9.3 TESTING OF CNC MACHINE TOOLS

Every machine tool created by the manufacturer undergoes testing of machine properties – comparison of the designed and expected parameters and properties with the reached parameters and properties. This testing is made at a newly developed machine, at a machine which is generally produced as well as at a machine after the major overhaul. The tests are performed in dependence on the prescribed standards and procedures.

Testing of machine tools represents the specific branch of metrological measurings and by extension it means especially procedures, management with measuring instruments and checking their precision and others. Testing is subordinate to the legislation valid in the particular country. Considering the metrology as well as legislation, the superordinate institutes in the Czech Republic are the Ministry of Industry and Trade of the Czech Republic, the Czech Office for Standards, Metrology and Testing, the Czech Metrological Institute, authorized metrological centres, centres for calibration services and the Czech Accreditation Institute.

Testing of machine tools is the important life cycle part of the product – of the machine tool [Borský 1991]. The machine creator has the standards available which serve in many cases for the purpose that the machine manufacturer and the machine customer can speak "the same language". The standards usually say what shall be measured and checked and therefore they are completed by the procedures and methodologies which include directly or indirectly the operating instructions for measuring technology and technicians' knowledge and experience.

The tests of machine tools can be divided into three groups (Fig. 9.3.1). The first group of examinations and tests is connected with the contractual obligation between the machine seller and the machine buyer. Therefore, these tests are contained in the contract. The acceptance tests are usually performed in two steps – at first directly at the machine manufacturer and subsequently at the customer, after the machine is assembled. The tests have the target to verify the machine properties declared by the manufacturer. From the buyer's point of view, they verify whether the machine has the properties (output, precision) which the buyer purchased. The contents and the extent of the acceptance tests are usually arranged in the contract. The agreed tests are based on the standards which are recognized on the international level and which determine the particular measuring types for the particular machine type.

The prototype tests (Fig. 9.3.1) are specified to verify the properties of the newly designed and manufactured machines. The prototype tests extend the acceptance tests by many measurings which shall give the important information, especially for the machine creator. The designed and expected properties of the new product are examined and at the same time the unknown properties are discovered which cannot be anticipated at the product origination. The target of the prototype tests it to find (discover) the limit states of the machinery behaviour or such operation conditions when the machine behaves in the unexpected way. The statistic acceptance (test of the process capability) is used for demanding customers when it is necessary to keep the workpiece quality for a long time.

The standards which are most often met in the measuring and inspection branch are from the group ČSN ISO 230, ČSN ISO 10791 and for example VDI/DGI 3441. The other foreign equivalents are ANSI B5:54 and JIS B 6330-1980. The standards can be replaced only with big difficulties, therefore it is very important to determine in the machine contract which standards and rules will serve to assess the machine tool properties.

Acceptance tests

Check of technical data – the essential building dimensions of the machines and the courses are checked in the particular coordinates, this check deals also with the feed and speed sizes, with the installed capacities of the motors of the machine itself and of peripheries (e. g. coolant pressure), the built up area, etc. (Fig. 9.3.2).

The geometric machine accuracy and its measuring are regulated by the standards

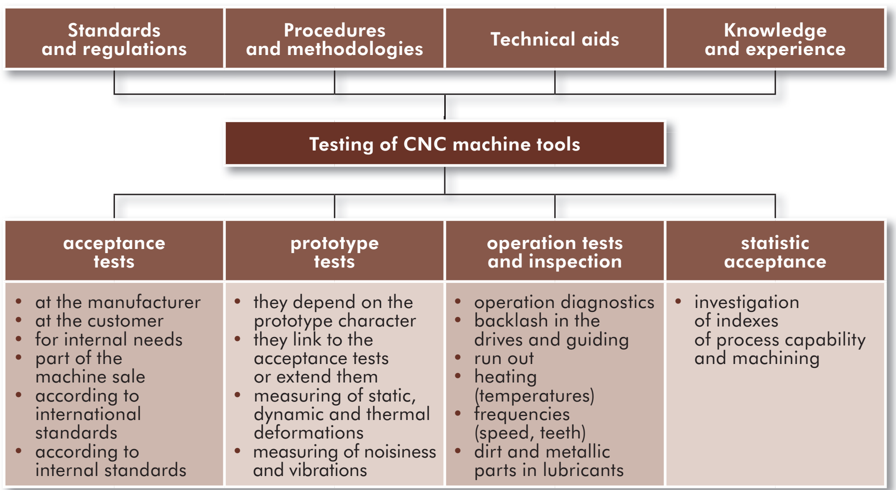

Fig. 9.3.1: Testing of CNC machine tools

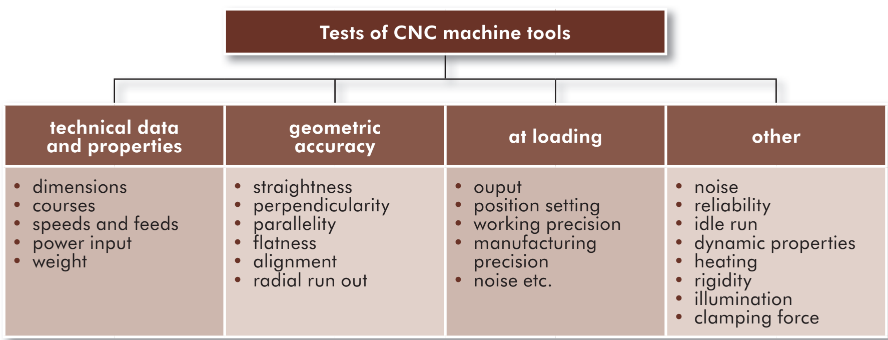

Fig. 9.3.2: Acceptance tests of machine tools

ČSN ISO 230 (previously ČSN 20 0300-1 to ČSN 20 0300-30). The first set of standards (230-1 to 230-7) is related to the accuracy tests and it does not deal with the functional machine tests (typically vibrations at machining, jerking motions of the parts. etc.). The standards do not deal with the determination of the characteristic parameters (speeds, feeds) either, because these test shall be usually performed before the accuracy tests [ČSN ISO 230]. In practice for example it is possible to meet the requirement on the spindle speed uniformity (the speed can vary in the specified / agreed range). These measurings are performed and checked in addition to the above mentioned standards and they are usually agreed contractually. ČSN ISO 230 – this is a large set of documents (Fig. 9.3.3) dealing with the purely internal mechanical machine properties as well as with the temperature influences on the machine operation and with the machine influences on the ambient (noise). The standards ISO 230-8 and the other ones are still in the preparation stage and therefore they have not been able to be harmonized up to now.

Standards ČSN ISO 230 – Acceptance tests of machine tools

- ČSN ISO 230-1 – measuring of the geometric accuracy
- ČSN ISO 230-2 – determination of the position setting accuracy in numerically controlled axes
- ČSN ISO 230-3 – measuring of thermal behaviour and temperatures
- ČSN ISO 230-4 – determination of the circular interpolation accuracy
- ČSN ISO 230-5 – measuring of the acoustic pressure and output
- ČSN ISO 230-6 – determination of the setting accuracy on the diagonals in the working area
- ČSN ISO 230-7 – determination of the spindle run accuracy during rotation
- ISO 230-8 – vibrations (between the tool, machine, workpiece influence on the surface quality)
- ISO 230-9 – it deals with measuring inaccuracies
- ISO 230-10 – (workpiece) measuring on the machine tools

Fig. 9.3.3: Standards of the ČSN ISO 230 group

The geometric accuracy tests are regulated specifically by the standard ČSN ISO 230-1 (Geometric accuracy of machines operating under no-load or finishing conditions). In addition to the introduction and notes this standard includes the sections about preparation of measuring (preparation work), machining tests and geometric tests. The standard final part deals with special measurings. The other standards dealing with accuracy are ČSN ISO 10791-6 (Test conditions for machine centres – Part 6: Accuracy of feeds, speeds and interpolations), ČSN ISO 6155 (Machine tools – Test conditions for horizontal spindle turret and single spindle automatic lathes – Testing of the accuracy), ČSN ISO 10791-7 (Test conditions for machining centres – Part 7: Accuracy of a finished test piece).

ČSN ISO 230 also admits the utilization of other methods which are not included in it, if they bring comparable or better information about the machine. Therefore, the standard is not limiting for the manufacturers. The important (great) machine manufacturers in the whole world determine the standards by themselves and in many cases these standards are stricter that the standardized standards.

The purpose of the geometric accuracy test is to determine the geometric structure of machine tools, i. e. the accuracy of shapes, mutual positions and motions of those functional parts (Fig. 9.3.5, Fig. 9.3.6 and Fig. 9.3.7) which can influence

Measuring of the machine geometric accurasy – technical aids

mechanical	optical	electronic
• dial gauge • water levels • measuring rules • angles • measuring plugs (cylindircal) • measuring prisms • aids and jigs	• laser interferometers • laser tracers and trackers • laser tomographs	• dial gauges • water levels • self centring heads

Fig. 9.3.4: Overview of technical aids specified to measure the machine geometric accuracy

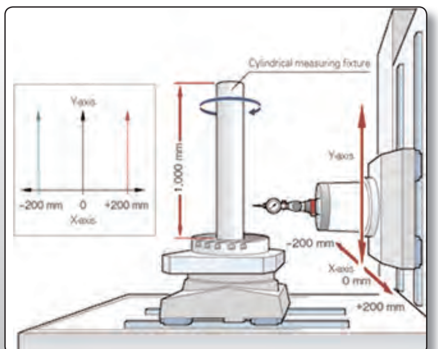

Fig. 9.3.5: Measuring of the accuracy (straightness) of the Y axis [Dixi Machines]

9.3 TESTING OF CNC MACHINE TOOLS

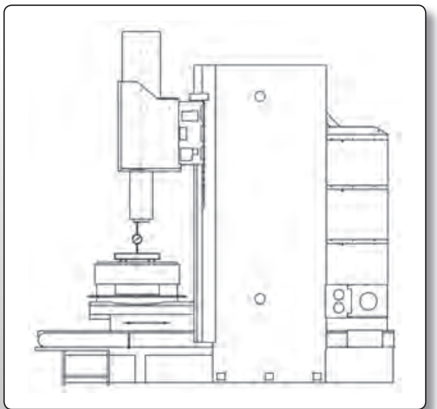

Fig. 9.3.6: Example of measuring of the rectilinear motion of the slide with the technological pallet in the Y axis in the horizontal plane [Toshulin]

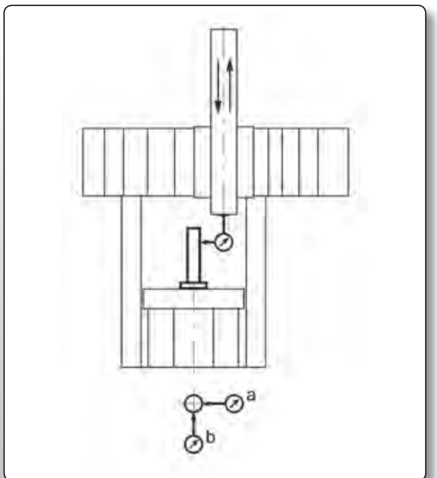

Fig. 9.3.7: Example of measuring of the radial run out of the inside cone in the straight head [Toshulin]

the working precision. This measuring type was introduced by Dr. Schlesinger in the first third of the twentieth century. His name often appears in the informal name of these tests. Before the geometric accuracy tests start, it is possible to remove the machine protective guards and the other accessories which would obstruct measuring. The machine tool must be set and levelled in the horizontal position on the unyielding foundation (levelling by a water level), i. e. as if it were in the operation condition (the tests can be performed on another place than the final machine location is, typically at the manufacturer). This position must not be changed or modified during the tests. The machine shall be also put to the stabilized thermal condition. Which method is used to reach this, it can be a part of an agreement between the manufacturer and the customer. Temperature variation must range from 2 % to 10 %, in dependence on the accuracy degree of the machine tool. The same is valid for the used testing instruments and measuring aids. The machine measuring is performed in its condition without operation loading or during its idle run [Prokop 1985]. The main measuring types are measuring of straightness (Fig. 9.3.5 and Fig. 9.3.23), measuring of flatness, measuring of parallelity, measuring of alignment, measuring of perpendicularity and measuring of run out.

The straightness test is performed especially at the guideways and it is performed by means of the water level, of the autocollimator or by means of the measuring telescope and the laser interferometer (Fig. 9.3.4). The water level shall have the sensitivity of 0,04/1000 mm at least (Note: the water levels having higher sensitivity require longer time to stabilize the bubble). The water level is moved along the bed during measuring so that the measured positions can be overlapped. The measuring is also influenced by the water level length (the size of the reflector base, see hereinafter), as it can be seen in the following figure. The measuring instrument base having bigger dimensions covers inaccuracies artificially (Fig. 9.3.8).

The test of the rectilinear motion (e. g. the motion of the lathe rail head or of the planing machine table along the bed) is still and still more often performed using the laser measuring instruments. The assessment is implemented by means of sensitive sensors or electronics (the laser measuring instruments cannot be designed like the optical autocollimators because of the risk of eyesight damage). The laser measuring is very efficient at shorter beds or at middle sized beds, because the laser beam is not influenced very much by the ambient which it passes through. If the measuring is performed in bigger distances, the ambient has the significant influence on the measuring (this is also valid for position setting).

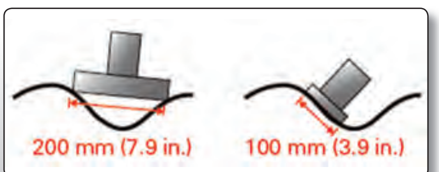

Fig. 9.3.8: Influence of the measuring instrument base size on the measuring accuracy [Dixi Machines]

The test of the rectilinear motion (e. g. the motion of the lathe rail head or of the planing machine table along the bed) is still and still more often performed using the laser measuring instruments. The assessment is implemented by means of sensitive sensors or electronics (the laser measuring instruments cannot be designed like the optical autocollimators because of the risk of eyesight damage). The laser measuring is very efficient at shorter beds or at middle sized beds, because the laser beam is not influenced very much by the ambient which it passes through. If the measuring is performed in bigger distances, the ambient has the significant influence on the measuring (this is also valid for position setting).

The flatness is tested e. g. at the clamping surfaces of the tables of planing machines and milling machines, at the tables of vertical lathes, at the base plates of radial drilling machines, etc. The surface plates or measuring rules and water levels are used for this purpose (they are put in the directions which are perpendicular or diagonal to each other). The bridges and plates with sensitive dial gauges or optical instruments are used for the flatness measuring having a more demanding character.

The parallelity of guideways (i. e. of two planes) is tested e. g. by the water levels put in the transversal direction or by the inside micrometers (the planes are parallel ones) with dial gauges. The parallelity of the surfaces with the axes or of the axes to each other (e. g. at working spindles) is checked by the measuring plugs in the spindle axis extension by means of the dial gauges, etc.

The perpendicularity of two surfaces (e. g. of the table clamping surface towards the guiding on the column) or of the working spindle axis towards the table clamping surface is usually checked by means of the measuring cylinders with dial gauges or by means of the measuring prisms. If the optical way is used, the perpendicularity can be measured e. g. by the laser interferometer, if the five sided prism guarantees the perpendicularity of the refracted reference straight line.

The alignment is checked by two measuring plugs with the dial gauge or if one measuring plug is wound by the dial gauge attached to the co axial plug or in the optical way.