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Complex Automation of Machine Building Design and Production with Software the Basing of Parts on CNC Machines

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***Abstract.** The purpose of the research is to consider the problems of computer-aided design in order to develop an integrated methodology for the design of technological processes and control programs. Research methods – analysis of design problems and modeling of technological processes. The problems of computer-aided design are considered, as well as the problems of technological preparation of producing the of complex shape on machine tools with numerical control. A comprehensive methodology of designing technological processes and control programs for CNC machines using the methodology of software-oriented referencing and modern electronic measuring instruments is proposed. Complex techniques are described. The existing problems of basing in mechanical engineering are analyzed. The merging of the industry into large structures is considered. The article considers the dependence of mechanical engineering on labor productivity, successful activities of the leading sectors of the economy, ensuring the scientific and technological progress of the country as a whole.*

***Keywords:** CNC machine tool, automation, basing, CAM/CAD/CAE systems, mechanical engineering, theory of basing.*

Introduction

The most important reason for the differences in approaches to the definition of the concepts of «basing», «base», etc., the formalization of the «choice of bases», as well as the lack of workable formal methods for the appointment of basing schemes, installation schemes and the route of processing the blanks of body parts and in general CAD TP synthesis for body parts is the imperfection of some provisions of the theory of basing.

Despite the numerous works of major Soviet scientists devoted to basing in mechanical engineering, and the introduction of GOST21495-77 «Basics in mechanical engineering. Terms and definitions» are still subject to criticism and debate in the CIS countries on this issue. The reason for such misunderstanding and uncertainty is the fact that when formulating basic terms and definitions, there was no clear support for the tasks that are solved at the base.

The theory of basing in mechanical engineering was engaged many major researchers. In early works (K.M. Gladkov, D.P. Maslov, E.I. Glushchenko, A.M. Karatygin, E.G. Annenkova, etc.) there was no unified approach to the classification of bases and to the formation of basic concepts and definitions of the theory. The choice of a set of technological bases was recommended to be based on general recommendations suitable for some types of parts (M.O. Jacobson, A.V. Ettel, B.L. Bespalov, L.A. Glaser, and others).

New advanced computer-aided design (CAD) tools are now available that allow not only to draw objects on a computer, but also to determine forces, stresses and movements. You can now create objects directly from a computer model using rapid prototyping tools. These tools can also be used to teach basic engineering material.

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

Research results

Selection of the operation is a multidimensional task. When choosing an operation it is necessary to take into account a number of factors, such as the design of the product and its conditions, such as the size of compensation and the mutual location of the structural elements. When choosing an operation, the process engineer should optimize consistency, control careful installation of meters, medium sizes, removable consumables, time standards, passes, etc. The development and implementation of information technologies in various industries has made the term «digital enterprise» a sign of innovation, which allowed the described enterprises to produce highly competitive products with high consumer properties at minimum cost. In a virtual company (that is,

before the production of the product) designers and technologists can take into account all the risks and analyze many different options to optimize the production series of transformation of semi-finished products into a finished product. The following algorithm was proposed for designing a machine process based on a digital product model to form an information model (image) of your product:

a. 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. choose the type of technological process;

b. to choose a blank;

c. choose a set of technological bases;

d. determine the sequence of forming of each part;

e. to form operations (production sequence);

f. select the equipment;

g. 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 installation components) on the base diagram can be both more and 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 affect 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 machine-tool bases shall be called the installation bases.

The plane and axis of symmetry in accordance with GOST 21495-77 are called hidden technological bases, the other bases of the set – the 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 mutual position and dimensional relations to the structural elements to be processed are set shall be determined.

The machine-building complex in the majority of developed countries is recognized as the leading branch of industry. At present the industry is merging into large structures. Labor productivity, successful activity of the leading branches of economy, provision of scientific and technical progress of the country as a whole depend on the level of development of machine-building industry. Prospects of economic and social development of the country impose new requirements to the level of mechanical engineering. It is not superfluous to study the functioning of mechanical engineering in the countries leading in this field on the world market. This industry is a driving force for other industries in the country.

At present, engineering education faces the task of improving the level of training of specialists capable of applying information technologies to effectively solve engineering and technological problems. Therefore, the most important directions of improving the training of engineers of the design and technological profile are computerization, ensuring the fundamental and professional orientation of education in the university.

An important place in the training process of mechanical engineers is occupied by the issues of material science, heat treatment and technology of manufacturing parts in mechanical engineering. Often, traditional methods of hardening machine parts (deformation, thermal, chemical-thermal) are not effective enough. Currently, the machine-building enterprises (especially in the automotive industry) are mastering more and more advanced technologies that allow to intensify many physical and chemical processes through the use of the nature of materials and features of structural transformations occurring in them. These include thermal cyclic laser, plasma treatment, powder metallurgy and other methods of processing. These methods make it possible to obtain unique structural changes that bring materials to a new level of structural strength and wear resistance.

Electronic model of the product (EMI), created by the designer in the environment of machine-building CAD, in a certain way is transformed by the technologist into the model of blanks, developed by means of CAD as well. 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.

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. Operating model we will call the EMP, 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 the allowance build-up, an idealized blank EMP is created for all operations. 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 successively remove allowances until the final shape of the workpiece is obtained with a certain quality of work surfaces.

Regardless of the approach, the availability of a set of design and operating models gives the technologists significant advantages over the traditional (local) approach to the BCP. First, a precise description of the geometric shape of the workpiece on each operation appears. This is important both for the CNC technologist and the tooling designer. Secondly, in comparison with the traditional process development, the production of technological sketches for processing is automated. Thirdly, the productivity of technological design is increased (up to 70% of technologist's productive work time is saved).

The coordination of geometrical modeling processes at the design and technological stages of the BCCP contributes to the achievement of optimal design result, which ensures the improvement of the quality of manufactured products and productivity of processing equipment.

At complex application of EMI there is an opportunity to automate such a complex and tudno-formalizable procedure of BCCP as working off the product for manufacturability. In this case, objective criteria can be used. For example, already at the modeling stage set limits on the size of the allowance, the required accuracy and quality of surfaces, the minimum size of roundings and slopes.

During the development of technological processes for CNC equipment equipped with electronic measuring instruments, the so-called «software» based methods can be used. In contrast to traditional methods of blank basing, long and successfully used for universal machining equipment, controlled by skilled workers, the software method of basing the blanks on CNC machines. The software-based method involves the use of electronic measuring instruments. They can be either software-controlled or uncontrollable. The measurement results allow to determine the position of the workpiece and assign the zero and axes of the machining program.

Software basing differs from the «manual» methods in that the software solves the inverse problem of correcting the position of the main axes of the CNC machine with respect to the coordinates of reference points measured on an empty surface attached to the machine [2]. At the same time, it becomes acceptable to install the workpiece on the device on the machine table quite simply and quickly.

The use of a software-oriented design changes the structure of production errors. It is known that error settings consist of error booking and error deployment: Mounting parts of the bug can be taken into account in the program and can usually be ignored: The basic bug is completely eliminated because the software zero, is not related to the installation of the workpiece surfaces, and surfaces that were developed in previous operations, or the whole and all parts from the surface. This makes the software approach similar to the experimental steps of the method. The only error taken into account when using the software is the electronic measurement system error.

In terms of technology, the development of a highly automated process combines measuring, process and design bases. In this case, the transition from basing on clear surfaces to basing on hidden bases. Hidden is commonly referred to as imaginary surfaces, axes and points, usually coinciding with the design bases. Application of the principle of aligning the bases in the control program can dramatically improve the accuracy of processing and reliability of technological processes.

It should be noted that the ideas of adaptive part processing on the hidden bases, when proposed to correct the cutting process depending on the measurement results are not new. But possibilities of the modern digital equipment, in a combination to functionality of the applied CAD software allow to use qualitatively new technological decisions and to automate in a complex way design-production stages of life cycle of products.

For studying of efficiency and an illustration of possibilities of complex processes of automation it is offered to use «S» – the figurative curves constructed by analogy with a technique of research resulted in [3].

In this case the integral criterion of quality and accuracy of manufacturing can be used Φ, compliant with design errors (P_k) and technology (P_t) models, as well as the manufacturing process (P_m) details:

$$\Phi = f(P_k, P_t, P_m). \quad (1)$$

Conclusions

Complex method of automation of design and manufacture of products on CNC machines allows simultaneously with the improvement of quality of parts processing to significantly reduce the time of manufacture of products.

REFERENCES

1. A.A. Cherepashkov, N.V. Nosov, Computer technologies, modeling and automated systems in machine building (Prospekt Nauki, St. Petersburg, 2018).

2. A.A. Cherepashkov, Izvestia of Samara Scientific Center of the Russian Academy of Sciences, v. 12(33), pp. 619-622 (2010).
3. K.V. Khrustitskiy, A.A. Cherepashkov, Bulletin of the Samara State Aerospace University, v. 5 (36), pp. 61-71 (2012).
4. B.S. Balakshin, Adaptive management of the tool (Machine-building, Moscow, 1973).
5. B.M. Bazrov, Module technology in machine building (Machine-building, Moscow, 2001).

СББ білдектерде бөлшектерді бағдарламалық негіздеу кезінде машинажасауды жобалау мен өндірісін кешенді автоматтандыру.

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***Аңдатпа.** Зерттеудің мақсаты технологиялық процестер мен басқару бағдарламаларын жобалаудың интеграцияланған әдістемесін құру мақсатында компьютерлік жобалау мәселелерін қарастыру болып табылады. Зерттеу әдістері – жобалау мәселелерін талдау және технологиялық процестерді модельдеу. Сондай-ақ, сандық бағдарламалық басқарылатын білдектерде күрделі пішінді бөлшектерді өндіруді технологиялық дайындау мәселелері қарастырылады. Бағдарламалық-бағдарланған қысқаша мазмұн жасау және заманауи электрондық өлшеу құралдары әдістемесін пайдалану арқылы СББ білдектеріне арналған технологиялық процестер мен басқару бағдарламаларын жобалаудың кешенді әдістемесі ұсынылған. Кешенді әдістемелер сипатталған. Машинажасаудағы қазіргі базалау проблемалары талданды. Саланы ірі құрылымдарға біріктіру қарастырылды. Машинажасаудың еңбек өнімділігіне, экономиканың жетекші салаларының табысты қызметіне, тұтастай алғанда елдің ғылыми-техникалық прогресін қамтамасыз етуге тәуелділігі қарастырылды.*

***Кілт сөздер:** СББ білдегі, автоматтандыру, негіздеу, CAM/ CAD/CAE-жүйелер, машина жасау, негіздеу теориясы.*

Комплексная автоматизация машиностроительного проектирования и производства при программном базировании деталей на станках с ЧПУ

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***Аннотация.** Цель исследования – рассмотрение проблем автоматизированного проектирования с целью разработки комплексной методики проектирования технологических процессов и управляющих программ. Методы исследования – анализ проблем проектирования и моделирование технологических процессов. Также рассмотрены проблемы технологической подготовки производства деталей сложной формы на станках с числовым программным управлением. Предложена комплексная методика проектирования технологических процессов и управляющих программ для станков с ЧПУ с использованием методики программно-ориентированного реферирования и современных электронных измерительных средств. Описаны комплексные методики. Проанализированы существующие проблемы базирования в машиностроении. Рассмотрено сливание отрасли в крупные структуры. Рассмотрена зависимость машиностроения от производительности труда, успешной деятельности ведущих отраслей экономики, обеспечения научно-технического прогресса страны в целом.*

***Ключевые слова:** станок с ЧПУ, автоматизация, базирование, CAM/CAD/CAE-системы, машиностроение, теория базирования.*

REFERENCES

1. A.A. Cherepashkov, N.V. Nosov, Computer technologies, modeling and automated systems in machine building (Prospekt Nauki, St. Petersburg, 2018).
2. A.A. Cherepashkov, Izvestia of Samara Scientific Center of the Russian Academy of Sciences, v. 12(33), pp. 619-622 (2010).
3. K.V. Khrustitskiy, A.A. Cherepashkov, Bulletin of the Samara State Aerospace University, v. 5 (36), pp. 61-71 (2012).
4. B.S. Balakshin, Adaptive management of the tool (Machine-building, Moscow, 1973).
5. B.M. Bazrov, Module technology in machine building (Machine-building, Moscow, 2001).