Diagnosis of CNC machine tools in terms of circular interpolation’s accuracy figure

R M Khusainov, S F Belov, O V Chukhontseva
Kazan Federal University,
423800, 68/19 Mira avenue, Naberezhnye Chelny, Russia

E-mail: chelny@kpfu.ru

Abstract. The article deals with circular interpolation test on CNC machines and determination on the basis of their performance the machine accuracy.

1. Introduction
Accuracy testing of circular path is a comprehensive assessment of the geometric accuracy of machine tools with CNC. Almost all factors influencing the geometrical accuracy parameters and therefore rejecting a mobile unit motion trajectory conduce to the fact that the radius of the actual work piece circumference deviates from the programmed circle one. Hence, the reverse is also true - if measured coordinates of the actual circular path and compare them with the programmed one, applying appropriate calculation methods, one can obtain the deviations figures of the machine accuracy, and overall technical assessment [1; 2; 3].

2. Basic part
Standard [4; 5] provides performing this type tests of reference mandrel spinning. But it does not set any specific testing methods, neither the methodology of processing results. One can propose the following procedure for conducting tests (Fig. 1, Fig. 2):

1. Install and secure control frame 3 in the spindle. Fit on the holder 2 on the machine table.
2. Combine the axis of the holder 2 and mandrel 3 (Fig. 1) for example by using an edge finder. Navigate in the CNC system to the control field «Options», into the category of «Zero shift». Identify the actual coordinates X and Y as zero program, for example under the address G54.
3. Move the machine table at the level of about 50 mm in the X-axis with manual data entry (MDI).
4. Move the spindle stock down so that the arbor 3 fit the bar notch (Fig. 2).
5. Install and secure indicator 1 in the strap, set it to «0».
6. In MDI mode enter and practice circular interpolation program clockwise (G2) recording indicator in regular trajectory intervals.
7. Graph deviations $\delta r$ depending on the angle $\theta$ in polar coordinates:
\[ \delta r = f(\theta) \]

8. Similarly to paragraph 6 work out the circular interpolation program counterclockwise (G3). Plot in the same coordinate system, which in paragraph 7.

Figure 1
Figure 2

Figure 3 - Graphics-precision testing circular path.
G2 - actual trajectory when moving clockwise, G3 - actual trajectory when moving counterclockwise, norm - a perfect circle. Magnitudes in the graph are in microns.

According to the results one can define the following geometrical errors of the machine:

1. The circular interpolation deviation from circular trajectory. The highest magnitude $\delta r$ is accepted as a result.

2. The axis positioning errors [6]. Considering the small increment of the polar angle $\theta_j$, at each step, one can define the axis positioning errors, for example Y axis, as $\delta r$ projections on the Y axis in a positive direction:

$$
\Delta Y_j \uparrow = r(\theta_j) \sin \theta_j; \quad \theta_j \in \left[0; 180^0\right] 
$$

3. The backlashes in the actuator supply.

The testing showed that the backlash is determined as the difference of coordinates of the positioning error graphs on the same length of travel. Processing the obtained data, one can find the maximum and average magnitudes of the backlash on the X axis. The average one can be recorded in the memory system CNC for the software error compensation.

On the basis of diagnostic results, one can:

- assess the machine capabilities to ensure the necessary machining precision;
- assess the ability of software errors compensation [3];
- determine the necessity and concrete measures to eliminate the causes of errors by adjustment or repair [7; 8];
- assign a works schedule on maintenance service and repair of the machine with identified errors, technological and economic characteristics of concrete production [9]. The accurate identifying the
exact faults of a machine allows to organize an effective and targeted service, thereby reducing the machine equipment downtime.

3. References

[1]. Sinopalnikov VA, Grigoriev S.N., Reliability and diagnostics of technological systems: Textbook 2005 M.: High school, 343 pp.

[2]. A G Skhirtladze, Ukolov MS, Skvortsov AV Reliability and diagnostics of technological systems: Textbook 2008 Moscow: Novoe Znanie, 518 pp.

[3]. VV Yurkevich Control and diagnostics in automated production. Mashinostroitel, 2003, №1 - №5.

[4]. GOST 30544-97. Metal-cutting machines. Methods of verifying the accuracy and consistency of circular path testing. 2001 - M: Publishing house of standards, 6 pp.

[5]. Russian National Standard ISO 230-1 - 2010. Testing machines. Part 1. Methods of geometrical parameters measurement. M, 2011 - 90 pp.

[6]. GOST 27843-2006. Testing machines. The definition of accuracy and repeatability of positioning axes with numerical control. - M: Standartinform, 2007 - 7 pp.

[7]. The model time norms for maintenance of machine tools with numerical program control and robots (manipulators). M: Economica, 1990, 64 pp.

[8]. R M Khusainov Reliability of technological systems. “Design and analysis of technical systems: the interuniversity collection of scientific works. 2012 Issue №4 (18)/ edited by V.G. Shibakov – Nab. Chelny: Publishing house of Kama State Academy of engineering and economics

[9]. A I Yaschura System of technical service and repair of industrial equipment: Handbook. M: Publishing house SC ANAS, 2006, 360 pp.

[10]. Siemens SINUMERIK 840Dsl/828D. Extended programming. A programming Handbook. 2011 6FC5398-2BP40-2PA0. Siemens AG. 09/2011 – 609 pp.