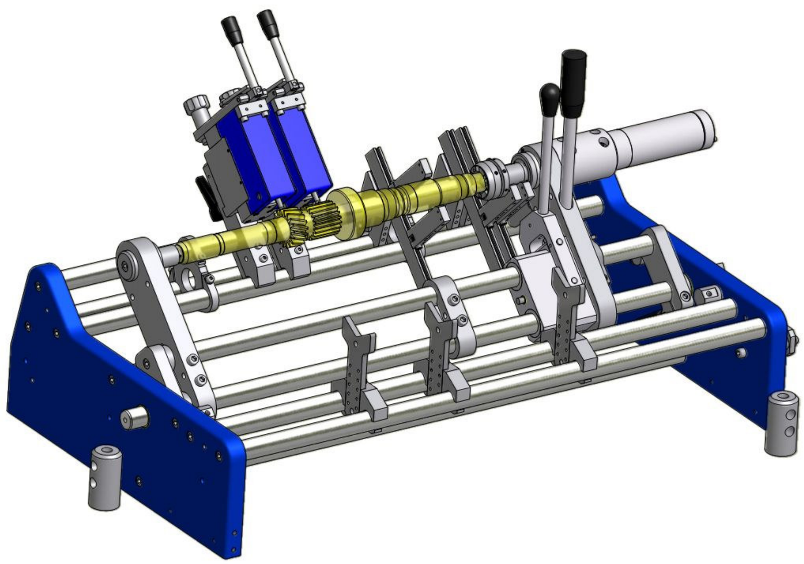

Figure N°1- *Equipment for shafts pre-arranged for OBD control*

These additional measuring components are fixed with Allen head screws that allow an easy adjustment in axial direction. At the same time the active control elements are adjustable in a radial way. Two longitudinal bars hold the counter stock support blocking the part. This part can be moved in two positions. The first loading position brings the counter stock close to the operator in order to facilitate the upload and download outside of the measuring station to avoid any possible damage of the probes.
The second is the working position, that is indicated in the illustration,
The motion from one position to another is determined by a hand operated lever, but these systems are also predisposed for automatic upload and downloads.
In figure N° 1, you can see details regarding this interesting system set up in this example for ball diameter measurement of two different gears on a shaft.
Rotation is given to the shaft under control, by a coaxial motor of the same shaft.
In figures N° 2a and N° 2b are respectively represented, an application for the control of all diameters and shims of a shaft which is without teeth and a control of a gear with master.

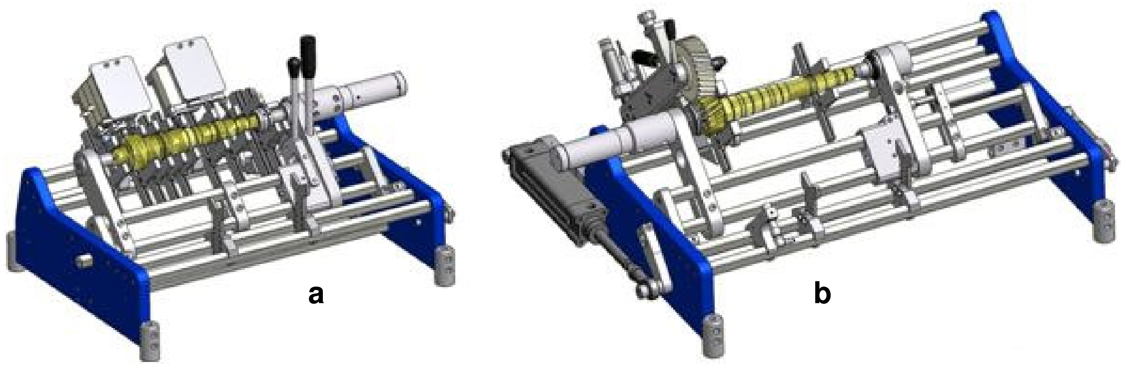

Figure N°2- *Shafts equipment pre-arranged for control of diameters and shims (a) and tooting (b)*

You can clearly see that the structure is the same and that in different applications, different probe slides are used. They can be easily inserted and modified at another time.
The evident advantage is that no big modifications are necessary in case where the shaft to control has changed. In addition, you can easily change the destination of this equipment; for example it can be used for tooting measurements even if it was originally purchased for diameter measurements and vice-versa. The same concept was used in the case of toothed wheel measuring systems.
For a vertical structural design, the slides can be positioned with various probes and masters, and all together have the possibility of easy regulations in a wide dimensional range.
Figure N° 3 shows a simple manual system, equipped with a master for radial run out measurement, centre distance and presence of possible nicks on the teeth.

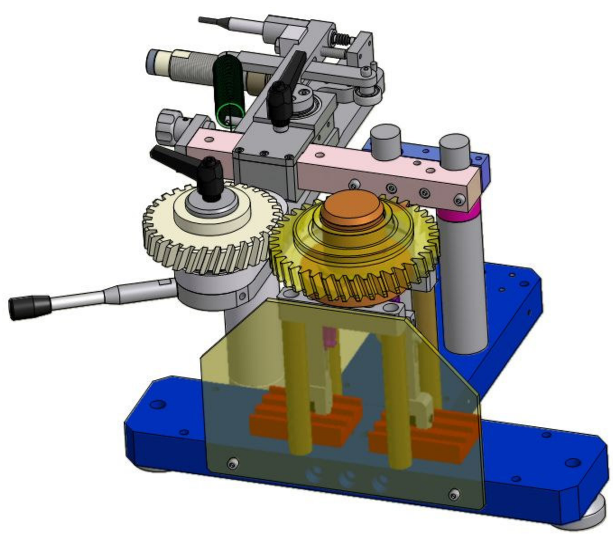

Figure N°3- *Manual rolling gear tester for control of a single gear*

Rotation is given by an electric motor that rotates the master which is meshed with the part positioned in its working position.
We can note in this figure that the position of the master holder carriage is adjustable for the entire length of the horizontal bar which allows simple retooling for gears with different centre distance.
The extreme simplicity and modularity of this system does not jeopardize its precision, in fact, the repeatability of meshing measurements is less than one micrometer. Another big advantage, much appreciated by users, is the rapid delivery of these systems which can be assembled and delivered in a short period of time.

Types of controls that can be performed.

As already mentioned, the controls which can be performed by this system are multiple and essentially include tooting control and dimensional control.

It however always deals with comparative type post- process controls, that is to say, not based on the absolute dimension value.

They are in substance, controls that detect the deviation with respect to the master or zero setting gauges.

To be more concise, in the case of a diameter control, the probe is set to zero on a sample of this diameter having the theoretic dimension (master) and the control consists of reading the deviation of the part under exam from the master used as zero reference. Such procedure introduces the undisputed advantage to compensate within ample limits automatically, the wear-out of supports and probe tips, allowing a continuous use under grave conditions, even by personnel with limited experience.

The systems are able to assume compositions always more complex, eventually adding dimensions to check during the same cycle.

Figure N° 4 is a schematized example of a shaft control with four gears controlled contemporarily, plus two diameters and two shims. Naturally, this is absolutely not an operative limit because we can add all transducers necessary in order to control each shaft part. The only limit is the encumbrance of the different probes, but as you will see, Metrel builds high reliability micro probes today that occupy a very limited space.

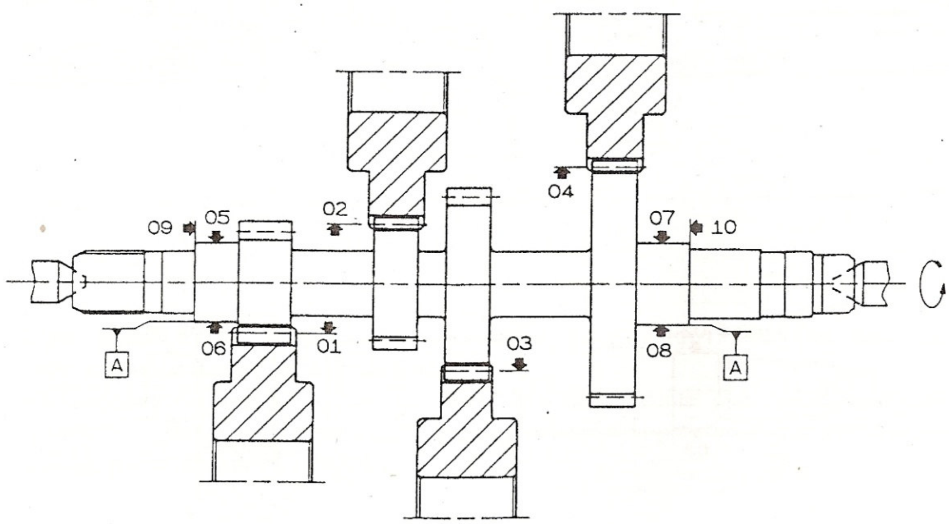

Figure N°4- *Measuring diagram of shaft with different gears*

A key factor for reliability of multiple controls of this type, either those on shafts as depicted in the figure N° 4 example or single gears, is the individualization of a reference axis which excludes positioning and rotation errors caused by shaft deformation or single gear bore tolerances.

For this purpose, through probes that reveal the diameters, we calculate the electrical axis for which all the measurements will reference to. In other words, we take into account the positioning errors of the real axis, as consequence modifying the other measurements. In case of a gear with a central hole of great importance, besides the tooting control, hole analysis, its ovality and taper.

This analysis is permitted through the adoption of four probes positioned two by two on different section as indicated in figure N° 5.

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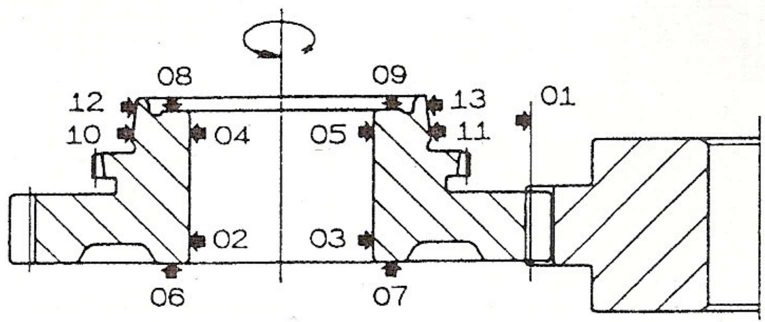

Figura N°5- *Complete control diagram of a gear with hole*

In the same figure, we can observe how to measure the diameter and taper of the synchronization cone. Naturally, all 13 probes of this example work simultaneously and the signals are collected and processed together from the electronic unit, for which after a few seconds, a complete picture of the gear dimension measurement is available.

Ball diameter control

This is a device that combines extreme flexibility with high accuracy and great measurement speed for different parameters of cylindrical gears with either straight or spiral teeth.

The basic system allows the radial run out F_r'' tooting control according to ISO 1328-2, of the minimum and maximum ball diameters, oval shape and radial run out of the bore diameter with two additional probes.

The measurements are obtained by counting the distance between the balls inserted in each single tooth compartment and gear centre determined by the two additional probes.

This device allows gear measurements with a range of diameters from 20 to 200mm, and allows a precise position of the balls in axial direction on the toothed side for an extension of 50mm.

The base version is suitable for gear measurements with modules from 1,7 to3mm, dividing this range into three sectors, for each which is necessary to mount balls with appropriate diameters as indicated below:

- ►Modules from 1,7 to 2 mm = ball diameter 3,175 mm
- ►Modules from 2 to 2,4 mm = ball diameter 3,969 mm
- ►Modules from 2,4 to 3 mm = ball diameter 4,762 mm

The retooling of the equipment for gear change takes approximately 10 minutes.

This measuring equipment can be integrated in the rolling gear tester mentioned above and all can be inserted into automatic production lines.

Measuring time is approximately 0,5 seconds per tooth and therefore perfectly compatible with modern automatic lines.

Figure N° 6 shows a polar diagram of radial run out errors detected by this system.

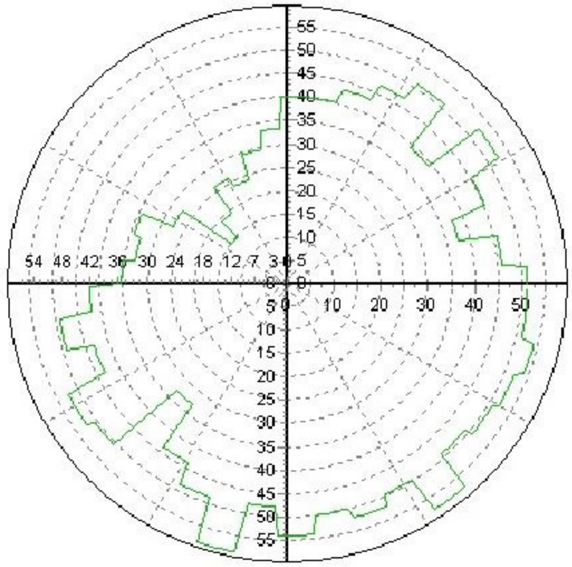

Figure N°6- *Diagram of radial run out errors on a cylindrical gear*

Transducers

Transducers (or probes) are built internally at Metrel and constitute under certain aspects, the origin of signals that will be then processed by the electronic equipment to provide the measuring results. From a technological point of view, they are truly incredibly sensitive objects.

The heart of the transducer consists of two solenoids with 5 mm diameter of which a cylinder (nucleus) made of magnetic iron can slide internally.

In its dormant state with the nucleus centred between two solenoids, the inductance of the solenoid is balanced and holds an electrical circuit in equilibrium.

When the cylinder is moved from its equilibrium position (electrical zero), the circuit becomes unbalanced and a voltage can be revealed in a branch of the circuit. All normal up till now, but the extraordinary thing (at list for me) is that a movement of just 0,1 µm is sufficient to generate a measurable voltage. 0,1 µm is an incredibly small length and can be compared to the dimension of a virus, in other words, not visible to the naked eye, yet the probes of which we speak succeed in measuring the movements of this entity.

The signal in the order of 18 µV, well below electrical interferences commonly present in production areas is then sent to electronic systems where it is processed, and amplified so it can be displayed on the monitor.

0,1 µm is the sensitivity of the probe, but before the signal reaches the monitor, it travels a long way and in this passage chain, it looses some of its reliability, even for effects of purely mechanical causes (bending, thermal expansion, hysteresis, vibrations, etc…).

However the repeatability of a transducer of this type is approximately 0,2-0,3 µm, more than enough for the overwhelming majority of the measurements that are done in the mechanical industry.

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Figure N°7- Series of pencil and lever type transducers.

Mechanical and electrical features of pencil probes which are mostly used are listed in table N°1. They are produced in three fundamental types that differ substantially for the zero position inside the measuring stroke.

Table N°1- Pencil probes features

	Mod. 1.10.00	*Mod. 1.10.120*	*Mod. 1.10.161*
Fixing diameterG6)	*8 mm*		
Measuring pressure in horizontal position	*0,98 N*		
Diameter of standard tungsten carbide probe tip	*3 mm*		
Linear measuring stroke around zero	*- 0,3 mm* *+ 1,0 mm*	*+ 0 mm* *-1,0 mm*	*- 0,6 mm* *+ 1,0 mm*
Total mechanical stroke	*5 mm* $\pm 5\%$		
Outward travel from zero	*-0,3 mm* $\pm 5\%$	*-1,3 mm* $\pm 5\%$	*-0,6 mm* $\pm 5\%$
Inward travel from zero	*+4,7 mm* $\pm 5\%$	*+3,7 mm* $\pm 5\%$	*+4,4 mm* $\pm 5\%$
Zero position adjustment	*no*		
Spring force at elec. zero	*0,98 N*		
Bearing	*Bronze*		
Voltage	*3 - 10 V*		
Frequence range	*10 – 18 KHz*		
Absorption at 10 KHz	*0,3 mA/V*		
Calibration voltage	*6 V*		
Calibration frequency	*15,625 KHz*		

Electronic measuring systems

Metrel has of a wide range of electronic systems that cover all possible requirements regarding measuring data collection and management.
The most flexible of these systems is a multi-gauging microprocessor with graphic display, available either in a monochrome or colour version in high visibility.
Identified as Nanosys, the unit can effectively replace the normally used control column viewer packs with a single system which is more compact, economic and flexible.

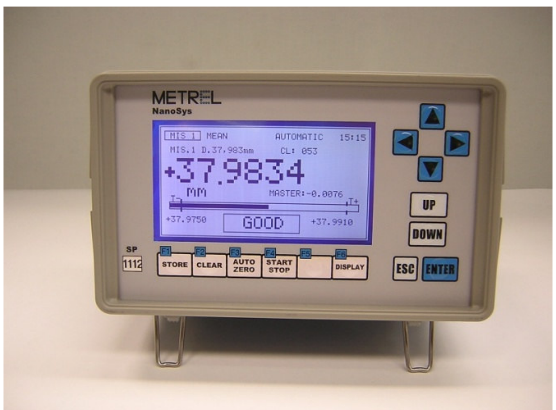

Figure N°8- *Microprocessor comparator Metrel Nanosys SP1112 and Nanosys C SP1278*

It can be used for automatic and manual controls and can perform up to eight independent measurements, each using up to 12 inductive transducers and two digital (opto232, encoder TTL) algebraically configurable. It Allows connection and use of up to12 plugs or electronic forks, a gauge and encoder with self acknowledgement of component in use and automatic visualization of the measured dimension.

In case of the colour unit, column or visualized value automatically change according to the measured value: green if the measured dimension is intolerance, yellow if the dimension is close to the tolerance limit, red if the dimension is out of tolerance.
The series of other systems available from Metrel and share the same basic formulation regarding the programming and execution of the measurements increase in capacity and complexity until we reach model M4M System which is the most evolved and flexible.
In figure N° 9, we can see Model Lite which represents an all-in-one system suitable for the adaptation for the major part of the mid –complex metrology applications.
M4M Lite is a complete multi gauging and multi program system designed for dimensional control applications in a workshop environment. The system can compensate measurements for temperature, in real time, considering the part, master and gauge temperatures.
Such features together with accurate hardware planning allow its use both on gauges, manual equipment and semiautomatic benches, or in applications for automatic lines.

It is a powerful acquisition centre and data processor, it can in fact, manage 300 probes per program, 24 probes for measurements, 300 measurements per program with 300 programs and 30 station per machine.
It is composed by two hardware components: SP947 (Industrial PC) and SP948 (real time unit) and windows 32 bit native software: The real time unit allows management of critical measurement task independent from Windows visualization, of which timing does not affect the repeatability and speed of the geometric measurements. Communication between the two units happens via a TCP/IP protocol and can be extended onto a network LAN, allowing remote assistance and remote control characteristics which are intrinsic to the system.

Figure N°9- *M4M Lite System*

This system is able to elaborate any type of statistics for controls performed and supply results on any type of printer (they are all compatible) and allows export of data in HTML- Excel- Lotus 123 – RFT- Word formats as well as in all ODBC compatible data bases.