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THE EFFECTIVENESS OF THE APPLICATION OF CNC MACHINES FOR PROCESSING HARD-TO-MACHINE PARTS OF AIRCRAFT

ЭФФЕКТИВНОСТЬ ПРИМЕНЕНИЯ СТАНКОВ С ЧПУ ДЛЯ ОБРАБОТКИ ТРУДНООБРАБАТЫВАЕМЫХ ДЕТАЛЕЙ ЛЕТАТЕЛЬНЫХ АППАРАТОВ

ҰШУ АППАРАТТАРЫНЫҢ ӨҢДЕУ ҚИЫН БӨЛШЕКТЕРІН ӨҢДЕУГЕ АРНАЛҒАН CNC СТАНОКТАРЫН ҚОЛДАНУ ТИІМДІЛІГІ

Abstract. The article discusses the mechanical processing of aircraft parts on CNC machines made of hard-to-process materials. Methods of preparation of control programs for CNC machines are considered. A control program for an airplane part has been developed using the SolidWorks software product. The efficiency of the technological process of mechanical processing depends on the correct choice of equipment, technological cutting modes, and the choice of cutting tools.
Key words: hard-to-process materials, CNC machines, control program, aircraft parts.

Аңдатпа. Мақалада өңдеу қиын материалдардан жасалған СБҚ станоктарында ұшу аппараттарының бөлшектерін механикалық өңдеу қарастырылған. СБҚ машиналары үшін басқару бағдарламаларын дайындау әдістері қарастырылған. SolidWorks бағдарламалық өнімі арқылы ұшақ бөлшектерін басқару бағдарламасы әзірленді. Өңдеу процесінің тиімділігі жабдықты дұрыс таңдауға, кесудің технологиялық режимдеріне, кесу құралын таңдауға байланысты.
Түйін сөздер: өңдеу қиын материалдар, СБҚ машиналары, басқару бағдарламасы, ұшу аппараттарының бөлшектері.

Аннотация. В статье рассмотрены механическая обработка деталей летательных аппаратов на станках с ЧПУ из труднообрабатываемых материалов. Рассмотрены методы подготовки управлящих программ для станков с ЧПУ. Разработана управляющая программа для самолетной детали с помощью программного продукта Solid Works. Эффективность технологического процесса механической обработки зависят от правильного выбора оборудования, технологических режимов резания, выбора режущего инструмента.
Ключевые слова: труднообрабатываемые материалы, станки с ЧПУ, управляющая программа, детали летательных аппаратов.

Introduction. The aerospace parts manufacturing industry maintains high quality standards, rigorous testing practices, and strict regulatory requirements in order to ensure the function, fit, and reliability of every part. The aerospace industry uses many specialized parts and, given the nature of flight, many of these parts are mission-critical [1].

Parts of a modern aircraft and an aircraft engine work in difficult conditions: they are exposed to heavy loads, variable temperatures and a chemically active harmful environment.

The final processing of a complex workpiece of aircraft parts includes machining on numerically controlled machines. In modern manufacturing, expensive automated equipment, numerically controlled machines, flexible production systems based on metalworking equipment of various configurations controlled by a computer are increasingly consumed. The effectiveness of the use of numerically controlled machines is determined by how optimally prepared the control program for processing parts of complex shape. As usual, well-known programs for the preparation of technological processes for machining parts on CNC machines work according to a template entered into the database, which does not take into account specific processing cases.

The current state of the use of CNC machines. The aerospace industry relies on safety-critical parts within stringent tolerances. CNC machining is the primary method of creating these parts in today's digitally driven ecosystem. Common aerospace parts created using CNC machining may include:

Engine components; Fuel panels; Landing gear components; Engine mounts; Airfoils; Vanes; Turbine assemblies [2].

The increase in the complexity of mechanical processing is a consequence of the ever-expanding use of hard-to-process materials, such as titanium alloys and high-strength steels, as well as large-sized wing and fuselage structures (panels), including those made of high-strength materials. So, for a number of aircraft products, the volume of machine work exceeded 30% of the total complexity of airframe manufacturing. The volumes of use of structural materials as a percentage of the total weight of the airframe according to the data are presented in Table 1.

Table 1. The scope of application of structural materials in the airframe

Product	**The volume of materials used in % of the airframe weight**			
	Titanium alloys	**Aluminum alloys**	**Steels**	**Other materials, including PCM**
Il-86	14	54	15	17
B747	4,25	68	10	17,75
F-14	24,4	39	17	19,6
F-15	26,7	35,5	3,3	34,5
F-18	11,7	47,7	15	25,6
B1	22,5	41,3	18,5	27,7
YF-17	7	71	10	12
SR-71	95			
F-22	24	35	5	36
MiG-25	8	11	80	
MiG-31	16	33	50	1

A CNC machine is an automatic power tool with computer controlled for turning, milling, engraving, cutting, drilling, grinding, welding, spinning, winding in modern industrial manufacturing.

A CNC machine works with CAD/CAM software and G code for automated machining. The most common types of CNC machine include [3].

Advantages of CNC machines [4]:

Capability: This technology uses computer precision to go beyond the limitations of manual capabilities. More complex and intricate operations are possible with CNC machining.

Consistency, Precision and Redundancy: With computer software, the design of any given product only needs to be programmed once. The CNC machine can then perfectly replicate that design, for any order quantity.

Fewer Personnel: Because computer software controls the machinery, fewer technicians are needed for operation and oversight, cutting overall expenses.

Continuous Use: Unlike manual labor, CNC machinery (barring any malfunction or maintenance issue) can work continuously over any period of time without a break. This greatly increases productivity and efficiency.

Low Skill Requirement: CNC machine operators require little training and skill when compared to manual machine operators.

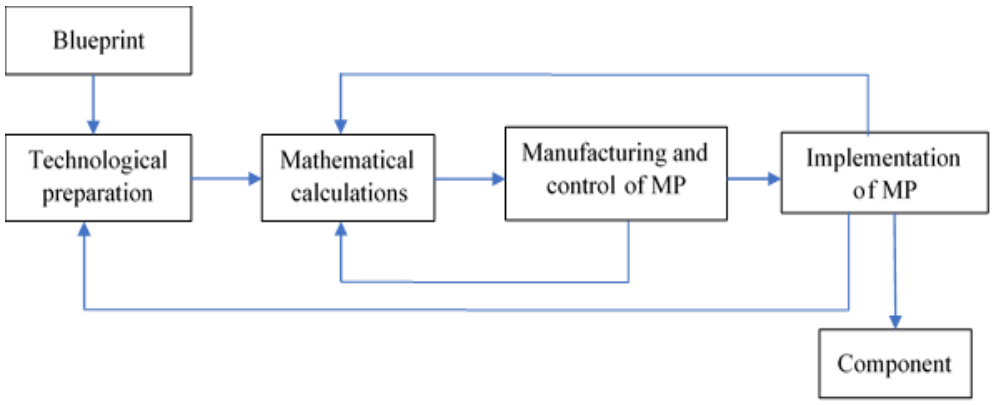
Flexibility: The software can be reprogrammed quickly and easily to produce different parts, allowing operations to keep up with shifting customer demands.

Preparation of control programs for CNC machines. For modern CNC machines, there are three methods of programming processing and creating a control program:

• manual programming
• programming on the control panel of the CNC control system
• Programming using CAD/CAM system.

Manual programming is a long, monotonous and monotonous activity. However, all technologists-programmers should know the technique of manual programming base for further training. There are still many enterprises in our country that use the manual programming method. Indeed, if the plant has several CNC machines, and the manufactured parts are simple, then a competent programmer is able to work quite successfully without automation of his own labor.

The method of programming on the control panel of a CNC machine has gained particular popularity only in recent years, which is associated with the development of the technical base (touch screens, solid-state memory, high-performance systems of minimal dimensions), improving the interface of control panels and their technological capabilities. When programming on the control panel of the CNC system, programs are created directly on the screen, controls using the joystick keyboard and touch screen. Modern control panels of CNC machines work very quickly and efficiently, allowing you to optimize the control program for the specific machine on which they are installed. Most CNC control panels offer an interactive programming language, which greatly simplifies the process of creating a control unit, makes "communication" with the CNC convenient for the operator.



Picture 1. Transformation of information in the "drawing-finished part" system

The third method - programming with the help of Computer-Aided CAD Design Systems allows you to "raise" the process of writing processing programs to a higher level. Working with Computer-Aided Design Systems, a programmer technologist saves himself from time-consuming mathematical calculations and gets tools that significantly increase the speed of writing. Computer - aided design Systems include the following software products:

- CAD systems (computer-aided design - computer design support) this is software that automates the work of a design engineer and allows you to solve the problems of product design and registration of technical documentation using a personal computer.

- CAM systems (computer-aided manufacturing - computer manufacturing support) this is software that automates the calculations of tool trajectories for machining on CNC machines and provides the output of control programs using a computer.

- CAE systems (computer-aided engineering - computer support for engineering calculations) this is a software that is designed to solve various engineering problems, for example, for structural strength calculations, analysis of thermal processes, calculations of hydraulic systems and mechanisms.

CAD benefits [5]:

Compared to traditional technical sketching and manual drafting, the use of CAD design tools can have significant benefits for engineers and designers:

- Lower production costs for designs;
- Quicker project completion due to efficient workflow and design process;
- Changes can be made independent of other design details, without the need to completely re-do a sketch;
- Higher quality designs with documentation (such as angles, measurements, presets) built into the file;
- Clearer designs, better legibility and ease of interpretation by collaborators, as handmade drawings are not as clear or detailed;
- Use of digital files can make collaborating with colleagues more simple; and
- Software features can support generative design, solid modeling, and other technical functions.

Types of CAD software:

The amount of CAD programs developed by different companies is tremendous. While some are created to assist designers in the fields like architecture or 3D modelling, others are specified to contribute in various mechanical industries from sketching and analyzing till final product. Mostly used CAD programs by the majority companies and individual users are:

Table 2. List of CAD programs

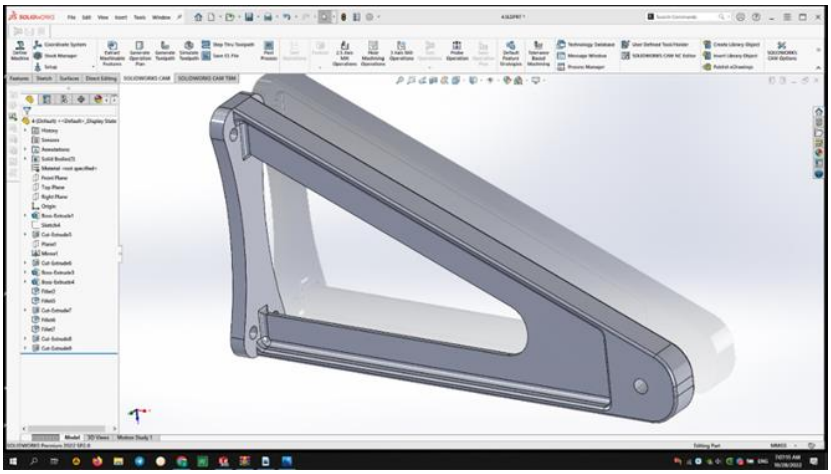
1	SolidWorks	8	Autodesk Inventor
2	Autodesk AutoCAD	9	Fusion 360
3	Catia	10	KOMPAS-3D
4	NX (Unigraphics)	11	T-FLEX CAD
5	MicroStation	12	OpenSCAD
6	Solid Edge	13	Altium Designer
7	Creo CAD	14	IronCAD

Main features of CAM software on the example of SOLIDWORKS [6]:

Rendering. SOLIDWORKS Visualize allows designers to create presentation-ready, photorealistic renderings. CAD files can be opened directly in SOLIDWORKS and rendered using accurate textures, reflections, and lighting. This is a powerful feature used by most designers but is

particularly useful for product designers as it allows them to demonstrate their final concept before going into production.

SOLIDWORKS Simulation. SOLIDWORKS Simulation allows designers to put their designs to the test, and quickly and accurately identify any flaws. The designer will be provided with highly accurate data, which means they can make changes to the design before a physical prototype is produced.



Picture 2. Aircraft part

Mechanical engineers can save a lot of time, money, and effort by identifying issues with their designs early in the process.

Intricate Evaluation. The Drawings tool allows a designer to quickly create 2D representations of any aspect of a design, with the option to add dimensions with the click of a button. This is useful for designers, engineers, and architects, offering the ability for a thorough evaluation.

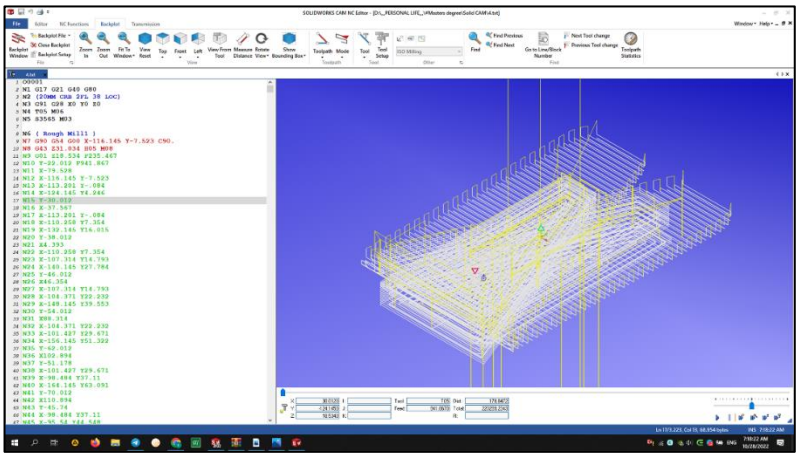
Manufacture with Ease. Once the design is complete, and the designer has eliminated potential risks identified in the simulation and evaluation, a prototype can be made. SOLIDWORKS CAM produces the design files that can be sent straight to production. The software also includes a searchable database of 3D Printers generating 2D slice data from solid geometry, while the 3DEXPERIENCE Marketplace enables you to outsource prototype and part manufacturing from right inside the UI (User Interface).

Tasks solved in SOLIDWORKS:

• Design preparation of production (DPP):

- 3D design of products (parts and assemblies) of any degree of complexity, taking into account the specifics of manufacturing
- Creation of design documentation in strict accordance with GOST
- Industrial design
- Reverse engineering
- Design of communications (electric hoses, pipelines, etc.)
- Engineering analysis (strength, stability, heat transfer, frequency analysis, dynamics of mechanisms, gas/hydrodynamics, optics and lighting engineering, electromagnetic calculations, dimensional circuit analysis, etc.)
- Express analysis of manufacturability at the design stage
- Preparation of data for IETR

- Data and process management at the CHECKPOINT stage



Picture 3. Component processing on SOLIDWORKS CAM

• Technological preparation of production (TPP):

- Design of tooling and other means of technological equipment
- Analysis of the manufacturability of the product design.
- Analysis of the manufacturability of manufacturing processes (plastic casting, analysis of stamping, drawing, bending, etc.)
- Development of technological processes according to ESTD.
- Material and labor rationing.
- Machining: development of control programs for CNC machines, verification of UP, simulation of machine operation. Milling, turning, turning-milling and electroerosion processing, laser, plasma and waterjet cutting, cutting dies, coordinate measuring machines.
- Data and process management at the TPP stage.

Conclusion. Programming CNC machines using CAD/CAM system has some advantages over other methods, in particular, the possibility of direct interaction with processed parts and programs that automatically design them, which opens the way to their widespread use. SOLIDWORKS and similar applications provide reliable and simple communication between the User and the manufacturer by combining these functions.

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