New types of coordinate measuring machines and symbols used for their parameters Part III. Examples of cantilever type machines

Nowe rodzaje współrzędnościowych maszyn pomiarowych i oznaczenia ich parametrów Część III. Przykłady maszyn o konstrukcji wspornikowej

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Coordinate measuring machines of cantilever type are specifically intended for use in production environment, for measurement of the produced parts and machine elements, especially automotive parts. Common types of these machines are presented with their properties, such as measuring range and accuracy explained.
KEYWORDS: coordinate measuring machines, cantilever type machines

Coordinate measuring machines with cantilever structure have relatively small measuring ranges. They are produced by a few companies [1], including Carl Zeiss (DuraMax machine [2]), Wenzel (Smart CMM [3]), Hexagon Metrology (TIGO SF [4]), Mitutoyo (QM-Measure [5]), and Mora (Pico [6]).

The cantilever machines are basically designed to measure small parts, usually within 500 mm, and few of these machines have a laboratory character. They are mostly ball-bearing and therefore can operate in conditions independent of the aerostatic power supply. They are dust-proof and can easily be moved in the production hall thanks to their relatively high resistance to temperature and vibration of the substrate.

Carl Zeiss coordinate measuring machine DuraMax

The DuraMax machine (fig. 1) has a measuring range of 500 × 500 × 500 mm. It is equipped with a VAST XXT measuring head for both single point and scannable measurements. The length of the spindle in the axis of the head is 30 to 150 mm and the length of the spindle is 30 to 65 mm.

The accuracy of DuraMax machine is expressed by the following parameters (subject to the use of the VAST XXT measuring head with a 70 mm spindle and 8 mm measuring tip diameter for scanning measurements, scanning speed up to 500 points per second):

- permissible limit error for length measurement $E_{L0,40,MPE}$ = (2.4+L/300) µm, if the machine will operate at 18÷22 °C or $E_{L0,40,MPE}$ = (2.9+L/200) µm for temperature 18÷30 °C; where L – length in mm,
- maximum permissible limit for repeatability distance $R_{0,MPL}$ = 1.7 µm,
- permissible limit head error for scanning measurements MPE_{THP} = 2.9 µm, τ = 55 s,
- permissible limit error for the shape of a single spindle $P_{FTU,MPE}$ = 2,4 µm,
- permissible limit error for the shape of multi-spindle assembly $P_{FTM,MPE}$ = 3.9 µm,
- permissible limit error for dimension of multi-spindle assembly $P_{STM,MPE}$ = 1.2 µm,
- maximum permissible limit value of the position of the multi-spindle assembly $P_{LTM,MPE}$ = 2.7 µm.

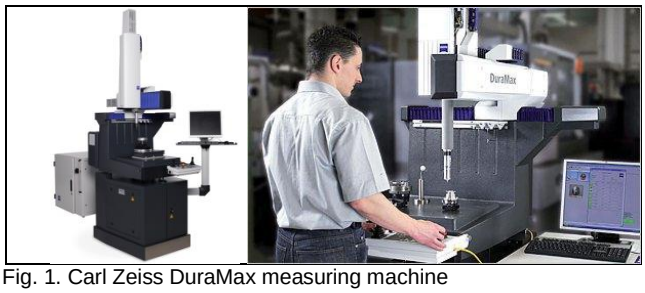

Fig. 1. Carl Zeiss DuraMax measuring machine

DuraMax has installed optoelectronic length standards with a signal resolution of 0.2 µm. Temperature gradients are as follows: 2.0 K/h, 5.0 K/d and 1.0 K/m. The measurement speed can be up to 100 mm/s. In CNC version, the maximum axial velocity is 300 mm/s, while the vector is 520 mm/s. Axial acceleration is up to 1 m/s^2 and vector – up to 1.7 m/s^2.

The special feature of the DuraMax is its ability to be installed in a production environment due to its relatively high resistance to temperature and vibration (integrated passive vibration damping system), dust protection (fully shielded rails) and the fact that it does not need aerostatic power supply, because it has a rolling bearing installed. In addition, the machine is equipped with an automatic system of exchange of measuring head sets.

DuraMax can be installed directly into the production line for classic measurements and measurements of gears. It has CALYPSO basic software and GEAR PRO involute software for gear measurement.

Smart CMM measuring machine

Coordinate measuring machine Smart CMM Offered by the German company Wenzel (fig. 2) has measuring ranges of 500/1000×450×400 mm. The permissible limit error MPE_E is 4.5+L/300 µm, and permissible limit error of the measuring head assembly for point measurements MPE_P is 3.5+L/300 µm. The speed of moving machine assemblies V_{max} = 650 mm/s and the acceleration a_{max} = 2 m/s^2.

Click'n Measure software was used for measurements, which allows for preparing the graphical protocol. It also includes a package of statistical analyzes related to the quality assessment of the manufacturing

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process based on the result of the measurement of controlled objects.

Fig. 2. Wenzel Smart CMM measuring machine

The Smart machine is designed for measuring small and medium objects by contact method – both point and scan – as well as optical heads. Most commonly used, there are the TP200 and SP600 Renishaw heads and the PH10T rotary/tilt heads and their new generation PH20.

TIGO SF measuring machine

Hexagon Metrology offers the TIGO SF (fig. 3) with measuring range 500×580×500 mm. It allows to measure the length with the permissible limit error $E_{0,MPE}$ = (2.2+L/300) µm.

The machine employs multi-sensor temperature compensation to allow measurements even at ambient temperatures of 15÷30 °C. Because of this, and thanks to the installation of active ground damping, protection against dust, dust and oil mist, and especially because no air supply is required (the aerostatic bearings are not required), TIGO SF can work in a production environment, which is also favored by relatively simple adjustment of the machine.

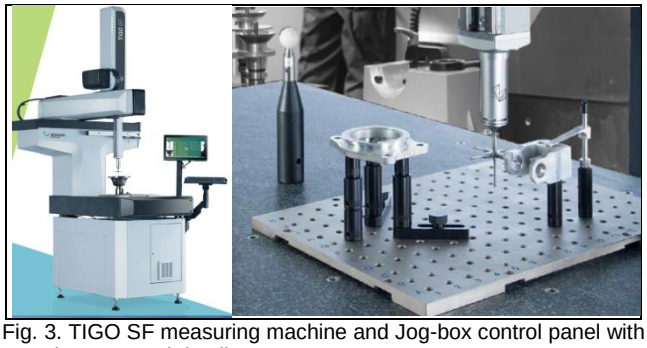

Fig. 3. TIGO SF measuring machine and Jog-box control panel with sample measured details

Typical spot and scan measurements are available using the LSP-X1c head or the TesaStar head with TesaStar-m5° swivel head.

The PC-DMIS TOUCH software is richly equipped with graphics, and the final protocol (in addition to the numerical data – measurement results) includes a graphical view of the object being measured.

QM-Measure measuring machine

The QM-Measure (fig. 4) – Mitutoyo's measuring machine – is offered in two models that differ in measuring ranges: 300×300×300 mm and 300×500×300 mm. At a temperature of 20 ± 1 °C, their MPE_E error limit = (3.0+0.4L/100) µm provided the TP2/TP20 measuring head is used. Limit permissible head error for point measurements MPE_P = 4 µm. With optional temperature compensation, it can operate in the range 15÷30 °C. Temperature gradients are 2 K/h, 5 K/d, 1 K/m. The resolution of the measuring systems is 0.5 µm. The machine is equipped with MCOSMOS software for measuring, analyzing and reporting results.

Fig. 4. Mitutoyo QM-Measure measuring machine

Pico 655 cantilever machine

The measuring range of Pico 655 (fig. 5) – a cantilever machine produced by the lesser-known German company Mora – is 600 × 600 × 500 mm.

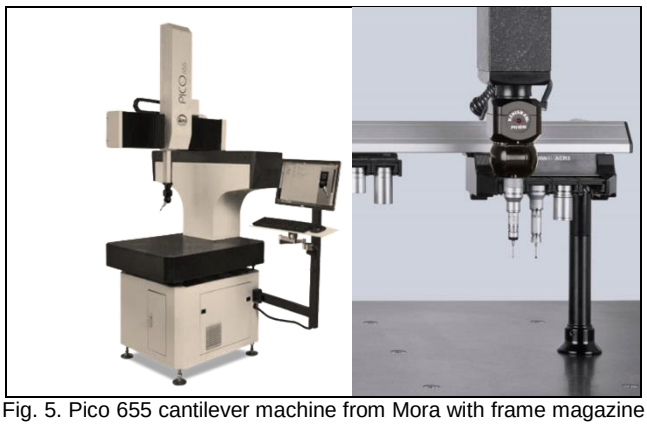

Fig. 5. Pico 655 cantilever machine from Mora with frame magazine for measuring heads

Permissible limit error of the length measurement at 18÷22 °C is 3.0+L/300 µm. The machine can be equipped with a whole range of Renishaw printheads, for example: TP20, TP200, SP25 scanning head, PH series rotary heads, as well as an optical sensor head. Uses Inca 3D software developed by the French company Inspect 3D. Each axis of the machine uses temperature compensation.

Conclusions

Most coordinate measuring machines have the character of laboratory equipment where it is necessary to maintain a certain temperature and allow for changes over time. Also the substrate should be in proper condition and with low vibration level. Usually in laboratories measuring machines are located outside the production hall, which makes it difficult to use them for the current needs of the machining process. Contemporary quality control systems for products and products require measuring equipment to be as close as possible to the machining process. Therefore, special production booths for measuring machines are built in the production halls, providing the right temperature

level. Usually the operator is outside the cab and the machine is entrusted to the robot or manipulator.

More and more often, this concept is abandoned to new construction machines built from special materials that can be used in the production environment. For a measuring machine to be suitable for such conditions, it must meet the following requirements:

- have higher speed (displacement in individual axes) than coordinate machines and high acceleration. While typical measuring machines reach speeds up to 0.2 m/s and acceleration to 0.5 m/s^2, the machines used to handle production should reach speeds of up to 0.5 m/s and acceleration of up to 4 m/s^2;
- be resistant to external influences such as temperature, vibration of the substrate, and contamination such as oil mist or cooling fluid. The classical measuring machine maintains a catalog of acceptable measurement uncertainties at a temperature of 20±2 °C or 20±4 °C, while a measuring machine intended for use in a production hall should operate even when the temperature is within the range of 15÷30 °C. In some cases, when the environment is heavily contaminated or contains aggressive ingredients (eg in foundries), specially shielded robots with increased internal pressure build up to prevent intrusion into the air – not just air particles but also fine particles;
- have a high degree of flexibility, adequate to the flexibility of the machining system, and the measurement time adjusted to the rhythm of production – hence the requirements for high speed and acceleration respectively. Compliance with these requirements is facilitated by palletization and the mode of transport of objects, combined with loading and unloading systems, using manipulators and even industrial robots;
- give the opportunity to monitor the machining process and influence the quality of the process. In some cases, a direct connection with the machine for correcting – based on the measurements of the workpiece – its settings, e.g. during machining of the gears;
- offer accuracy similar to classic measuring machines, which is difficult to achieve with these abnormalities in the production environment in which the machine is to operate. The requirement of high accuracy is basically fulfilled by enclosed machines (so called cabins). Accuracy of unbuilt machines, e.g. boom construction, is less than medium-accurate CMMs. This is in many cases accurate enough, since a significant proportion of such machines are used in car body inspections, where dimensional tolerances, in this case sheet metal, are much higher than tolerances for machine objects;
- machines with cantilever structure have most of the properties mentioned, although they are characterized by lower accuracy (compared to cabin machines) (the limit of permissible error is in the range 2.2÷4.5+L/300) and the relatively small measuring range of 500×500×500 mm.

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