Development of NC Program Simulation Software Based on AutoCAD

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Abstract. Computer-aided manufacturing (CAM) is a production approach that uses computer software and automated technology to manufacture high-quality, precise items. To increase efficiency and eliminate waste, the suggested CAM approach would design new or adapt existing industrial setups. In order to deal with the problems of less optimization and cumbersome operation of complex and small batch parts in practical machining applications, a development method of AutoCAD-based NC program simulation software is proposed. Firstly, starting from the feature processing method of complex and small batch parts, the processing technology of common key parts in industrial steam turbines is studied, combined with the idea of group processing, through the analysis of processing features, the typical process files are compiled and the docking relationship is established. Then, using the functions of AutoCAD, the generated NC code is simulated and compared with the traditional AutoCAD software algorithm to verify the correctness and rationality of the NC code. This is accomplished by lowering energy consumption and accelerating the production process and tooling. Product planning, development, administration, storage, and transportation may all be aided by CAM.

The end result was extremely consistent, high-quality, and precise. The experimental results show that the numerical control programming software proposed in this paper can process 25.4% more blank peaks than the traditional AutoCAD algorithm and reduce the processing time by 23.7% when simulating blank processing.

Keywords: CNC machining; CNC programming; CNC simulation; AutoCAD secondary development; NC code batch customization; group processing.
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1 INTRODUCTION

The principle and characteristics of the deformation design used in industrial steam turbine products have greatly increased the number of parts of the same type with different sizes the requirements of low cost and quick response of enterprises [1]. CAM can automate workpiece milling in applications that require subtractive manufacturing. CAM may be used by machinists to accurately remove excess material from workpiece blocks [2, 3]. When CAM is utilized, the amount of waste caused by manual machining is decreased. Because the likelihood of error is minimal, a higher number of goods may be produced from the same amount of raw material. This type of increased productivity adds up over time. The manufacturer may now either increase his profit margins or set competitive prices, or both [4, 5]. Although many commercial computer-aided design systems such as Pro/E, UG and other software have the function of computer-aided manufacturing (CAM), they can automatically generate the numerical control program for machining the part according to the geometric model of the part. Computer-aided manufacturing (CAM) is a production method that use computer software and automated technologies to create high-quality, accurate objects. Thanks to advances in machine and software technologies, we can now produce better components with more control over the whole process. However, these systems need to carry out the multi-step interactive operation is cumbersome; and the main problem is that when the parts are deformed, the software needs to re-operate interactively, extract data, and set parameters. The work is repetitive and inefficient.

Some of the primary applications of the traditional CAD system include glass working, woodturning, metallurgy, spinning, and graphical improvement of the entire manufacturing process. Using ornamental lathes, a CAD system may create three-dimensional solids with enhanced intricacy and detail. Candlestick holders, table legs, bowls, baseball paddles, crankshafts, and half shafts may all be made using the CAM technology. In the manufacturing technology of small batch customized products, group technology has important strategic significance. Group technology is a related activity that is vital in the development of a CAPE system. Group Technology is a production approach that includes grouping similar items in order to capitalize on their commonalities. Group Technology is a way of locating and assembling related elements in order to capitalize on their design and manufacturing similarities. "Group technology" production data storage substantially aids this identification process. It can change the productivity lag problem of traditional multi-variety and small batch production. The core of this technology is to make maximum use of the similarity of the machining features of parts, to classify and group the machining features of the same type and different sizes [6]. Fig. 1 is a kind of NC bullet knife program designed by group technology.

The proposed CAM technique will design new or modify current industrial settings to boost productivity and reduce waste. It does this by reducing energy use and speeding up the manufacturing process and tooling. CAM can help with product planning, development, administration, storage, and transportation. The finished product was incredibly consistent, high-quality, and exact. Starting from the actual situation of steam turbine product manufacturing, combined with the related technical ideas of group processing, this paper provides a NC code programming method and corresponding program software for small batch customized parts. It has been verified by practice that ideal results have been achieved, the manufacturing level of the enterprise has been improved, and the product processing cycle has been shortened.

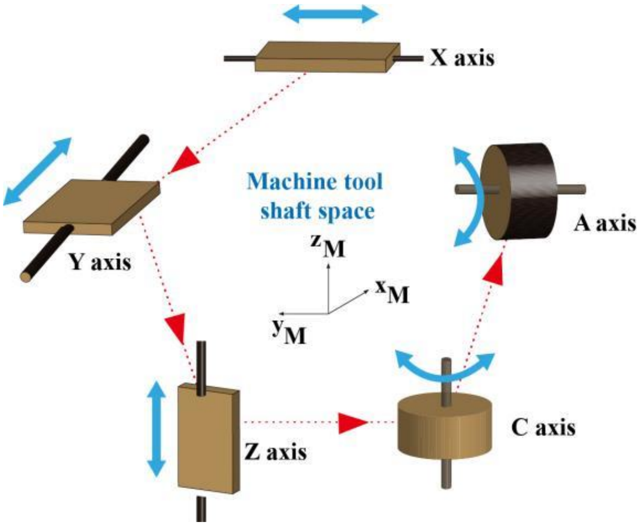

Figure 1: Schematic diagram of NC bullet knife program based on group technology.

The aforementioned section is the introduction to the paper. Section 2 is the literature survey based on the latest work done in the field. Research methodology has been covered in section 3. The analysis of results has been done in section 4. Section 5 concludes the manuscript along with future scope.

2 LITERATURE REVIEW

Gao, S. et al. pointed out that computer-aided automatic programming has always been the trend of CNC programming. With the rise of 3D software, 3D software such as NX (UG), Solidworks, ProE is used for product design, mechanical analysis, machining simulation, assembly, etc. The integrated design approach is becoming more and more popular [7]. However, in comparison to consumer industries, adoption of this new CNC technology has been sluggish. There are several reasons to be cautious with CNC technology, particularly because the parts produced by CNC machines are usually critical components in highly regulated industries such as aerospace [8, 9]. When flying at 30,000 feet, most people feel safer knowing that the production of a certain item that has passed extensive testing is not authorized to change without extensive retesting [10, 11].

Moreover, Corel CAD is a straightforward application with a powerful range of features tailored to architects, manufacturers, builders, and engineers. SOLIDWORKS is one of the best tools for engineers and designers to use when creating a high-quality product and bringing it to market to meet customer demands. In the research report of Cui, J. et al., it is pointed out that computer-aided numerical control machining programming originated in the United States, and scholars have designed a programming language specially used for numerical control machining of mechanical parts, called APT. The APT programming language is a CNC machine tool path description language. APT stands for Automatically Programmed Tool. APT is software that allows you to program numerically controlled machine tools to create complex components using a moving cutting tool. It is used to determine the route a tool should travel in order to construct the required form. APT is a special-purpose software application that predates today's CAM technology. In a long period of time, computer-aided numerical control programming based on APT language has been greatly developed and applied [12]. APT is a software that allows you to programme numerically controlled machine tools to create complex components using a moving cutting tool. It is used to determine the path a tool should travel to obtain the desired form. APT is a special-purpose programming language that predates today's CAM technology [13, 14]. It was created in the late 1950s and early 1960s to make it easier to compute the geometry points that a tool must traverse in space in order to cut the intricate parts required in the aerospace sector [15, 16].

Wang, Y. et al. pointed out that due to the rapid development of computer technology, the computer's ability in graphics processing has been greatly enhanced. Therefore, a computer-aided programming that can directly convert the geometric information of parts into CNC machining programs automatically the technology, "graphic interactive automatic programming", is produced by special computer software. This software is usually based on mechanical computer-aided design (CAD) software. Draw on the computer to form the graphic file of the part, then call the numerical control programming module, specify the part to be processed by means of human-computer interaction, and then input the corresponding processing parameters, the computer can automatically perform the necessary mathematical processing and compile the numerical control processing. procedure [17]. Luo, S. et al. believe that because of its advantages of high speed, high precision, good intuition, easy use, and easy inspection, "graphical interactive automatic programming" has become a widely used method in advanced CAD/CAM software at home and abroad.

The advantages of using computer-aided numerical control programming are many, the programming efficiency is high, and the interface is intuitive and easy to understand. At the same time, general CAM software has its own simulation module. As long as the correct models of machine tools, tools, fixtures, work piece blanks, etc. are imported, the entire processing process can be simulated completely, and the error probability is low [18]. Afrilia, C. et al. studied and proposed that CAM software can call different post-processing templates according to different CNC systems. Programmers can program CNC machine tools without mastering NC codes, and the professional requirements for programmers are also reduced. In addition, group technology has also been widely used in computer-aided programming [19].

Solvang, H. et al. believe that group processing requires parts to be classified according to process similarity to form a processing group. The parts produced in this processing group can adopt similar processing strategies, and can quickly perform NC programming of similar products [20]. The research report of Vasileva, Y. et al. shows that the group processing technology was proposed by Soviet experts and has experienced sixty years of development. It is the technical basis for computer-aided design, computer-aided manufacturing and flexible manufacturing systems [21]. Denisova, L. A. and others believe that there are still many deficiencies in the application of traditional CAM software in group machining, especially the optimization of high-precision complex shaft and whole machining features in traditional machining: the more popular NC software is foreign NX (UG), EdGECAM, MastErCAM, etc.

In China, such as CAXA, the design ideas of software are different, but in order to meet the needs of various industries, such software generally focuses on multi-axis surface processing or mold processing. , For high-precision complex holes or shafting processing features, the processing technology of the parts cannot be well integrated into the software. Therefore, for products such as industrial steam turbines with many product structures and large dimensional changes, many times in actual use, it is no better than manual programming convenient [22]. Dong, L. et al. proposed that the simulation of such software is before the generation of NC code. Once the NC code is exported, the simulation check cannot be performed again for the NC code, and additional software needs to be purchased. However, due to the particularity of the products of industrial steam turbines, many large-scale parts such as cylinders, rotors, rings, etc. are mainly single-piece or small-batch parts. The processing preparation period is short, and the parts and product structures are diverse. Problems are often encountered in actual processing. It needs to be solved on the spot, so it is necessary to adjust the program in real time during the processing process, and it is often necessary to simulate the NC code [23].

Adeel, M. B. et al. pointed out that such programming software such as NX (UG) is often bundled with 3D design software, which is generally expensive and a great burden for enterprises [24]. The researchers have investigated the major methodologies of artificial intelligence research and development in a fast and exact code environment. Graphics collecting system, mould processing system, system optimization and NC code automated creation, as well as a series of automatic coding processes are among them [25, 26].

3 RESEARCH METHOD

3.1 Feature Machining Method of Complex Small Batch Parts based on AutoCAD

The recommended technique has applicability in multiple CNC workshops due to its benefits in metallurgical machining components and capability to meet the large demand of production. Human error has been removed. It is simple to save and modify thoughts and designs that are affordable to modify. In large-scale manufacturing, computer-aided manufacturing (CAM) assures high precision and speeds up processes. In the NC code of CNC machine tools, the most important part is the coordinate information of the processing tool. Generally, for the processing of whole system features with high precision requirements in mechanical processing, common processing methods include drilling, milling, boring, and reaming etc. The conventional tools used include drills, U-drills, milling cutters, boring cutters, reamers, etc. In the machining process of parts, they can be divided into three processes according to different machining allowances: rough machining, semi-finishing, and finishing, the tools, processing technology and scope of use corresponding to the three processes are different. The following summarizes the process flow of each processing method [27].

3.1.1 Rough machining

Rough machining refers to rough machining of the blank when there is a large amount of blank allowance, removing most of the blank allowance, and releasing most of the stress generated during cutting to avoid deformation of the parts. Rough machining generally has low surface roughness, and mainly pursues machining efficiency [28]. The characteristics of the rough machining method of whole parts are shown in Table 1. Various kinds of machining tools along with their processing method and scope of application have been mentioned in Table 1. The drilling method has high efficiency as compared to other operations. Helical milling is a hole-making technique in which the milling tool follows a helical path while rotating around its own axis, providing several advantages over standard drilling.

Machining Tools	*Processing Methods*	*Processing Efficiency*	*Scope of Application*
Drill	Drilling	High	No pre-drilling required
Rough Boring Tool	Boring	Low	Pre-drilled holes are required, and there is not much allowance
End Mill	Helical Milling	Medium	Depending on the tool and machining diameter, pre-drilling is required

Table 1: Characteristics of rough machining methods for hole parts.

3.1.2 Semi-finishing

Semi-finishing generally refers to a process in which a certain finishing allowance is left on the finishing surface before finishing. Among the high-precision machining features, semi-finishing has a great impact on the quality of the final finished product. Therefore, during semi-finishing, it is necessary to ensure the geometrical tolerance of feature size, surface finish, etc., to avoid hard spots or positional deviation on the surface during finishing. According to the actual processing methods and materials, semi-finishing generally needs to be reserved on each side There are finishing allowances ranging from about 0.05-0.25mm, so semi-finishing should achieve a certain balance between processing efficiency and processing quality [29]. Semi-finishing generally uses drills, boring tools or end mills for processing, and in some low-precision hole processing, it is not necessary to perform finishing, and the semi-finishing method is directly used to process the finished product size. The tools and processing methods generally used in semi-finishing are similar to roughing, see Table 2 [30].

Machining Tools	*Processing Methods*	*Processing Efficiency*	*Scope of Application*
Drill	Drilling	High	Suitable for hole machining with low precision requirements
Semi-Fine Boring Tool	Boring	Low	Suitable for semi-finishing of holes with high precision requirements
End Mill	Milling Circular Milling	Medium	It is suitable for semi-finishing of holes with high precision requirements, especially those with high geometric tolerance requirements.

Table 2: Characteristics of semi-finishing method of hole parts.

3.1.3 Finishing:

For holes with high precision above IT7 level, finishing is an important step to ensure the final machining size and surface accuracy. Finishing is generally performed 1-2 times to ensure the accuracy of the size. Adjustable fine boring tools or reamers are generally used for finishing tools, and the processing parameters have a great influence on the quality of the final product. The specific tools and processing methods are shown in Table 3 [31].

Machining Tools	*Processing Methods*	*Advantages*	*Disadvantages*
Fine Boring Tool	Boring	The processing straightness is good, fine-tuning is possible, and the size is easy to guarantee	Smaller holes are not as effective due to lower line speeds
Reamer	Reaming	Machining quality is guaranteed at low speeds, and holes with smaller diameters can be machined	The straightness is poor and must be guaranteed in advance during semi-finishing; the cost is high

Table 3: The characteristics of the finishing method of hole parts.

3.2 NC Program Simulation Software Development

For some common complex processing feature groups, such as the emergency interrupter hole of the steam turbine main shaft, the cylinder split hole, the outer cylinder valve seat hole and other processing features, because the general structure is similar, only the size changes, after finishing the NC programming, the Its processing procedures and technological processes are saved as typical technological processes, and the numbers are set to facilitate management. When processing these typical processing feature groups in subsequent processing, it is only necessary to call up the corresponding typical process flow, and re-enter the corresponding feature parameter data and the coordinate position of the hole, and then the similar structure can be efficiently completed on the basis of the same process flow. There is no need to repeatedly arrange the process flow and processing method each time, which greatly improves the efficiency of CNC programming [32].

The process of compiling a typical process is as follows: 1. Establish a parameter table, determine the data that needs to be parameterized, and give the name of the corresponding parameter, such as rotational speed, tool diameter or aperture; 2. Compile each process, use the corresponding value with the parameter name For example, the hole diameter of D20 can be replaced by the parameter "through hole diameter" to make it clear; 3. Open the parameter table and fill in the corresponding parameters to simulate and verify the NC code; 4. After the confirmation is correct, save the current process as a typical 5. For a typical process with many parameters, the corresponding schematic diagram is derived through the verified model, and a graphical parameter input operation guide is established to simplify the compilation process.

After completing the typical process flow, the programming process for similar parts is as follows: 1. Open the typical process file; 2. Fill in the parameters in the corresponding parameter table, or open the graphical parameter wizard, and modify the corresponding parameters according to the schematic diagram; 3. Carry out The NC code is simulated and verified, and the code and machining process card are exported [33].

4 RESULT ANALYSIS

The 3D solid simulation is to import the blank of the part into AutoCAD in the form of a 3D solid, and simulate the relative position of the tool and the part during the experiment to check the cutting condition of the part, the collision of the tool, the overcut, etc. The simulation verification effect of the 3D solid is obviously higher than 2D simulation. To perform 3D solid simulation on AutoCAD, in addition to the basic tool path file, there must also be the solid file of the part blank and the solid modeling file of the tool, as well as the solid intersecting operation structure generated by the relative motion of the two. Since we only perform geometric simulations, we simplify the 3D model of the tool to consider only the geometry of the tool, that is, the maximum enveloping contour during rotation. Three-dimensional solid simulation is divided into three processes, namely initial blank, process blank and finished product model. The first is the initial model, that is, the shape of the part blank before machining, which can be obtained by drawing it by itself or imported from other CAD software; then the process model, that is, the real-time situation of the blank during the movement of the tool, which is obtained by the computer during the simulation process. The tool and the initial blank are obtained after continuous Boolean calculations; the final model is the finished product, that is, the finished shape of the part after processing. In these three processes, the calculation of the process blank undoubtedly consumes the most computer resources, and the biggest difficulty in 3D solid simulation is the efficiency. Because AutoCAD is relatively weak in 3D processing capability, the speed of 3D cross Boolean operation is slow. As a result, the processing speed of the blank during the simulation process is very slow, which affects the actual use effect.

Figure 2 and Figure 3 are the comparison charts of the number of blank peaks and the processing time of blank processing using the classic AutoCAD software and the numerical control programming software proposed in this paper during the simulation process. It is clear from the figure 3 that simulation time has reduced as compared to traditional algorithm. During manufacturing level of the enterprise has been improved, and the product processing cycle has been shortened. It can be seen from the figure that the numerical control programming software proposed in this paper can process 25.4% more blank peaks than the traditional AutoCAD algorithm and reduce the processing time by 23.7% when simulating blank processing. This is mainly due to the focus on optimization of the numerical control programming software in this paper. In order to optimize the process blank of the three-dimensional simulation, the computer calculation amount in the operation process is reduced. Since the main function of the process blank is to display the real-time situation of the blank and increase the authenticity of the simulation effect, the accuracy of the model realization effect is not high, so we consider to appropriately simplifying the process blank. For example, when the tool moves from one point to another during the movement, it passes through other four points in the middle of the movement. At these positions, we only calculate the result of the cross Boolean operation between the tool and the blank at the current position, and do not calculate the sweep of the tool during the movement. The overall area after the tool leaves the work piece surface or accumulates a certain movement distance; the overall area swept by the tool movement process is calculated to obtain a real finished model.

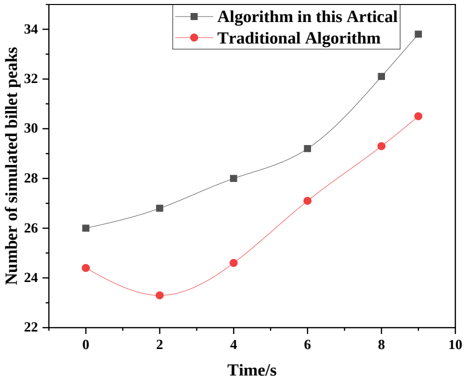

Figure 2: Short, centered caption, terminated with a full stop.

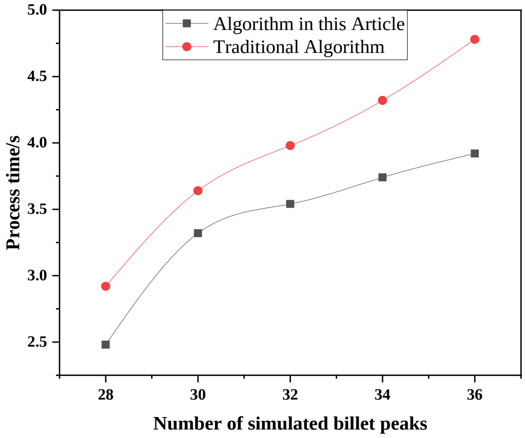

Figure 3: Short, centered caption, terminated with a full stop.

4.1 Discussions

A development technique of AutoCAD-based NC program simulation software is provided to address the concerns of less optimization and burdensome operation of complicated and small batch components in practical machining applications. To increase efficiency and eliminate waste, the suggested CAM approach would design new or adapt existing industrial setups. This is accomplished by lowering energy consumption and accelerating the production process and tooling.

Product planning, development, administration, storage, and transportation may all be aided by CAM. The end result was extremely consistent, high-quality, and precise. The observations show that the simulation time has decreased as compared to the conventional approach. The enterprise's production level has improved, and the product processing cycle has been reduced. When simulating blank processing, the numerical control programming software suggested in this study can process 25.4 percent more blank peaks than the typical AutoCAD approach and reduce processing time by 23.7 percent.

5 CONCLUSION

In this paper, the theoretical research on the NC programming technology of small batch customized parts is carried out in the industrial steam turbine industry. Combined with a lot of practical experience, as well as the theoretical basis of group processing and parametric programming, it is proposed that a processing feature sister Refine into a single machining feature, compile the corresponding NC code, parameterize its key dimension data, save it as a typical machining feature group, and then use the parameter data to drive and regenerate the customized NC code. Based on the above principles, this paper compiles the NC programming software through the AutoCAD programming language, and develops the corresponding simulation system through the AutoCAD graphics interactive system to simulate the generated NC code and verify its reliability.

Due to the limited time and the limitation of my professional level, this paper still has certain limitations. In the future, I can continue to study in depth from the following aspects: (1) This paper mainly focuses on the main processing characteristics of the key components of industrial steam turbines, especially the complex holes. In-depth research and discussion have been carried out on the machining of the system, while the corresponding shaft machining and surface machining are mainly based on simulation, without in-depth research and practice. In future research, it is considered to further expand the scope of application of the system. (2) Although conventional machining can be very suitable for macro parameter programs, for complex surface shape processing, it is still not completely covered by macro parameter programs, such as trochoidal machining, plunge milling, etc., still cannot be realized only by the macro parameter program, so there is still a lot of room for improvement in the toolpath generation system in the software, which needs to be further improved in the future.

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