

Investigation of the Thermal Deformations of a CNC Lathe

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GOAL OF THE STUDY

Accuracy management of the turning parts requires that technical and organizational measures related to thermal deformation errors be identified more at the technological design stage. All components of the processing system are subjected to heating and, accordingly, generate thermal deformation errors. In a number of scientific analyses, experimental research is used to obtain thermal deformation values, in which a scheme is applied for their direct measurement by measuring the relative displacement between the axis of rotation of the spindle and the cutting tool. They do not take into account the real operation of the machine tool, associated with uneven loading and different spindle rotation frequencies, including downtime periods associated with the replacement of worn cutting inserts, fine dimensional adjustments, workpiece replacement, etc. In order to bring the results closer to real conditions, some studies simulate machining with variable cutting speeds and the introduction of downtimes. These schemes practically take into account the influence of the most significant heat source of the machine, while not taking into account the influence of other thermal factors (ball screw pair, bodies of the carriage and cross slide, energy from the cutting process and ambient temperature). The latter are not as powerful, but cover larger areas of the machine tool and can have an impact on the resulting value of the error under consideration. Observation of numerous machining processes performed on CNC lathes shows that thermal errors are of smaller value and intensity than the results obtained in the studies under the considered scheme.

Taking into account the influence of all factors causing thermal deformations of CNC lathes is the subject of this publication.

EXPOSITION

To obtain a better estimate of the resulting thermal error, it is necessary to conduct the study under conditions determined by the real parameters of the process and the machining system, taking into account the impact of all thermal factors, including their mutual influence. The study was conducted on a machine tool CE063 during the machining of the “Cylinder” part - Fig. 1. The detail is made of ductile iron GGG50, and its machining is performed with cooling.

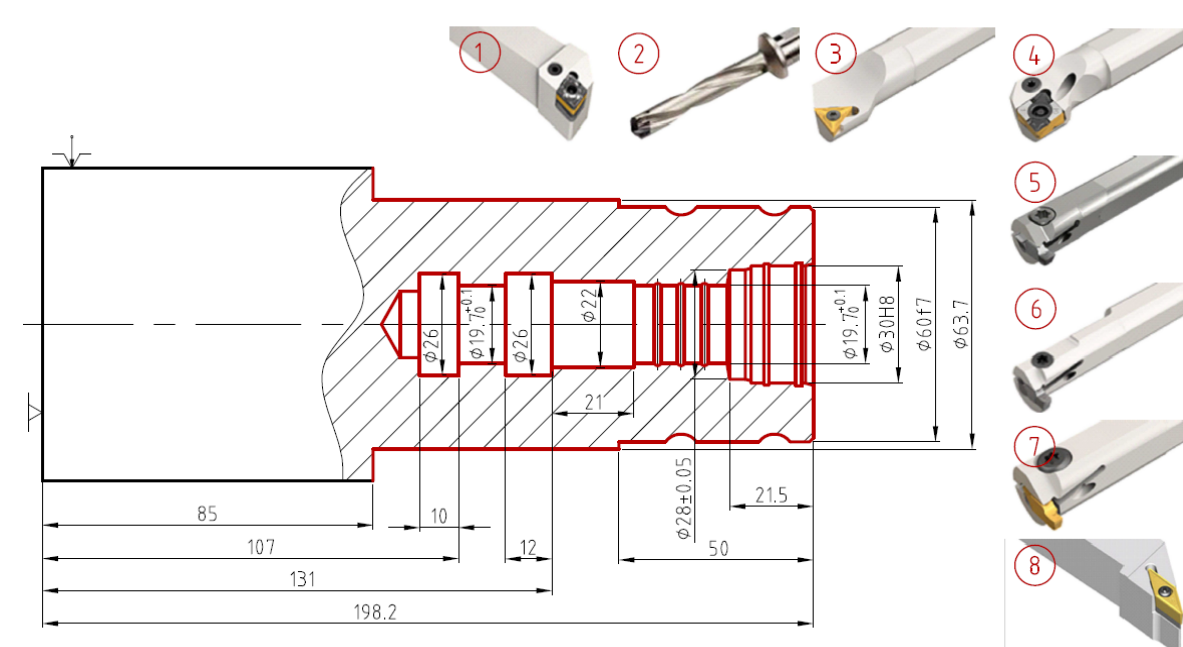


Fig. 1. Scheme of a Cylinder part, its machined surfaces and cutting tools

The measurement of thermal deformations of the spindle is performed with a specially designed and manufactured device. To determine the thermal deformations of the carriage, its temperature is measured at points K_1 , K_2 and K_3 (Fig. 2) with three digital contact thermometers. To obtain reliable information for the thermal deformations occurring in the screw, two approaches are used. The first one is computational and is based on the measured temperature at points K_2 , K_3 and K_4 . They are closest to the working section of the screw. To measure the thermal field in the area between the nut of the ball screw pair on the X axis and the tool base of the turret, control points K_4 , K_5 and K_6 are located.

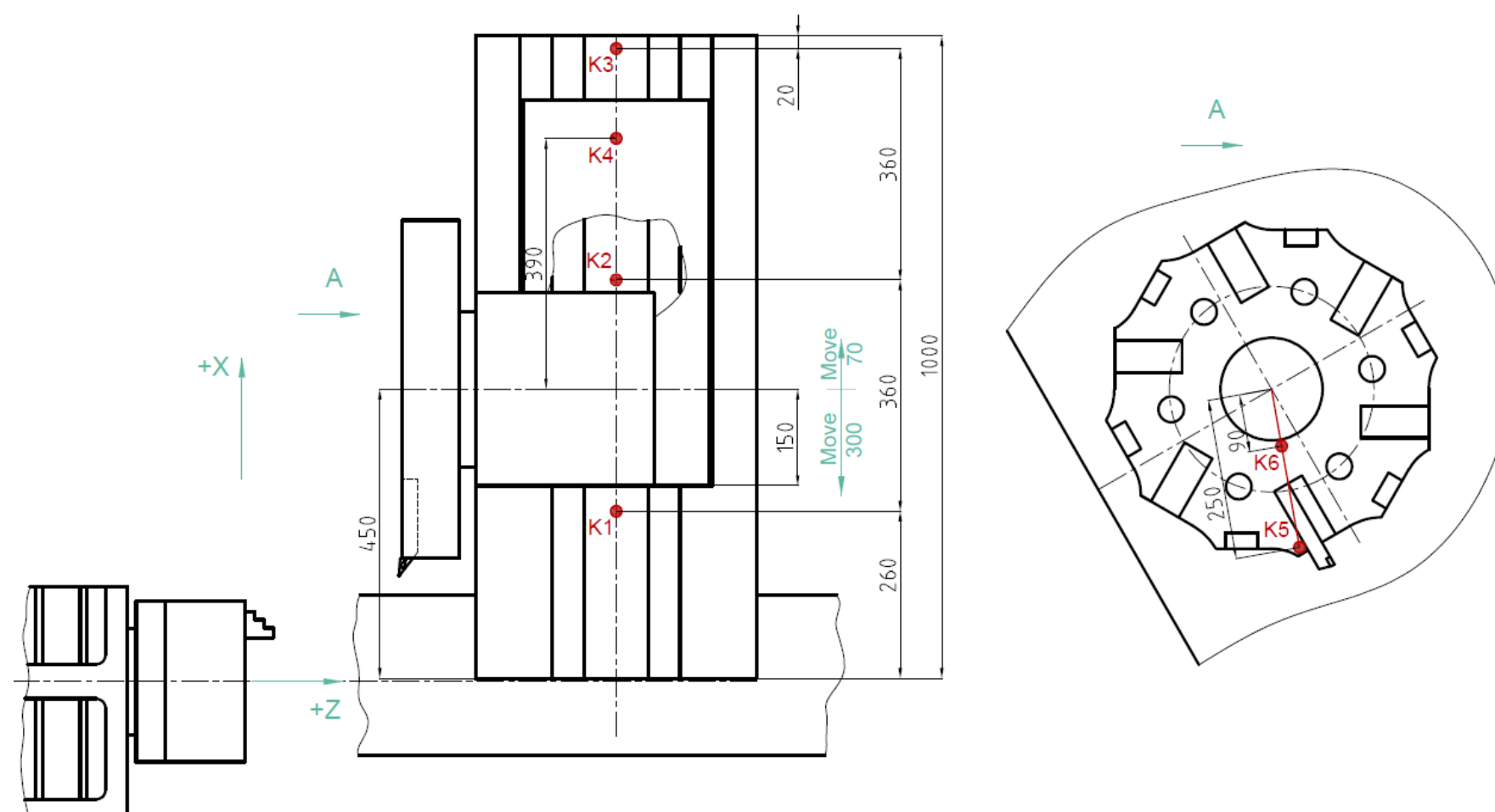


Fig. 2. Location of control points

Based on these input data, the increase in the temperature of the screw is calculated from the generated heat, to which its elongation from the change in its temperature under the influence of the environment and the working environment is added. The second method is experimental, which involves simulating the same loading conditions as during machining of the part. This is achieved by repeatedly, after execution of the programmed machining cycle, a measurement is made to establish the screw extension.

Fig. 3 shows the graphs of temperature changes at the control points and Fig. 4 shows the thermal deformations of the nodes of the machine tool and the resulting error from them.

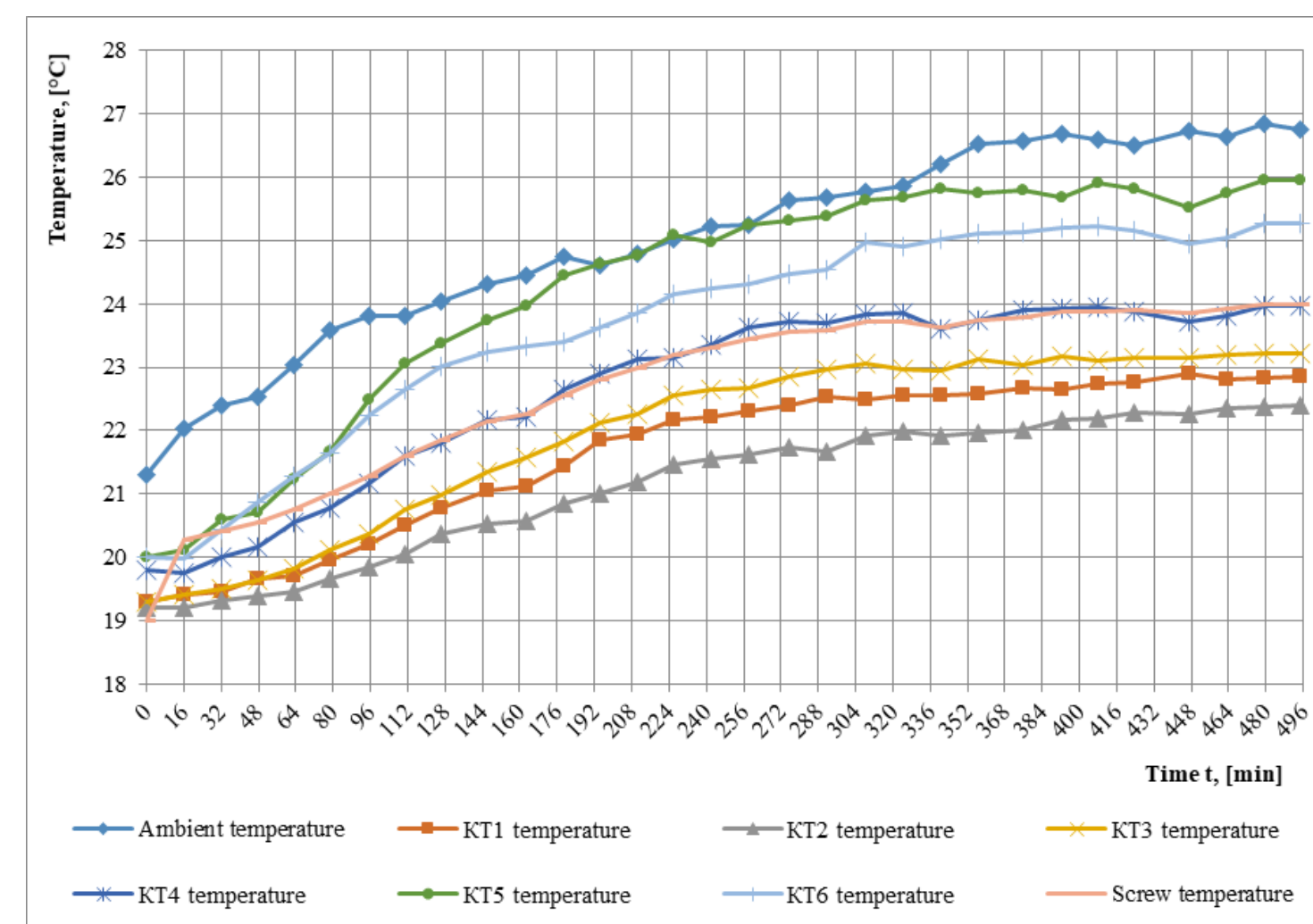


Fig. 3. Change of temperature in the control points

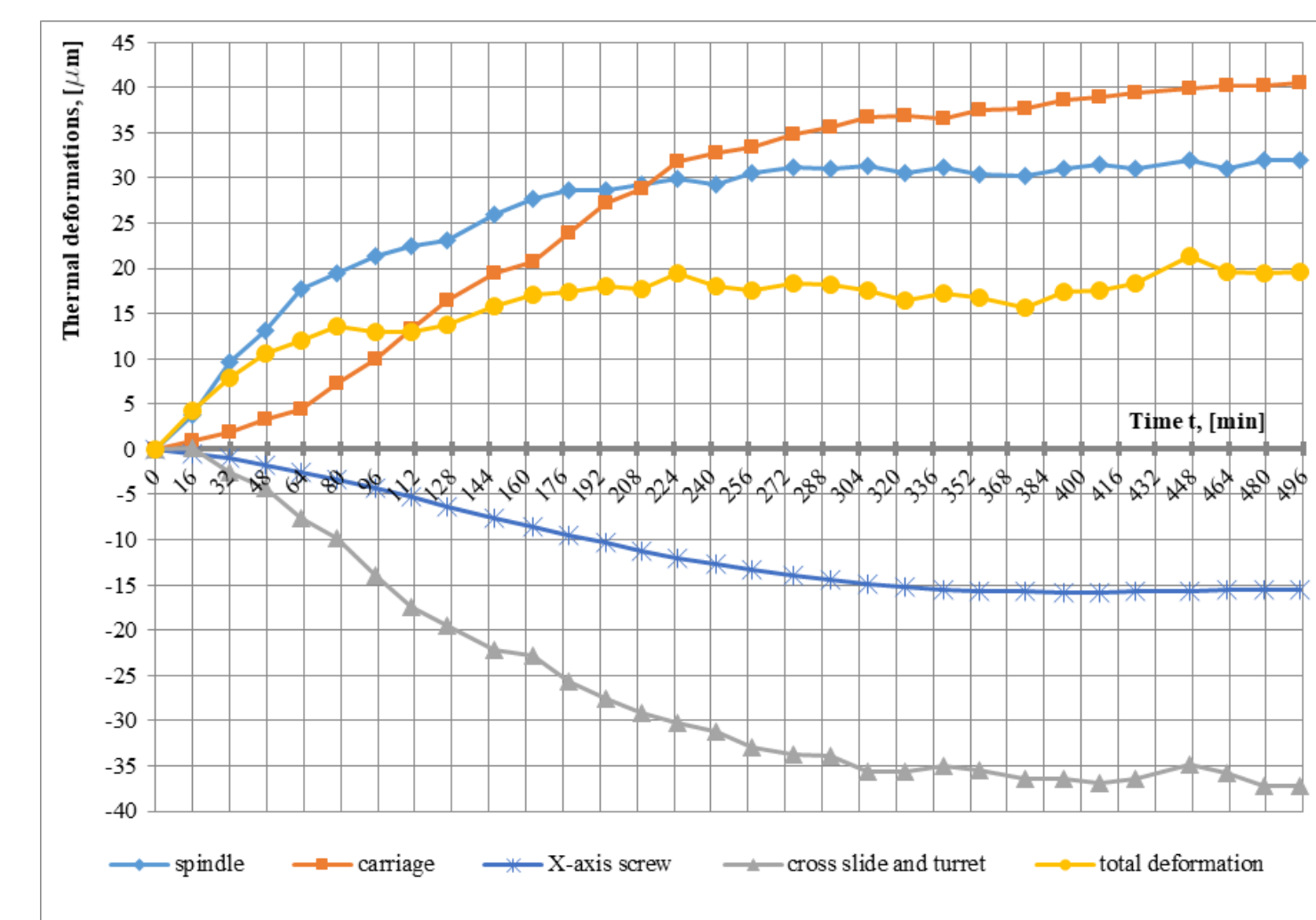


Fig. 4. Changes in thermal deformations of the nodes from the cutting tool

The air temperature (ambient environment) T_{amb} affects the thermal deformations of all nodes by means of their additional heating and improving the heat dissipation of the nodes generating heat. In the conducted studies it changes in the range $T_{amb} = 21.3 \div 26.75^\circ\text{C}$, i.e. 5.45°C . In order to assess the influence of T_{amb} , computational modeling is performed, assuming its change to 2°C . In Fig. 5 the changes in the deformations of all nodes are presented, and in Fig. 6 the resulting errors in the temperature changes are compared

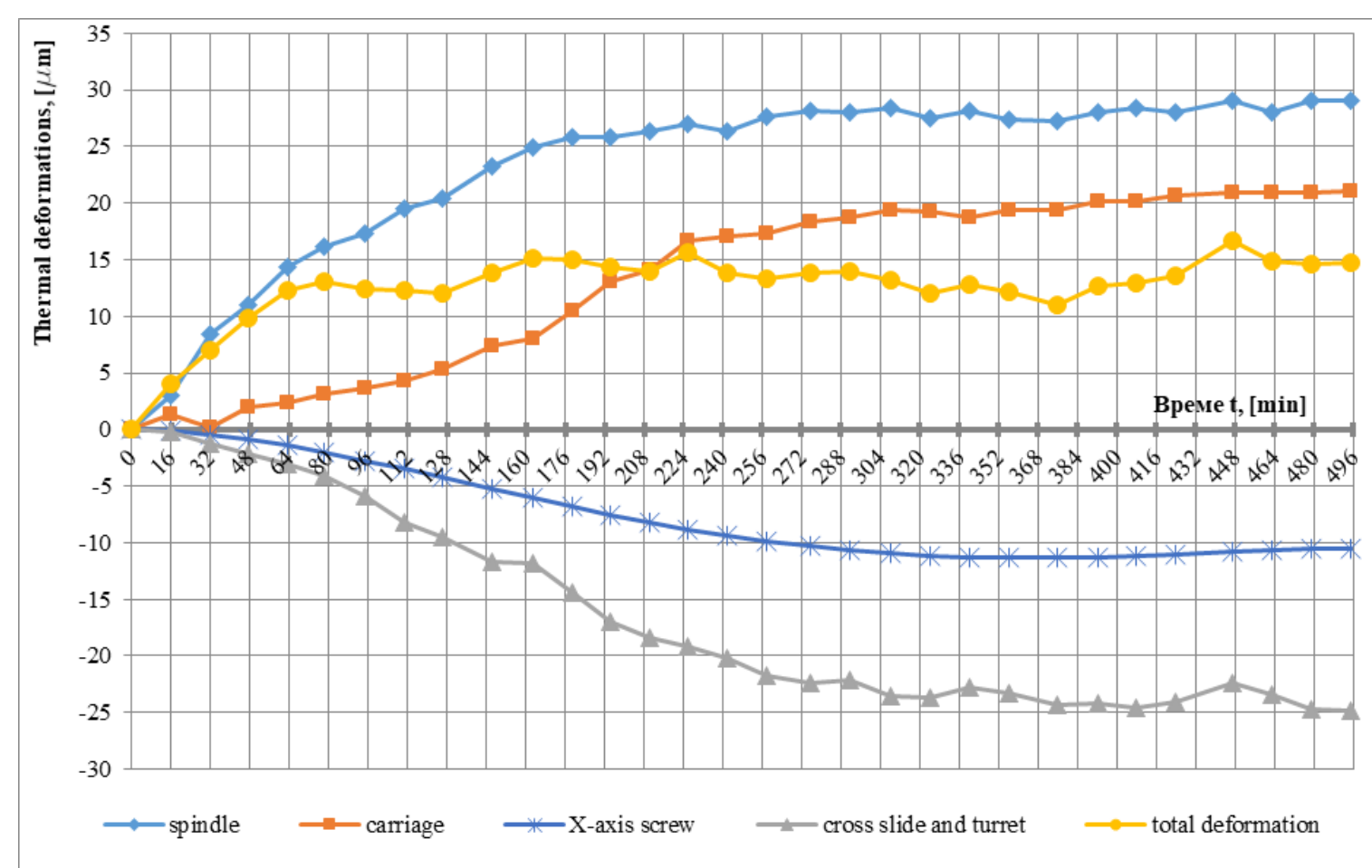


Fig. 5. Location of control points

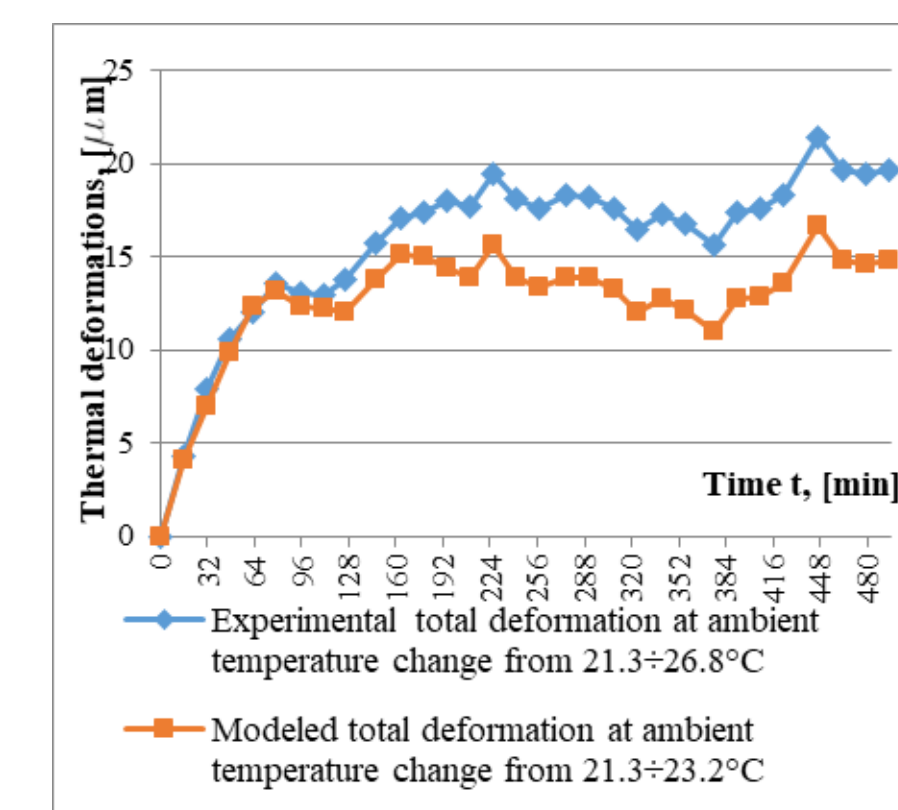


Fig. 6. Location of control points

The total effect is about $5\mu\text{m}$, when reducing the change in the ambient temperature T_{amb} from 5.45°C to 2°C , which is reached at the equilibrium state. The reason for the weak effect in the transition period is due to the large time constant of the deformations caused by the ambient temperature.

CONCLUSIONS

The resulting error affecting the dimensional accuracy is a combination of thermal deformations of the various assemblies of the machine tool.

The real values for the thermal deformations are: spindle – $32\mu\text{m}$; carriage – $40.5\mu\text{m}$; X-axis – $15.5\mu\text{m}$; cross slide and turret – $37\mu\text{m}$; total thermal deformations – $20\mu\text{m}$. The carriage, which has the largest size, plays the role of a compensating variable for changes in the ambient temperature. The degree of influence of the screw is determined by the diameter of the surface being machined, as it will generate a larger error when machining surfaces with smaller dimensions, which at the same degree of accuracy have smaller tolerances.

The changing of ambient temperature gives rise to thermal deformations of every nodes of the machine tool. Because of this for processing with normal or increased accuracy have to monitored for the change of ambient temperature. The influence of thermal deformations should be taken into account already at the stage of designing the technological process, when the technological transition to achieve dimensional accuracy is determined.

ACKNOWLEDGMENT

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