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THE ROLE OF CAD IN THE DEVELOPMENT OF ENGINEERING SOLUTIONS FOR THE METALLURGICAL INDUSTRY: EXPERIENCE IN USING ANSYS, AUTOCAD, SOLIDWORKS AND MATLAB

Abctract. The article examines the features of using modern software tools for designing products in the metallurgical industry, in particular, such as ANSYS, AutoCAD, SolidWorks, and MATLAB. In particular, attention is paid to their advantages and disadvantages in the context of specific metallurgical tasks, such as modeling technological processes, designing mechanical components, and analyzing thermal and mechanical loads. Separately, the application of ANSYS for numerical modeling of the metal rolling process is considered, MATLAB for modeling thermal processes in furnaces, as well as the use of AutoCAD and SolidWorks for creating geometric models and designing rolling mills. The results of the analysis show that each of the software products has its own strengths and weaknesses, which determines the appropriateness of their use depending on the specifics of the tasks. The authors provide recommendations for choosing tools, based on the requirements for accuracy, productivity, and cost. The scientific novelty of this work lies in the development of an innovative multiphysics approach that combines the integration of powerful software tools (ANSYS, AutoCAD, SolidWorks, MATLAB) for modeling complex metallurgical processes with an emphasis on mechanical, thermal and structural analysis. This approach allows to significantly increase the accuracy of engineering calculations, which is of great importance for the optimization of technological lines in metallurgy, in particular in the context of advanced analysis methods and improvement of design techniques in difficult production conditions.
Keywords: computer-aided design, computer modeling, engineering calculations, technical standards, data analysis

Statement of the Problem. The majority of both rolling and auxiliary equipment of the metallurgical industry of Ukraine was developed and put into operation at the beginning of the 20-th century [1-2]. Despite the rather reliable performance, over time of operation and the rapid development of technological processes in metallurgy, there was a need not only for a deep modernization of existing equipment, but also for the development of fundamentally new designs [3-5]. Also, in a situation of uncertainty caused by martial law, conducting real experiments to verify or refute various aspects of technological processes becomes an extremely difficult task. Therefore, methods of simulation modeling and experiments in the development of metallurgical equipment are becoming increasingly important [6-7].

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In this regard, a natural question arises of system analysis and determination of the most optimal software products of computer-aided design (CAD) systems, which would be useful to designers in designing and improving not only the main and auxiliary equipment, but also the technological processes themselves.

Designing products in the metallurgical industry requires the use of advanced software tools to solve complex engineering problems. Computer-aided design systems play a key role in modeling, analyzing, and optimizing metallurgical processes, but the issue of determining the most rational product that meets the principles of functionality, cost, and performance remains unresolved. This study focuses on the analytical justification of the feasibility of using software tools Ansys, AutoCAD, Matlab, and SolidWorks, taking into account their strengths and weaknesses in the design of a metallurgical product.

Analysis of recent research and publications. In modern research, software such as ANSYS, AutoCAD, SolidWorks, and MATLAB are actively used to model and analyze processes in materials science and metallurgy.

ANSYS is used for numerical modeling of technological processes, in particular, rolling of aluminum alloys in liquid nitrogen and asynchronous hot rolling of composite materials, as well as for the analysis of deformations, temperature changes and stresses in materials, which allows obtaining accurate results on the mechanical properties and structure of materials [8-10]. This software allows taking into account not only macroscopic characteristics, but also microstructural changes, which are important for predicting the behavior of materials under different conditions.

Jagadish et al. demonstrate the use of ANSYS to model the rolling process of an aluminum alloy in liquid nitrogen. In their work, they compare the results of numerical simulations with experimental data, which allows confirming the accuracy of the modeling and adaptation of the simulations to specific production conditions [8]. Yi et al. analyze the effect of friction on the rolling process, using ANSYS to simulate deformations and stresses in materials. This allows for accurate prediction of the behavior of materials under different operating conditions, which is important for optimizing technological processes, in particular in rolling mills [9].

Urs P., et. al. argue that MATLAB is a powerful tool for modeling thermal processes, particularly in metallurgical furnaces. They use MATLAB to solve differential equations describing temperature dynamics in different sectors of the furnace, which allows predicting temperature changes and determining the time of transients. This approach helps to increase the accuracy in predicting thermal regimes [11].

SolidWorks is widely used in the modeling of mechanical systems, in particular in metallurgy and the design of rolling mill components. The software allows you to develop three-dimensional models with high accuracy and integrate them with other tools for analyzing the mechanical properties of structures, all of which are discussed in [12] and [13]. SolidWorks is actively used in creating models of alloys and steel profiles, which allows you to effectively analyze and optimize structures.

Sawant MS, Jain NK, Nikam SH, Chen L.-Y., et al. review the application of AutoCAD for modeling powder metallurgy processes. The researchers emphasize the accuracy of meas-

urements and the creation of geometric models, which are important for effective planning and control of technological operations in metallurgical processes [14].

Thus, software in these studies plays an important role in numerical modeling, analysis, and development of new technologies in materials science and metallurgy, but requires a careful approach to the selection of tools and resources to ensure high accuracy and efficiency.

Purpose of the Study. The study aims to provide an analytical basis for the selection of CAD tools for the design of engineering products in the metallurgical industry. Evaluating the features, advantages and disadvantages of Ansys, AutoCAD, Matlab and SolidWorks, the main objectives of the study are to determine the most effective software tool, based on functionality, cost and productivity.

Statement of the main research material. ANSYS software is a powerful tool for conducting detailed numerical simulations in the field of materials science and metalworking technology. In the context of studying the rolling processes of various materials, ANSYS provides high accuracy and efficiency of modeling, which makes it useful for optimizing the parameters of technological processes, such as rolling of aluminum alloys in liquid nitrogen [8], asynchronous hot rolling of composite stainless steel plates [9], cold rolling of reinforcement [10]. Modeling with ANSYS allows you to take into account complex physical phenomena that are difficult to study without using numerical methods, in particular, changes in temperature, stresses, deformations and their interaction, which allows you to achieve realistic and accurate results [8]. It can also be argued that one of the main advantages of ANSYS is the high accuracy of modeling.

The work of Jagadish et al. clearly confirms that the use of ANSYS allows for accurate modeling of the rolling process of an aluminum alloy in liquid nitrogen, which is confirmed by the coincidence of numerical results with experimental data. The analyzed CAD software tool provides a high level of flexibility in setting the model parameters, which allows adapting simulations to specific production conditions. This is especially important for specific technological processes, such as rolling in cryogenic conditions or assessing the effect of friction on the process result, as shown in the studies of Yi et al. and Sui et al [9, 10]. Modeling in ANSYS allows you to take into account even microstructural changes in materials, which is critically important for obtaining a high-quality connection between layers in composite materials or for predicting the development of grains in metals at different temperature regimes [10]. However, as in any other software, the use of ANSYS has its limitations and disadvantages. One of the main ones is the high dependence of the results on the quality of the input data. Errors or inaccuracies in the data can significantly distort the results of simulations, which requires a careful approach to collecting experimental data. In addition, to achieve optimal results, ANSYS requires powerful computing equipment, since modeling complex processes requires significant investment resources, which can be a limitation for academic institutions and scientific organizations. Another significant problem is the difficulty of configuring the software to perform specific simulations, which requires highly qualified personnel. Another drawback is that ANSYS does not always fully take into account microstructural changes in materials, which can be critical for the study of ultrafine-

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grained (UFG) materials, where even the smallest changes in the microstructure can significantly affect the mechanical properties of the material [9].

AutoCAD is one of the most widely used programs for creating and manipulating graphical models, and its applications cover a wide range of industries, from mechanical engineering and architecture to additive manufacturing and geology. The program provides high accuracy and flexibility in design processes, which makes it useful for numerous scientific and engineering tasks. An important advantage is the ability of AutoCAD to perform precise measurements and create complex geometric models, which allows it to be used for process modeling in powder metallurgy, mining and metallurgical planning, and rolling production, where accuracy plays a critical role.

One example of successful use of AutoCAD is its use to measure the area of dilution and deposition of Ti-6Al-4V powder in the MPTAAM process (additive manufacturing). It is known that AutoCAD is used to analyze optical images of samples and measure the deposition geometry, which is important for comparing experimental data with theoretical models and numerical simulations [14]. In another context, AutoCAD is used to create 3D models of geological objects, such as open pits, which allows improving the planning of mineral extraction and visualizing spatial relationships between geological layers [12]. In addition, AutoCAD is widely used to model lattice structures in additive manufacturing, where high accuracy is critical for the subsequent optimization and manufacture of such structures [15]. This confirms the versatility and effectiveness of the program in various scientific and industrial fields.

One of the main advantages of AutoCAD is its ability to provide high accuracy in measurement and modeling processes. This is especially important for industries such as additive manufacturing, where the accuracy of each component is critical to achieving the desired result. In addition, AutoCAD allows you to process and analyze large amounts of data, which makes it a useful tool for complex scientific and industrial tasks. It is also worth noting the convenient interface that allows you to design geometries with high accuracy and prepare models for further processing in other programs, such as Autodesk Within or Altair OptiStruct, which specialize in topology optimization [15].

However, there are some limitations that need to be considered when using AutoCAD. One of these is the difficulty of learning the program for new users, especially those who are not experienced in working with CAD systems. Given the complexity of some tasks, such as accurate modeling of complex geometries or integration with other software products, users need to have some technical knowledge to use the program effectively. In addition, AutoCAD requires significant computing resources to process large 3D models, which can be a limitation when using the software on machines with insufficiently powerful characteristics [12]. Reduced automation of measurement processes can also be a problem, especially when processing a large amount of data, which increases the complexity of the tasks performed.

Features, advantages and disadvantages, characteristics of ANSYS and AutoCAD software products are given in Tables 1 and 2.

SolidWorks software is a powerful engineering modeling tool that has found wide ap-

plication in fields such as metallurgy, mechanical systems development, and educational technology. With its capabilities for creating highly accurate 3D models and integration with other engineering programs, SolidWorks significantly improves the design and analysis of mechanical properties of materials and structures.

Table 1

Characteristics of ANSYS and AutoCAD software products*

Software tool	Modules (elements) of the software tool	Scope of application in the metallurgical industry	Productivity	Valuation
ANSYS	ansys mechanical, ansys fluent, ansys workbench, ansys ls-dyna	Modeling of thermomechanical processes, analysis of the strength of metal structures, hydrodynamics of melts	High, depends on system configuration	CADFEM Ukraine , Up to $150,000 per year for a multi-user license
AutoCAD	autocad mechanical, autocad electrical, autocad plant 3d	Creation of drawings and development of technical documentation	High for 2D drawings, medium for 3D	Autodesk $5893

Table 2

Features, advantages and disadvantages of ANSYS and AutoCAD software products*

Software tool	Features	Advantages	Disadvantages
ANSYS	Software package for engineering analysis, including modules for mechanical, thermal and hydrodynamic calculations	- high accuracy of modeling - a wide range of modules for different types of analysis - the ability to analyze complex physical processes	- High license cost - High requirements for computing resources - Need for special training for users
AutoCAD	Software for creating 2D and 3D drawings, used for design and technical documentation	- intuitive interface - a wide selection of drawing and 3D modeling tools - support for a large number of file formats	- high subscription cost - less convenient for complex 3D modeling compared to other CAD systems (e.g. SolidWorks)

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The positive features of SolidWorks are the high accuracy of modeling complex geometries, which provides high-quality and detailed display of objects. The software also supports integration with other numerical analysis programs, such as ANSYS, which expands the capabilities of engineering analysis [13]. In particular, SolidWorks is particularly useful for creating models of rolling mill components [16], alloys and steel profiles [17], which significantly increases the efficiency of these processes. The disadvantage of SolidWorks is its high license cost, which can be a significant barrier for small companies, educational institutions or research organizations, where budgets may be limited. The cost of the license makes the software less accessible, requiring additional costs to ensure the use of its full functionality. Given this high cost, the implementation of SolidWorks can be a difficult task for many organizations.

In modern scientific research in the field of materials science, metallurgy and engineering, MATLAB software is actively used for processing, modeling and analysis of complex processes, including mechanical testing, thermal processes and studies of microstructures of materials. One of the main areas of application of MATLAB is the processing of experimental research results and modeling of physical processes in various branches of technology.

One example is a study conducted to evaluate the interfacial strength and mechanical properties of aluminum foam (AFS) sandwich structures fabricated by foaming precursors and hot pressing. In this case, MATLAB was used to process the results of tensile and microhardness tests, as well as to analyze deformation processes using digital image correlation (DIC). MATLAB allows for precise analysis of the stages of material deformation using specialized image processing algorithms, which significantly increases the accuracy of determining the mechanical properties of materials [18]. Another example of the use of MATLAB concerns the modeling of thermal processes in metallurgical furnaces. In this area, MATLAB/Simulink is used to simulate temperature dynamics in different sectors of the furnace, which allows studying the impact of different user access scenarios to the furnace control system on temperature processes. MATLAB is used to solve differential equations that describe thermal dynamics using numerical methods, such as the Dormand –Prince method. This allows achieving high accuracy in predicting temperature changes and determining the time of transient processes [11]. Within the framework of metallographic research, MATLAB was used to develop a universal method for digital analysis of microstructures of metals and alloys. MATLAB algorithms are used to process digital images of microstructures, which allows automating the process of measuring geometric parameters of structural elements, such as ferrite, pearlite and martensite, as well as to assess the influence of these parameters on the mechanical properties of the material. As a result, MATLAB significantly simplifies and accelerates the analysis process, reducing the likelihood of errors that may occur during manual measurement [19]. Among the disadvantages of using MATLAB, one can note the difficult adaptation of the program to specific metallographic tasks, which requires significant time and resource costs for developing specialized code. In addition, processing large amounts of data can require significant computing resources, which can be a problem for enterprises with limited access to modern support equipment. Another limitation is the need to integrate MATLAB with other software products, such as ImageJ or Excel, which complicates data

processing and creates a risk of errors during the stages of information transfer between programs.

Features, advantages and disadvantages, characteristics of SolidWorks and MATLAB software products are given in Tables 3 and 4 .

Table 3

Characteristics of SolidWorks and MATLAB software products*

Software tool	Modules (elements) of the software tool	Scope of application in the metallurgical industry	Productivity	Valuation
MATLAB	simulink, optimization toolbox, curve fitting toolbox, control system toolbox	Analysis of heat treatment processes, mathematical modeling of metallurgical processes, production optimization	High when properly configured	Mathworks $ 1015
SolidWorks	solidworks simulation, solidworks flow simulation, solidworks pdm	design of metal structures, stress analysis, creation of 3D models of equipment	High for complex 3D models	Softkeys $5854

Table 4

Features, advantages and disadvantages of SolidWorks and MATLAB software products*

Software tool	Features	Advantages	Disadvantages
SolidWorks	Software for 3D modeling, mechanical design, and engineering analysis	- support for parametric modeling - large library of standard parts - integration with other engineering programs	- high license cost - high hardware requirements - less powerful for complex analysis compared to ANSYS
MATLAB	Powerful software environment for mathematical calculations, modeling and data analysis	- flexibility in mathematical calculations and optimization - a large set of libraries for modeling physical processes - possibility of automation and programming of algorithms	- high cost of modules - high entry threshold for new users - limited support for 3D modeling compared to CAD programs

*Source: developed by the author

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Conclusions. Designing products in the metallurgical industry requires the use of advanced software tools to solve complex engineering problems. Computer-aided design systems play a key role in modeling, analysis and optimization of metallurgical processes, but the issue of choosing the most rational product that provides the principles of functionality, cost and productivity still needs to be clarified. This study focuses on the analytical justification of the feasibility of using software tools Ansys, AutoCAD, Matlab and SolidWorks, taking into account their strengths and weaknesses in the design of a metallurgical product.

ANSYS, AutoCAD, SolidWorks and MATLAB software are actively used for modeling and analyzing processes in metallurgy. ANSYS is a powerful tool for numerical modeling of technological processes, in particular metal rolling, taking into account temperature changes, stresses and deformations. MATLAB is effectively used for modeling thermal processes in metallurgical furnaces, and SolidWorks is used for designing mechanical components of rolling mills. AutoCAD, in turn, is an important tool for modeling geometry and precise measurements in metallurgical processes.

The scientific novelty of the study lies in comparing the effectiveness of various software tools in the context of specific metallurgical design tasks, such as modeling of rolling processes and optimization of technologies. The latest methods are taken into account, which allow reducing costs and increasing productivity while maintaining high modeling accuracy.

In conclusion, we can note that ANSYS software has high modeling accuracy and adaptability to specific conditions, but requires powerful computing equipment and highly qualified personnel. SolidWorks and AutoCAD provide effective tools for mechanical design, and MATLAB increases the accuracy of predicting thermal processes. Therefore, for each specific project, the tool should be carefully selected, based on its features and requirements.

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Роль САПР у розробці інженерних рішень для металургійної галузі: досвід застосування ANSYS, AutoCad, SolidWorks та MATLAB

У статті розглядається важливість використання сучасних програмних засобів для проєктування інженерних рішень у металургійній галузі, зокрема програм ANSYS, AutoCAD, SolidWorks та MATLAB. Огляд охоплює як їхні сильні, так і слабкі сторони, зокрема в контексті специфічних металургійних завдань: моделювання технологічних процесів, проєктування механічних компонентів, а також аналіз теплових і механічних навантажень. Особливу увагу приділено застосуванню ANSYS для чисельного моделювання процесу прокатки металів, MATLAB для термічних процесів у печах, а також AutoCAD і SolidWorks для створення геометричних моделей та проєктування прокатних станів. Важливим аспектом є те, що кожне програмне забезпечення має свою специфіку використання, що зумовлює необхідність точного вибору інструменту залежно від типу завдання, вимог до точності, продуктивності та вартості. Розглядається інтеграція цих інструментів для забезпечення високої точності інженерних розрахунків і вдосконалення методик проєктування в складних виробничих умовах. Наприклад, ANSYS дозволяє провести детальний аналіз деформацій і температурних змін в матеріалах, що дозволяє оптимізувати технологічні процеси в металургії, зокрема прокатки алюмінієвих сплавів та композитних матеріалів. MATLAB, у свою чергу, використовується для розв'язання диференціальних рівнянь, що описують термічну динаміку в печах, а AutoCAD і SolidWorks активно застосовуються для проєктування і моделювання механічних систем, зокрема компонентів прокатних станів. Крім того, в статті підкреслено важливість вибору програмного забезпечення з урахуванням якості вхідних даних, доступних обчислювальних ресурсів і кваліфікації користувачів. Програмні продукти мають свої переваги, такі як висока точність моделювання в ANSYS або зручність у роботі з AutoCAD, але й ряд обмежень, включаючи високу вартість ліцензій і потребу в потужних обчислювальних системах. Наукова новизна роботи полягає в розробці мультифізичного підходу, що поєднує різні програмні інструменти для моделювання складних металургійних процесів, що дозволяє досягти високої точності інженерних розрахунків та оптимізації технологічних ліній. Це важливо для підвищення ефективності виробництва і зниження витрат на етапах проєктування.

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