Printed as manuscript

Nadezhda A. Kucherenko

DEVELOPMENT AND OPTIMIZATION OF A QUALITY-CONTROL TECHNIQUE OF COMPLEX PARTS MACHINING ON THE CNC-MILL WITH APPLICATION POWERINSPECT TECHNOLOGY

Master's Program Automation of design and engineering

The abstract of the Master's Thesis

Krasnoyarsk 2014

The thesis work is done at the Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University»

Scientific supervisor:
Yakov Y. Pikalov, Ph.D. engineering, Associate Professor

Peer Reviewer:
Ivan A. Ryzhkov, Supervisor of metrology department, JSC "Radiosvyaz"

The thesis defence will take place on July 9, 2014 at Siberian Federal University, venue: 26, Academician Kirenskogo Street, Krasnoyarsk, 660074, Russia

Master's Program Leader:

Ph.D. in engineering,
Associate Professor — Michail. P. Golovin

GENERAL DESCRIPTION OF THE THESIS WORK

Significance of the work. Today the main mission of mechanical engineering is development and creation of new production technologies, so it can be defined as development and output of high-quality and hi-tech product that is marketable and competitive both in the domestic and foreign markets. A measurement assurance is a basis of the quality system, but most modern problems of Russian manufacture are connected with management of measurement assurance directly. However the most part of enterprises wends the way of lop-sided development, they invest small sums in buying and deployment of new high-accuracy processing equipment, that is able to process ruggedized but due to a poor development of metrological base the enterprise has no possibility to assess the accuracy of goods manufactured actually.

Significance of the work is defined as a solution of measurement assurance problems, which the most part of enterprises faces:

1) outdated standard instruments base;

2) an unsatisfactory status of the measuring equipment fleet;

3) there is a contradiction between the high machining technology and the outdated metrology control methods at the most of enterprises;

4) a non-system of the measurement assurance organization;

5) a high cost of multipurpose machining units and coordinate measurement machines (CMM).

The objective of master's thesis is supporting of the required precision and the intensity of complex part production on mill work centre by applying the proposed interoperation control method on the machine tools using Renishaw measurement system

The tasks of the work are:

1. An analysis of the measurement assurance status and its influence on the product quality;

2. A comparative analysis of the modern measuring apparatus and looking for effective ways to use manufacturing machinery to measure;

3. A development of interoperation control technique;

4. An identification of factors negative effecting the machining accuracy and productivity, a reduction of its negative impact.

Research methods:

1. Methods of mathematical modelling on the basis of topological methods of research and numerical modelling, mechanics of solids.

2. Multi-parametric optimization methods;

3. Experiment design and methods.

Integrity of the theoretical results is provided by standard practices and methods and experimental results.

Academic novelty:

1. The mathematical model for determining of deviations dimensions and the algorithm for its implementation, taking into account the parameters of machining technology.

2. The interoperation control technique of geometric accuracy of milled surfaces, providing the minimum cost of cutting time for workcenters.

Practical relevance of the work is an application of designed check-out methodology of accuracy in size, form and surface arrangement of complex parts on the CNC mill. The technique is focused on the industrial enterprises that have milling machine tools, equipped with the measuring head, and do not have the modern measuring equipment. In particular we refer OOO «Radiosvjaz» to this type of enterprises where a designed model implementation is planned.

Work approbation:

Obtained results of dissertation and its separate parts were reported at:

— Regional scientific and technical conference of post-graduates "Special engineering education" in 2013 (Krasnoyarsk);

— The 51-st International scientific conference "A student and scientific and technical innovation" in 2013 (Novosibirsk, distant participation);

THE MAIN CONTENT OF THE THESIS

Introduction. General issues and trends of metrological researches are discussed.

The first chapter is devoted to the analysis of problems of metrological control in Russia. The main factors affecting the current state of metrological assurance of engineering enterprises are discussed, namely:

1) The status of standard base enterprises;
2) The status of measuring instrument enterprises;
3) The methodological principles of metrological assurance enterprises;
4) Staff policy;
5) Legal and regulatory framework of metrological assurance.

In the first chapter the analysis of modern metrological hardware and software for geometric control is carried out, and recommendations of their choice of a specific enterprise are presented.

Table 1 – Analysis of the modern measuring equipment

Measurement system	Advantages	Disadvantages	Application field
Coordinate measuring machine	- high accuracy of measurements; - high productivity of measurements; - execution of the inspection cycle by the NC program; - compatibility with software of different enterprises	- the need for special thermostatic laboratory with controlled humidity; - measurements of large-scale parts is difficult technological task;	Measurement of dimension and poor shape precision and surfaces position of complex parts

Continuation of the table 1

Measurement system	Advantages	Disadvantages	Application field
		- irrational usage applied for interoperation control; - high cost	
Portable coordinate measuring machine	- mobility; - possibility to measure large-scale parts; - possibility to measure the tight part area; - compatibility with software of different enterprises; - possibility to measure complex parts	- manual way of inspection; - mean accuracy of inspection is about 35-45 µm; - rotary joints wear leading to diminution of equipment accuracy	Measurement of dimension and poor shape precision and surfaces position of complex parts, large-scale parts inspection
Laser scanners and optical instruments	- possibility to measure at long distances; - high measurements and scan rate; - high accuracy of the three-dimensional model of a real object; - mobility; - possibility to scan the tight part area; - high resolution (the accuracy of the points array is not lower than CMM)	- the need for multiple scanning of the tight part area; - expensiveness of modes of high accuracy (5-10) µm	measurements of geometric parameters in the tight part area, reengineering
NC interoperable control	- machining and inspection with the same position; - possibility to inspect cycle by the NC program; - minimum time used for transportation of parts; - possibility to develop operational solutions according to obtained results of measurements	- low-accuracy measurements (30-40 µm); - loss of machine time; - high accuracy of the CNC machine tool positioning is required	Measurement of dimension and poor shape precision and surfaces position of complex part on machine-tools

The second chapter is devoted to the theme of coordinate measurements. The essence of the coordinate measurement method is to determine coordinates of points of the object in the coordinate system consistently and to compute the geometric surface according to coordinates.

For control of the bore it is sufficient to measure the coordinates of three points, allowing us to determine the diameter and the center position. This condition allows each sample surface or section of it to present the smallest possible number of points. This condition can be called postulate priority (precedence).

This postulate corresponds to the fundamental theoretical position in metrology according to which the measured object has only properties as measured by the parameter is an object model, and the measurement result is the numerical value of the object model, the resulting physical experiment - measurement. In practice, the decisive question is metrology assessment correct choice of model. Using the priority postulate saves time control due to some increase of the random component of the inaccuracy that requires an assessment of the admissibility of such an approach in each case.

Essentially the most informative of coordinate measurement allows unlimited extend the set of monitored parameters. However, individual coordinate points do not show the inaccuracy of the surface. The algorithm for calculating of deviations based on means of analytic geometry was developed to move from point coordinates to the values of inaccuracy (table 2).

Table 2 – The mathematical model

Equation and decryption of quantities	Title equation and its application field
$A \cdot x + B \cdot y + C \cdot z + D = 0,$ where A, B, C, D – fixed numbers; coefficient	*General first-degree equation of the surface* General equation of the surface is used as the base of the algorithm development
$N\{A; B; C\}$	*Normal vector of plane* Surface normal vector is used as an element determining the position of the planes relative to each other and measured points
$i = \frac{x_0 - x_{изм}}{\lvert x_0 - x_{изм} \rvert}$ $j = \frac{y_0 - y_{изм}}{\lvert y_0 - y_{изм} \rvert}$ $k = \frac{z_0 - z_{изм}}{\lvert z_0 - z_{изм} \rvert}$ где x_0, y_0, z_0 – coordinate rating; $x_{изм}$, $y_{изм}$, $z_{изм}$ – measured coordinate	*Orthonormal basis vectors are for the tangent planes reorientation*
$\begin{vmatrix} x - x_0 & y - y_0 & z - z_0 \\ x_1 - x_0 & y_1 - y_0 & z_1 - z_0 \\ x_2 - x_0 & y_2 - y_0 & z_2 - z_0 \end{vmatrix} = 0$	*Three-point form* $M_0(x_0; y_0; z_0)$, $M_1(x_1; y_1; z_1)$, $M_2(x_2; y_2; z_2)$ *(noncollinear points)* The equation was used in determining the tangent planes by iterate over the surface points

Continuation of the table 2

<table>
<tr><td>Equation and decryption of quantities</td><td>Title equation
and its application field</td></tr>
<tr><td>$$d = \frac{A \cdot x + B \cdot y + C \cdot z + D}{\sqrt{A^2 + B^2 + C^2}}$$</td><td>Point to plane formula

Determination of flatness precision requires the distance from the measured point to the tangent surfaces. This formula is used to determine the distance in the algorithm.</td></tr>
<tr><td colspan="2">Mathematical model predicate:
-surfaces, parallel to the coordinate plane, are considered in the algorithm for inspection;
- non-measured points of the surface are obeyed to the law of the linear interpolation.</td></tr>
</table>

In calculating deviations the main task is to determine the adjoin surface. In accordance with the axiom of geometry the surface can be traced through any three points. On the basis of this axiom, search of combinations of the three points that define all possible tangent planes is provided in the algorithm. Distance from the measured point to the adjoin surfaces should be minimal, so the number of found tangent surfaces is selected, only the distance from which to the outermost measured point Δ is the smallest. This tangent surface will be sought the adjoin surface, and its Δ is the precision from flatness of the measured surface.

This algorithm has been implemented using software MathCAD and Delphi, language Object Pascal.

In the third chapter of this work we conducted experimental part of our research are described, and presented obtained results.

For the experiment, the following hardware was used: universal milling machine HAAS VM (3 +2 axis) with FANUC-6M NC system, jaw plate, the measuring head Renishaw OMP 40-2, measuring 6 mm diameter tip, PC, "null-modem" cable. Also, the software HyperTerminal (version 5.1) was used to collect data from the machine.

The purpose of the experimental research was to determine the correlation of bias and technological parameters of machining details. The obtained experimental data were used to develop a methodology for interoperational control of body parts.

Below is a plan of experimental studies, each item of which was carried out:

1. development of a part-sample, building its CAD-model;
2. design documents development;
3. a sample of part machining technological process (PowerMILL) development;
4. machine data communication program choosing;
5. development of measurement program for the part-sample;
6. machining parts on a milling machine HAAS and measure of the part-sample surfaces between machining stages;
7. data analysis (determination of form and position deviations);

8. roducts control model algorithm development.

Before developing of the part-sample for the experimental a prior analysis of the OOO "Radiosvyaz" production was carry out. Most of the products of the enterprises are involved in producing aluminum alloys. Typical body parts have the horizontal and vertical surfaces also many body parts consist of thin-walled design elements. Taking into account these design features the part-sample was developed shown in the figure 1. The geometrical shape of the part-sample contains the surface. Machining of these surfaces allows us to analyze the final form of surfaces.

The study treated thin wall showed that this element is the most malleable and its surfaces have the greatest precision of form and position.

The sampling size was nine aluminum parts-samples for which we developed three technological processes.

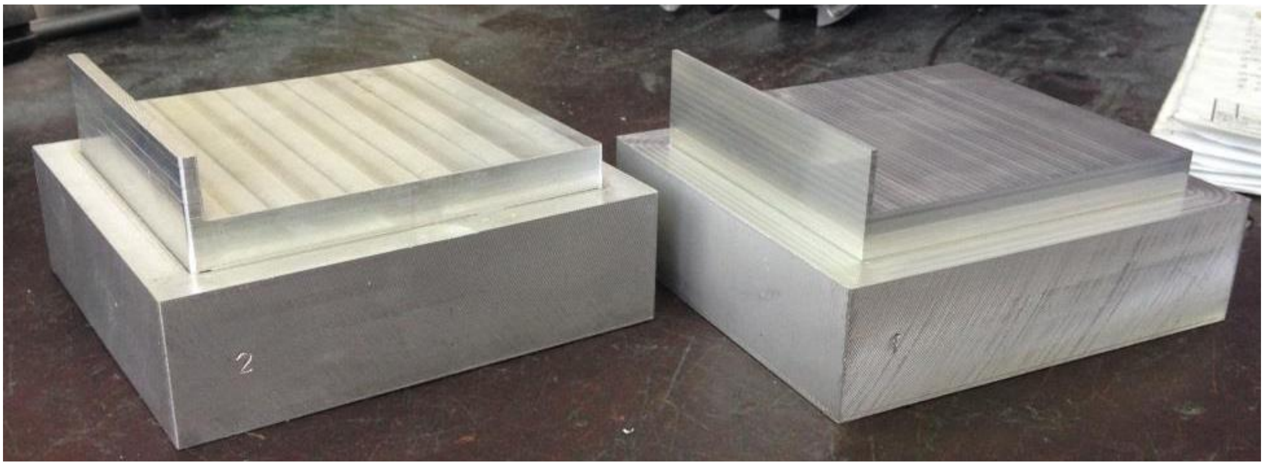

Figure 1 – The samples after roughing work (left) and after finishing work (right)

To investigate the correlation of machining parameters and shape of machined surfaces we made control to 1561 points. The control program of the measurements was generated the way that the measurement points were distributed over the surfaces of the grid with pitch of 3 mm.

Another part of the experimental study was to determine the effect of the feed rate of the probe to the measurement error. To do this, a single point measurement was carried out with different feed rates of the probe.

Control of surfaces was produced after each machining step.

The analysis of the data is followed by the conclusions:

- machining step does not affect the accuracy of measurements;
- the spread of the measured values increases difference with the cutter diameter increasing;
- increasing of cutter diameter conduces to increasing of the measured values spread;
- there is a linear dependence of the constant deviation on the velocity of the probe, which was expressed by a offset value;
- probe movement speed does not affect the spread of the measured values.

Using the algorithm deviations from flatness of the wall were calculated. Analysis of coordinates of points that form the adjoin planes, shows that these points are distributed along the edges of the measured surface. Thus, for determining the deviations from flatness is sufficient to measure points the most distant from each other in terms of the test surface.

These experimental results were used for creation of geometric accuracy interoperational control techniques on the machine-tool, it consist of following steps:

1. Analysis of machining strategies, tool and cutting conditions to determine the number and location of measurement points.
2. Conduct of measurements in points and getting results in a set of points coordinates.
3. Calculation errors of form and position in measurement points.
4. Machining parameters correction: when defect - to reduce the intensity of cutting, in the absence of defect – to intensify treatment to improve the performance.

THE MAIN RESULTS AND CONCLUSIONS

- We formulated fundamental principles of interoperation control technique of parts on milling processing centers;
- We identified the effect of processing technique on poor shape precision and position of milling surface;
- We determined correlation between velocity of the tester and results of measurement;
- We identified the parameters that do not affect the machining accuracy.

The prospects for further research based on the company OOO “Radiosvyaz” are marked:

- more detailed experimental research to investigate the effect of processing techniques on the shape of the machined surface.
- updating a forecasting techniques of shape of the machined surface.
- updating and developing the technique that is used for geometric measurements.

FUNDAMENTALS OF THE THESIS ARE PUBLISHED IN THE FOLLOWING SCIENTIFIC JOURNALS:

In journals approved by Russian Academy of Science:

1. Kucherenko N. A., Pikalov Y. Y. Analysis of technical and informational support of control systems used in geometrical accuracy of parts // Problems of engineering and automation - accepted for publication.

In other journals:

2. Kucherenko N. A., Pikalov Y. Y. Analysis of modern measuring equipment and control of geometrical accuracy of parts // Proceedings of the regional scientific and technical conference of post-graduates “Special engineering education”: Krasnoyarsk, 2013;
3. Kucherenko N. A., Pikalov Y. Y. Analysis of modern measuring equipment and control of geometric precision parts // Proceedings of the 51st International scientific student conference “Student and scientific and technical innovation”: Novosibirsk, 2013.