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 measurements 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 measurements 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 is 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
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 tests 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.

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 than 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
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]

Fig. 9.3.8: Influence of the measuring instrument base size on the measuring accuracy [Dux 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 flatness measuring having a more demanding character.

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 instruments without 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.