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Development of Measuring Cycles to Compensate for Errors in Basing, Algorithms for Forming Sets of Basic Technological Processes of Mechanical Processing of Parts

[1]***SAVELYEVA Nadezhda,*** *postdoctorant, n.a.savelyeva@gmail.com,*
[1]****ZHETESSOVA Gulnara,*** *Dr. of Tech. Sci., Professor, zhetesova@mail.ru,*
[1]***BERG Alexandra,*** *doctoral student, kibeko_1995@mail.ru,*
[1]***BERG Andrey,*** *doctoral student, kibeko_1995@mail.ru,*
[1]*NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,*
**corresponding author.*

Abstract. *Considered CNC machines and the ways to improve the process of milling. After analyzing all the presented factors that affect the accuracy of manufacturing the final product on milling machines. It was found that the most significant factor for controlling the structure of the formation of installation errors is its decomposition to the error of the workpiece basing. It is important to formulate a mechanism for compensating for the error of basing the workpiece relative to the machine plane to be processed. The introduction of new measurement cycles at the enterprise, to compensate for the error of basing, will significantly increase the efficiency of production – by reducing the processing time and at the same time increasing the accuracy of manufactured products. A method of introducing new measurement cycles to the enterprise to compensate for the error of basing is proposed.*

Keywords: *bases, CNC machines, errors, milling cutters, milling group machines, milling operations, mechanical engineering, CAD analyses, basing, machine tools.*

Research methods

Classification. Determination of position in space. New advanced computer-aided design (CAD) tools are available now and that allows you not only to draw objects in your computer, but also to determine forces, stresses and movement. It is now possible to create objects directly from a computer model using rapid prototyping tools. These tools can also be used for teaching fundamental engineering material [1-3].

In modern constructions of technological processes, processes are developed as documentation sets. In case of automated pre-production design, such process descriptions are stored in a database.

The choice of the operation is a multivariate problem. Choosing operations takes into account a number of factors, such as product design and its conditions, dimensional allowances and mutual arrangement of structural elements. During selecting operations the process engineer shall optimize the sequence, carefully set parameters, intermediate dimensions, removable stock, time standards, allowances, etc. That is why formalization of this stage within PPE is still an actual problem for modern enterprises with digital support. The development and implementation of information technologies in various industries has made the concept of «digital enterprise» a sign of innovativeness, allowing the enterprises described in this way to produce highly competitive products with high consumer properties at minimum cost. In a virtual enterprise (i.e. before manufacturing a product), planners and technologists can take into account all the risks and analyze many different options for optimizing the production sequence of transforming a semi-finished product into a finished product. The following engineering process design algorithm based on a digital product model is proposed [4]:

1) to form an information model (image) of your product: a. to recognize its structure; b. to form a set of structural elements (SE) with a list of important parameters;

2) check the model for manufacturability: a. perform quality tests; b. perform quantitative tests;

3) to design the technological process: a. to choose the type of technological process; b. to choose the billet; c. to choose the set of technological bases; d. to determine the sequence of forming of each detail; e. to form operations (production sequence); f. to choose equipment; g. to choose the tooling;

4) to calculate the norms of the time of manufacturing of the part;

5) choose the optimal technological process.

The number of reference points (points of contact with the installation components) on the base diagram can be more or less than six. Examples of «basing schemes» with three, seven and even nine reference points are given, but the number of real points of contact affects the number of errors in the technological bases and installation elements, and design basis, the result of which is a developed framework.

One of the key concepts of the theory is the concept of the basing error and installation error. Under the installation error is understood the inaccuracy of the position of the workpiece, cutting tools, fixtures, etc. in relation to the bases of the machine. They are taken for auxiliary bases (as a rule, guides) on which the assembly units, carrying the actuating surfaces. The bases of the machine are called the installation bases.

The plane and axis of symmetry according to GOST 21495-77 are called hidden technological bases, the other bases of the set are called explicit technological bases. Based on the concept of the design technological base, it is possible to introduce the concept of the design basis (in the future basis). We shall call basing the introduction of the reference system or the introduction of our own coordinate system conjugated (in contact with the technological bases). At the stage of identification of the set of orientation bases, the composition of the workpiece surfaces with respect to which the tolerances of the relative position and dimensional relations to the structural elements to be processed are set shall be determined.

Automated design and technological preparation of production (CAD / CAM / CAE ... – CA «x» technologies) are among the most important methods and facilities of information support of modern mechanical engineering [4]. And, as practice shows, the greatest effect is achieved with the complex application of technologies and technical facilities of industrial automation [5]. For the industrial enterprises the most actual are questions of automation of stages of designing and manufacture of life cycle of a product and corresponding to them base CAD-technologies: the automated geometrical modelling and designing (CAD), designing of operating programs for machine tools with CNC (cam), and also the automated measurement of the form of details (Sai).

Practice shows that the above mentioned project procedures and processes are significantly interdependent [6]. Already at the stage of geometrical modeling of the base surfaces of the processed parts it is necessary to take into account the accuracy, tools and equipment involved in production. In turn, all the above mentioned questions should be taken into account and concretized while choosing the processing strategies and parameters of control programs. The complex nature of computerization of design and technological preparation of production, manufacturing and measurement of parts significantly changes the approaches to binding of blanks to the processing equipment. Ideas for adaptive control of metalworking equipment based on direct measurement during cutting [7] and the use of geometrical modeling of machined surfaces [8] are not new. But only at the present stage of development of means of industrial automation and introduction of technologies of their complex use these approaches (we will call them «software» method of a binding of blanks) become practically achievable and economically expedient.

The geometry of parts designed by the designer taking into account different methods of manufacturing (casting, stamping, cutting, etc.) can vary significantly. And with the use of computer tools for geometric modeling and CNC machines significantly expand the choice of base schemes. Possible and even preferable are theoretical points, lines and surfaces, for example, associated with the position of axes of power elements, centers of gravity, pressure, etc.

The electronic model of a product (EMI) created by a designer in the environment of machine-building CAD, in a certain way is transformed by the technologist into a model of blanks developed also by facilities of CAD. Thus it is possible to assert that modern methods of automation of designing essentially change traditional approaches to designing of blanks and working out of technological processes.

Results and Discussions

So the decision of problems of automation of working out of operating programs lead to necessity of creation of operating models for all operations of technological process on which there is a form formation of surfaces of the future detail. The operating model will be called EMI, describing the shape of the blank on a particular operation of the technological process. The main approaches to the development of operating models are two and both approaches require consideration of the way the part is processed.

The first approach is based on sequential accumulation of allowances on the processed surfaces from the nominal parameters of the part assigned by the designer to the technological interoperation dimensions. As a result of increase in allowances on all operations the idealized EMI of a workpiece is created. Further on it the necessary geometrical elements defined by technology of reception of blank (slopes, roundings and allowances) are added. This approach makes it possible to obtain a theoretically optimal, almost perfect workpiece in automated mode.

The second approach involves the use of arbitrary (defined) shape blanks. In this case, it is necessary to perform the successive removal of allowances until the final shape of the part with a certain quality of work surfaces.

The milling group machines are leading by the number of units of the machine park in the production industry. Milling machines are designed for processing of various planes of body parts, rotational bodies, punches, dies, spline contours and other complex surfaces. Milling is performed with the help of milling cutters, where the main movement is the rotation of the milling cutter, and the workpiece is fixed on the machine working plane (table, fixture satellite, etc.) that makes the feed motion. These machines can be equipped with a numerical program control (CNC) system. It is important to take into account the real position of mechanisms and units of the machine during the operation on the workpiece. The task of the mutual orientation of the machine and the workpiece is solved by the base. Basing is the giving of a workpiece the required position relative to the selected coordinate system [9]. The basing ensures that a certain required position is given relative to the feed motion of the machining tool (milling cutter) during workpiece processing on milling machines of a milling group. The basing also excludes the possible misalignment of the workpiece during machining, for this purpose it is necessary to use the overlay of bilateral bonds on the workpiece, ensuring a constant position of the body with respect to the axes X, Y, Z, and turns A, B, C around these axes (Figure 1).

The bases are classified: by destination, by degrees of imprisonment and by nature of manifestations (Figure 2). Design – determines the position of the assembly unit in the assembly; Measuring – base for controlling the size of the part.

B Technological base

Technological base determines the position of the workpiece machining it on the machine; technological base has the greatest impact on the quality of the resulting surface of the workpiece. In the process of production of the part in the conditions of serial production the method of processing on the checking base surfaces is used, i.e. surfaces on which there is a verification of the position of the part on the machine. When using the machined surface as a test base – time for the operation is reduced. Combining the main technological base with the design significantly increases the accuracy of processing [9].

Accuracy is the rule of correspondence of the finished product in relation to the given initial characteristics. Ensuring accuracy is a set of actions aimed at achieving maximum accuracy within production resources. Ensuring accuracy is a timeconsuming and complex process that is carried out at all stages of product manufacturing. Uncertainty is the amount of actual deviation of a product from the specified initial characteristics. Uncertainty is subdivided into design uncertainty and production uncertainty. Design errors – affect the accuracy of product manufacturing before its direct production, are incorrigible and, in most cases, their manifestation is associated with insufficient

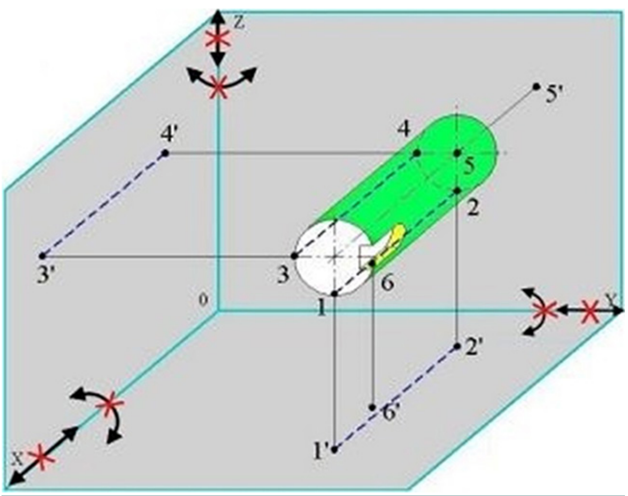

Figure 1 – Basing of the shaft on 6 points

qualification of design engineers. Production errors are the main class of errors that determine the technological accuracy of the product. When conducting research on the manifestation of errors, it is necessary to decompose the production process into separate operations, with direct identification of each error element and the degree of its influence on the TP [2,22]. There are two types of manufacturing errors: – Random – unexplained random factors (chip sticking, tool breakage, etc.); – Systematic – constant error factors (wear and tear of equipment, material properties, incorrect technological approach to machining, etc.).

Production errors are defined by 4 groups: theoretical, based, setting and processing errors (Figure 3).

The total number of deviations should not exceed the value of the tolerance field.

$$\sum \varepsilon \leq T. \tag{1}$$

$$\sum \varepsilon = \varepsilon_{theor} + \varepsilon_{setup} + \varepsilon_{setting} + \varepsilon_{proc}. \tag{2}$$

$$\varepsilon_{setup} = \varepsilon_{bas} + \varepsilon_{fix} + \varepsilon_{proc}. \tag{3}$$

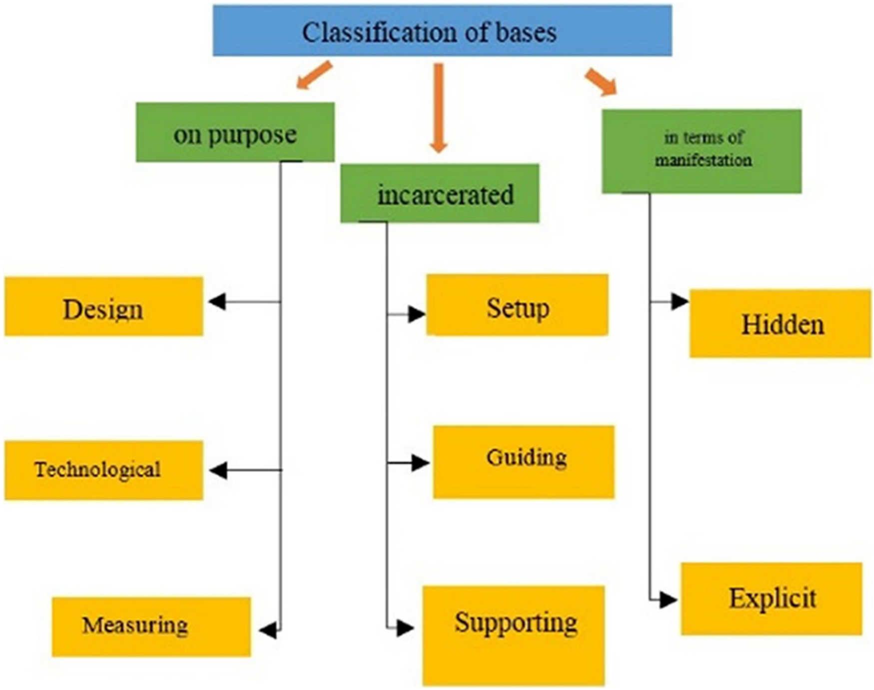

Figure 2 – Classification of bases

Production errors				
Theoretical errors	Theoretical setup	Setting errors	Processing Errors	
Based on compiling a mathematical model of the product with the resulting error factors	Based on the geometric sum of errors of the basing, fixture and fixture (base mismatch, displacement of the part, installation accuracy)	Accuracy of devices used at adjustment of the process equipment and qualification of the operator	Independent The error is due to the inaccuracy of the equipment, the technical service station and the tool	Dependent Factor of deformation influence, wear and tear, part stresses
ε_{theor}	ε_{setup}	$\varepsilon_{setting}$	ε_{proc}	

Figure 3 – Groups of production errors. The total number of deviations should not exceed the value of the tolerance field due to calculating the accuracy of the actual value and the value of the required

$$\varepsilon_{setup} \leqq T - k_T \sqrt{\begin{array}{l}(k_{T1}+\varepsilon_{bas})^2+\varepsilon_{fix}^2+\varepsilon_{setting}+\\ +\dfrac{\varepsilon_{proc}}{1+k_{T2}}+(k_{T1}\times\omega)^2\end{array}}, \quad (4)$$

where ε_{bas} – workpiece basing error; ε_{fix} – workpiece fixation; ε_{proc} – processing error; ω – economic processing accuracy; k_T – coefficient of normal distribution law value; k_{T1} – coefficient, limit value of basing error; k_{T2} – processing error by factors independent of the device.

In the considered formula (4) we can observe, that one of the most influencing factors of an industrial error is an error of basing of a billet. Machine errors of the milling group – the machine parts can be made with deviations, which affects the constant error, the absolute accuracy of the machine is impossible. For example, the ball screw has a certain range of connection error and accuracy, set in the factory tolerances of the manufacturer, the time of operation of the machine that meets these requirements, is determined by the mathematical formula for calculating wear. In accordance with this requires a certain period of planning and forced repair of components to ensure the accuracy of processing [9].

Conclusions

Analyzing all the presented factors influencing the accuracy of the final product manufacture on the milling group machines, we figured out that the most important factor for control in the issue of the structure of formation of errors of the unit is decomposition to the error of the workpiece basis. It is important to formulate a mechanism for compensation of the blank base error relative to the processed plane of the machine [3].

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Бөлшектерді механикалық өңдеудің негізгі технологиялық процестерінің жиынтығын қалыптастыру алгоритмдерін, базалау қателерін өтеу үшін өлшеу циклдерін әзірлеу

*[1]**САВЕЛЬЕВА Надежда Александровна,** постдокторант, n.a.savelyeva@gmail.com,*
*[1]***ЖЕТЕСОВА Гульнара Сантаевна,** т.ғ.д., профессор, zhetesova@mail.ru,*
*[1]**БЕРГ Александра Сергеевна,** докторант, kibeko_1995@mail.ru,*
*[1]**БЕРГ Андрей Алексеевич,** докторант, kibeko_1995@mail.ru,*
[1]«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,
**автор-корреспондент.*

Аңдатпа. *CNC машиналарын және фрезерлеу процесін жақсарту жолдары қарастырылды. Фрезерлік станоктарда соңғы өнімді өндірудің дәлдігіне әсер ететін барлық факторлар талданды. Орнату қателіктерінің құрылымын бақылаудың маңызды факторы, оның дайындаманың негізіндегі қателікке ыдырауы болып табылады. Машинаның өңделген жазықтығына қатысты дайындаманың орналасу қатесін өтеу механизмін тұжырымдау маңызды. Кәсіпорында жаңа өлшеу циклдерін енгізу, орналасу қателігін өтеу үшін өңдеу уақытын қысқарту және сонымен бірге өнімнің дәлдігін арттыру арқылы өндіріс тиімділігін едәуір арттырады. Кәсіпорында базалық қатені өтеу үшін жаңа өлшеу циклдерін енгізу әдісі ұсынылған.*

Кілт сөздер: *CNC машиналары, қателер, фрезерлер, фрезерлік топтар, фрезерлік операциялар, машина жасау, АЖЖ талдау, орнықтандыру, станоктар.*

Разработка измерительных циклов для компенсации ошибок базирования, алгоритмов формирования наборов основных технологических процессов механической обработки деталей

[1]***САВЕЛЬЕВА Надежда Александровна,*** *постдокторант, n.a.savelyeva@gmail.com,*
[1]****ЖЕТЕСОВА Гульнара Сантаевна,*** *д.т.н., профессор, zhetesova@mail.ru,*
[1]***БЕРГ Александра Сергеевна,*** *докторант, kibeko_1995@mail.ru,*
[1]***БЕРГ Андрей Алексеевич,*** *докторант, kibeko_1995@mail.ru,*
[1]*НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,*
**автор-корреспондент.*

Аннотация. *Рассмотрены станки с ЧПУ и способы улучшения процесса фрезерования. Проанализировав все представленные факторы, влияющие на точность изготовления конечного изделия на фрезерных станках, установлено, что наиболее значимым фактором для контроля структуры формирования ошибок установки является ее разложение на погрешность базирования заготовки. Важно сформулировать механизм компенсации ошибки базирования заготовки относительно обрабатываемой плоскости станка. Внедрение новых циклов измерений на предприятии для компенсации погрешности базирования позволит значительно повысить эффективность производства за счет сокращения времени обработки и одновременно повышения точности выпускаемой продукции. Предложен метод внедрения новых циклов измерений на предприятии для компенсации погрешности базирования.*

Ключевые слова: *базы, станки с ЧПУ, ошибки, фрезы, фрезерные групповые станки, фрезерные операции, машиностроение, анализ САПР, базирование, станки.*

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