FROM SIMULATION TO AUTOMATION: STREAMLINING CAD/CAM PROCESSES

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ABSTRACT: The research explores advanced technologies and software solutions that can improve Computer-Aided Design and Computer-Aided Manufacturing processes. The study emphasizes the importance of leveraging technological advancements to optimize these processes, which can lead to increased accuracy, efficiency, and cost-effectiveness. CNC Machine Simulation and 3D Scanning are two crucial technologies discussed in the research. CNC Machine Simulation enables manufacturers to create an accurate model of the manufacturing procedure, providing real-time feedback that can improve the fabrication process. Meanwhile, 3D Scanning allows capturing precise measurements of physical objects and convert them into digital models. The study also emphasizes the importance of optimization software for CNC Post Processor, Generative Design, and AI Solutions for CAM, which can automate and optimize the industrial process, resulting in faster and more efficient production. Overall, the research presents solutions that can help optimize the CAD/CAM processes and lead to significant improvements in the industry.

KEY WORDS: scanner, CNC, CADCAM, AI

1. Introduction

In recent decades, globally, the manufacturing sector has experienced a series of technological innovations that have changed the way design and manufacturing processes are carried out. In this context, the research with the theme "From simulation to automation: streamlining CAD/CAM processes" aims to present solutions and technologies that can be used to improve Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) processes within a local small and medium-sized enterprise.

3D scanning is one such technology that allows for precise modeling of production processes and provides real-time feedback, easily replacing conventional measurement methods. Additionally, simulating part processing reduces potential errors in Computer Numerical Control (CNC) machining centers, while the CAM post-processor verification and optimization program helps automate and optimize manufacturing processes, significantly reducing verification and manual code modification times. Furthermore, utilizing artificial intelligence for analyzing large volumes of data, identifying repetitive patterns, and recommending toolpaths for CAM represents another important solution for a domestic production system. This can significantly reduce the time required for CNC programming and improve the efficiency and accuracy of the manufacturing process. Additionally, solutions such as Generative Design and the implementation of Finite Element Analysis (FEA) in CAD software are particularly important as they greatly enhance common design and analysis capabilities.

Moreover, by integrating these solutions into production processes, significant benefits can be achieved in terms of increased productivity, improved quality, and reduced design and manufacturing time, all with minimal investment and simple implementation. Therefore, in an increasingly competitive manufacturing environment, these solutions can provide a major strategic advantage to companies seeking to enhance their production processes and achieve greater performance and profitability.

2. Current situation

The manufacturing industry is an extremely important sector for the global economy, and streamlining processes in this field is crucial to maintaining competitiveness and maximizing profits. In this regard, the use of modern CAD/CAM process optimization solutions could bring significant benefits to companies in this industry. Currently, many companies involved in the manufacturing of various objects still use traditional methods of measuring parts, such as calipers, which are relatively imprecise and can take a long time to complete. This can lead to errors in the production process and ultimately affect the quality of the finished products. In this context, the use of 3D scanners could bring significant improvement to the measurement process, thereby reducing the required time and improving accuracy. Additionally, modern CAM simulation solutions can be used to automate and optimize manufacturing processes, thereby reducing production time and costs. For example, using software to verify and simulate one's own machining center can reduce the time required for machining and allow for greater profitability and flexibility in production, helping to identify potential issues before the chip removal process begins, thus reducing costs associated with repairing or remaking products or replacing cutting tools.

Furthermore, implementing CAM post-processor optimization solutions can help reduce labor costs and increase production process efficiency, as many companies currently face challenges in modifying the code after using CAM software due to differences with the machining center. There is great potential for implementing modern CAD/CAM process optimization solutions in the manufacturing industry in Romania. The use of these solutions could bring significant benefits, such as improving precision and reducing production time and costs. It is important for companies to be willing to invest in these solutions and consider the long-term advantages of using them.

3. Actual methods of streamlining and their implementation

3.1. Measurement and design methods

3D scanning is one of the modern technologies used for design, inspection, and quality control. This contactless measurement technology converts a physical model into a digital 3D CAD design using various scanning programs. It becomes an essential tool for manufacturers who need precise dimensional inspection, virtual imaging, analysis, and even physical prototypes. This chapter focuses on the potential of 3D scanning for the industrial sphere, discusses practical industrial support 3D scanners, and develops the workflow of 3D scanners for industrial requirements. Additionally, the paper identifies major applications of 3D scanning from an industrial perspective. 3D scanners use sensors to perceive the details of any product. This technology can easily capture the virtual image of a physical object that can be analyzed, modified, and stored. 3D scanning is useful for reverse engineering, analysis, design, and measurement of complex curved surfaces, quality monitoring, prototyping, industrial tool development, and many more. This technology utilizes advanced software for precise measurements and analysis, which helps increase process flexibility and reliability.

These scanning technologies are used to scan physical components that often do not have drawings or CAD data. The geometric dimensions accuracy of the object can be quickly calculated and verified. It is beneficial for components with complex geometry, worn or damaged parts, being able to analyze construction accuracy and quality, such as integrity checking or different deviations resulting from use. The measurements of a part can be easily modified in CAD software. Initially, after scanning, the scanner program exports an .stl file, which will be opened in the design program as a mesh, and by selecting all the surfaces, a solid body can be created to which dimensional properties can be easily modified according to preference.

Laser-based 3D scanners [1] minimize the time required for designing a part and reduce the number of errors in data collection. A scanner rapidly captures details about the surfaces of objects and the environment, taking measurements in any direction. The process starts with placing the object to be scanned in the scanning area. The laser scanner (fig. 1) then emits a laser beam that scans the surface of the object and measures the distance from the scanner to the object's surface by emitting light pulses and recording the time it takes for these pulses to reach the surface and return to the scanner. This data is collected and processed by the laser scanner to create a 3D model of the scanned object. Depending on the type of laser scanner, this process can be achieved by using a rotating mirror to direct the laser beam in different directions, by rotating the object on a table, or by rotating the scanner around the object. Additionally, to remove surfaces we don't want to scan, markers can be placed on them, and the scanner's software will exclude them.

In addition to laser scanners, there are other types used in the industry:

Structured Light Projection Scanners (fig. 2), based on structured white light projection, use a projector to project a pattern of structured light onto the object we want to scan. A video camera will record how these patterns are reflected and distorted on the object's surface to create a 3D model. This is an efficient solution due to high-precision data capture and high speed. They are especially used for scanning small and medium-sized objects.

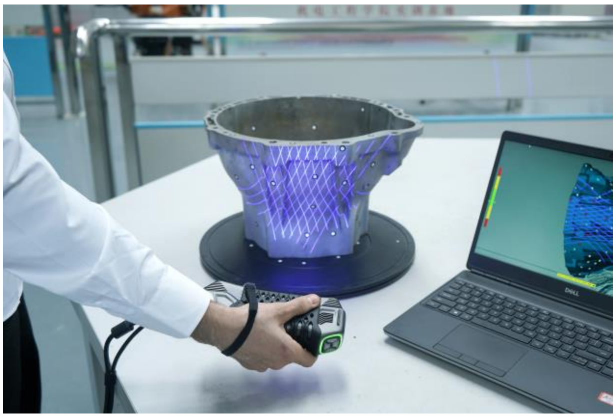

Fig. 1. 3D scanner based on laser projection, produced by Scantech [6]

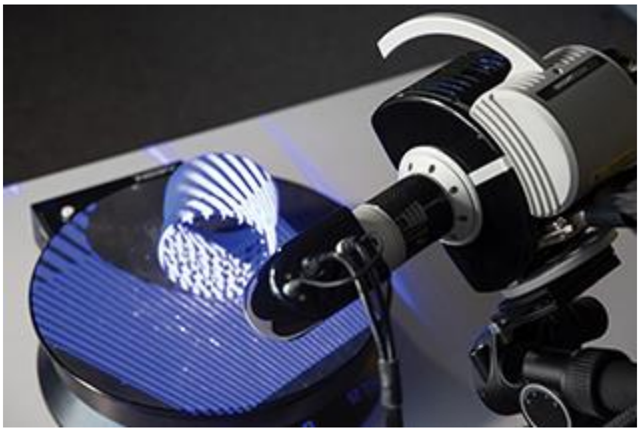

Fig. 2. 3D scanner based on structured white light, produced by Hexagon [5]

Photogrammetry-based 3D (fig. 3) scanners use multiple photographs taken from different angles to create a 3D model by analyzing and comparing common points on each photograph. The photogrammetry process involves using image processing algorithms and shape recognition technology to create a precise and detailed 3D model. The main advantage of photogrammetry-based 3D scanners is that they can create precise 3D models without the need to touch the object or have direct contact with it. They are also useful for objects or areas that are difficult to access or for creating 3D models of buildings and the surrounding environment.

Contact-based 3D scanners use a probe or a robotic arm to perform the scanning. They are useful for objects with complex shapes or that require high precision. The probe or robotic arm can be moved around the object to obtain a complete image of it, and the data is collected through a contact sensor that measures the distances between the probe and the object. Another advantage of contact-based 3D (fig. 4) scanners is that they can provide high precision, as the contact sensor can detect small details of the object. However, they are less suitable for fragile or sensitive objects, as the probe or robotic arm may damage or scratch their surface.

Fig. 3. 3D scanner based on photogrammetry, produced by Occipital [7]

Fig. 4. Contact-based 3D scanner, produced by Faro [8]

From personal experience (fig. 5), laser 3D scanning is the most efficient method for scanning objects of any size, providing high precision and ease of scanning. In the context of research and during an internship program at a company specializing in reverse engineering, I have scanned numerous metal parts to be later produced and distributed to clients. As such, scanning a part takes significantly less time than measuring all surfaces using traditional methods (calipers, micrometer, ruler, etc.).

Fig. 5. Personal experience laser 3D scanning

Furthermore, I have encountered parts with a complex structure that would have greatly hindered the production process if measured using traditional methods. Laser scanning has also highlighted structural defects in the parts, providing data for finite element analysis that I subsequently conducted. This has been a major advantage for further communication with the client regarding potential improvements to the part or issues encountered during use.

3.2. Fabrication simulation and the optimisation of CAM postprocesors

Simulation of machining and optimization of CAM post-processors are two key technologies in modern production processes. They play a crucial role in reducing errors in computer numerical control (CNC) machining centers, improving production efficiency, and enhancing the quality of produced parts. In this article, we will discuss how machining simulation and optimization of CAM post-processors are carried out, as well as their benefits in implementing these technologies in an enterprise.

Simulating the machining of parts to reduce errors in CNC machining centers is a technology that allows verifying the machining process of parts before it is launched into production (fig. 6). This technology utilizes virtual simulations to create 3D models of parts and the intended machining operations. As a result, CNC operators can verify the machining process before starting production, thus eliminating the risk of costly errors and improving the quality of produced parts.

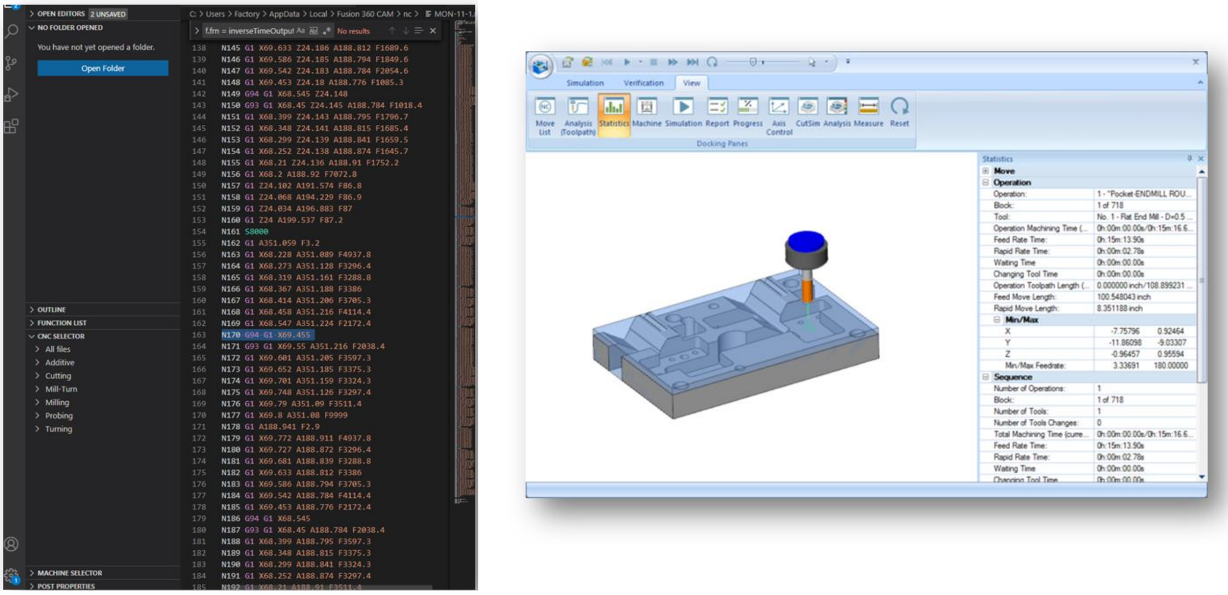

Fig. 6. Example of simulating the machining of parts

Implementing part machining simulation in an enterprise can bring several advantages. The first advantage is cost reduction by eliminating costly errors in production. Additionally, it can improve the quality of produced parts, and operators can be better prepared before launching production, thereby reducing the risk of human errors [4].

As for the optimization of CAM post-processors, it refers to the process of verifying and optimizing the efficiency of post-processors for G-code operations. One popular program for this technology is Vericut, which can be used to verify and optimize post-processors for a wide range of machines and controllers. Vericut allows operators to verify the CAM-generated G-code before it is launched into production, thus eliminating the risk of costly errors.

Implementing optimization of CAM post-processors in an enterprise can also provide several advantages. By verifying the G-code before production, errors can be identified and corrected, thereby improving the quality of parts and reducing costs. Additionally, operators can be better prepared before launching production, reducing the risk of human errors.

3.3. Using Artificial Intelligence to Improve Design Processes

An innovative approach in CNC machining is the use of artificial intelligence to analyze a large amount of data, identify repetitive patterns, and recommend the appropriate toolpath for machining [2]. These methods significantly reduce the time required to create the machining program and can enhance process efficiency. In this regard, companies like PTC have developed generative design tools that utilize AI to find optimized design solutions based on specified requirements. This process involves defining design parameters and specifying performance objectives for a part. The algorithm then explores various possible design variants and recommends the best structure for the given criteria.

Regarding CNC machining, the AI algorithm can be used to analyze and identify repetitive patterns in the machining process data. This can include using machine learning techniques to identify and recognize geometric shapes and machining patterns or analyzing historical data to identify trends and repetitive patterns. Based on this data, the algorithm can recommend an optimized toolpath for machining, which can reduce machining time and increase process efficiency.

4. Conclusions

The implementation of 3D scanners, simulation of machining, optimization of CAM post-processors, and the use of artificial intelligence for improving design processes represent modern methods to increase efficiency and accuracy in the field of mechanical machining. These technologies help reduce errors, eliminate manual processes, and reduce production time.

By using 3D scanners, companies can obtain precise and detailed three-dimensional models of parts, which can be used to create CAD models, verify the accuracy of manufactured parts, and perform finite element analysis. Simulating machining operations and optimizing CAM post-processors help reduce production time, eliminate errors, and increase machining efficiency. Furthermore, by utilizing artificial intelligence, the design and production process can be significantly improved by identifying repetitive patterns, recommending toolpaths for CAM, and optimizing part structures.

Implementing these technologies can bring numerous advantages, such as increased efficiency and quality, reduced production time, minimized errors, and eliminated manual processes. Moreover, these technologies can be integrated into existing production processes without major infrastructure changes.

In conclusion, the implementation of 3D scanners, simulation of machining, optimization of CAM post-processors, and the use of artificial intelligence represents a modern and efficient solution for improving production and design processes. These technologies can bring significant benefits in terms of reducing production time and costs, increasing efficiency and quality, and improving design and production processes.

5. References

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