Computer Aided Design and Manufacturing of Connecting Rod Mold

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Abstract. At present, most of the connecting rod mold design enterprises still use the traditional mold design method, mainly rely on the experience of mold designers and simple formulas. This design method cannot fully consider downstream manufacturability, assemblability, stamping process, and quality assurance in the early design stage. As a result, the design plan is repeatedly revised, the design efficiency is low, the mold quality is unstable, and the product quality is difficult to guarantee. This paper chooses to use computer-aided design and manufacturing technology to optimize the design of connecting rod mold design, which has important engineering practical application value. This article first analyzes the traditional design and manufacturing schemes of connecting rod molds, and draws out the existing problems and solutions. Then it studies the computer-aided design and manufacturing software in the aspects of connecting rod mold design, assembly, motion simulation and mold design optimization. Finally, a real mold was produced, and the assembly and operation effects were compared. The conclusions are as follows: Through the optimized design and cost calculation of the connecting rod mold, a faster and more accurate solution is obtained, which provides a strong support for the subsequent mold structure design. The optimized design of the connecting rod mold based on computer-aided design and manufacturing technology shortens the mold development cycle, improves the quality of molds and parts, reduces development costs, and improves product competitiveness.

Keywords: Parametric Design; Connecting Rod Mold; High-speed Cutting; Computer-aided Design and Manufacturing
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1 INTRODUCTION

Computer-aided design and manufacturing (CAD/CAM) is an important means to support modern manufacturing. CAD is based on graphic processing to efficiently and optimally design products. Dokken et. al [1] points out that CAM uses a computer-aided manufacturing system to generate a part processing program in a computer, and uses a CNC machine to process the product. In the machinery industry, CAD / CAM is an important technical means from automobile manufacturing, motorcycle manufacturing, mobile phone manufacturing, etc. of large enterprises to parts processing and mold parts manufacturing of small home-based enterprises. CAD / CAM has been widely used in the machinery industry. In recent years, the popularity of CNC machine tools and the rapid promotion of CAD / CAM technology have promoted the upgrading of China's manufacturing equipment. Palou-Rivera et. al [2] said the use of CAD / CAM technology in manufacturing has improved product quality, reduced product costs, and shortened production cycles. Aguirre et. al [3] continuously improve the competitiveness of our products in the international market. For China that has just joined the WTO, actively promoting CAD / CAM technology will help Chinese enterprises accelerate their integration into the global competition mechanism. There are many types of CAD / CAM software currently used in China, with different functions. Alam et. al [4] they use different technologies with their own characteristics. The appearance of Pro / e has brought the CAD modeling function to a new level; Mastercam is widely used in parts processing featuring wireframe modeling, simple and convenient curved surface processing, and software is a CAD / CAM software, both in CAD modeling and CAM processing, has excellent overall performance. In the modern manufacturing industry, the production process of mold production is complicated and the processing accuracy is high. In stamping mold processing, processing technology such as electric spark is also used. Krahe et. al [3] points that the cycle is long and the manufacturing cost is high. Small batch, personalized and diversified requirements. The shape of the working surface of the connecting rod mold is complex, and the modeling is difficult. This requires designers to be very proficient in 3D modeling software, and general engineering technicians are difficult to skillfully and quickly model through simple training. In the application of Mastercam, the cutting amount cannot be generated automatically.Galiziaa et. al [5] said in order to correctly set the cutting amount, the CAM operator must know the specific cutting data of each cutting material corresponding to the tool used. This requirement is difficult for ordinary operators. Based on the above analysis, to solve the problem of rapid construction, ordinary technicians can quickly construct it through simple training; in the operation of CAM, the problems of correct setting of cutting parameters are raised to the theory and integrated into the CAM software to achieve automatic cutting consumption Generated, thereby improving the practicability of the CAM software and reducing the difficulty of using the CAM software, so that general engineering technicians can use the CAM software to properly design and process the connecting rod mold through simple training. Bici et al [6] said through rapid modeling and automatic generation of cutting usage, the modeling and processing time is shortened, the modeling and processing difficulty and error rate are reduced, and its research results will generate greater economic benefits for the enterprise. The author first analyzed the manufacturing process of the traditional connecting rod mold, and aimed at its shortcomings, and proposed the application of CAD / CAM processing integration technology to realize the processing of connecting rod mold. This technology uses mid-end Solidworks and Mastercam software as a platform for connecting rod mold design and NC programming to complete high-speed cutting of the mold on a high-speed milling machining center, and from the perspective of extending tool life, it gives reasonable cutting parameters, which is effective Shorten the mold processing cycle and improve the processing quality.

2 REALIZATION OF KEY TECHNOLOGY OF CONNECTING ROD MOLD

2.1 Deficiency of Traditional Processing Technology of Connecting Rod Mold

In the past, most of the manufacturing of connecting rod dies used two-dimensional drawings to describe parts and mold design. The conversion from two-dimensional to three-dimensional was very complicated, and it was very inconvenient to modify the size. At the same time, in order to improve the processing performance and service life of connecting rod molds, high-strength wear-resistant materials are generally used. Sivarupan et. al [7], these materials are hardened after heat treatment and hardening, and it is difficult to process them by conventional cutting methods. Barbosa et. al [9], in the past, EDM technology was used to complete the processing of mold cavities. However, this "micro-cutting" process by discharge ablation is very slow, and micro-cracks can also be generated on the cavity surface. At the same time, due to the influence of the electrode translation, the roughness and dimensional accuracy often fail to meet the requirements of the mold. Therefore, it takes time-consuming manual grinding and polishing after electro-machining, which greatly reduces the processing efficiency.

2.2 The Realization of Parameterization of Main Dimensions of Connecting Rod Mold

Connecting rod mold design Solidworks is a Windows-based 3D design software, which has comprehensive part solid modeling functions and variable sketch contour drawing functions, and can perform dynamic constraint checking automatically. By using the functions of Solidworks to stretch, cut, rotate and chamfer, you can easily get the solid model you need.

Not only are the connecting rod models large in size, but the dimensions in many places are related (but there are also irrelevant). If the size of the center distance between the connecting rod pin hole and the crank shaft hole is simply changed, not only the model cannot be reconstructed, but also the tangency relationship at the tangent ends of the two ends cannot be changed, and a certain proportion of the width and the length cannot be changed. In Solidworks macro recording, each 2D sketch must be closed with parameters. Subburaj et al [8] said it is also necessary to consider that the local energy of the model can be reconstructed after individual parameter changes, so the size of this part is irrelevant. Under the premise of ensuring that the sketch is closed, there are two cases. Dubey et al [10], one is to change a size, and the other sizes must be changed to follow it proportionally, that is, the length, width, and height of the part are changed proportionally. Some constraint relationships, such as: tangent, the positional relationship remains unchanged; the second is to change a size, only change its size, and does not involve other sizes. Therefore, when establishing the parameter relationship, we must consider that these two situations can be satisfied. The realization of parametric modeling function includes: block diagram, program code.

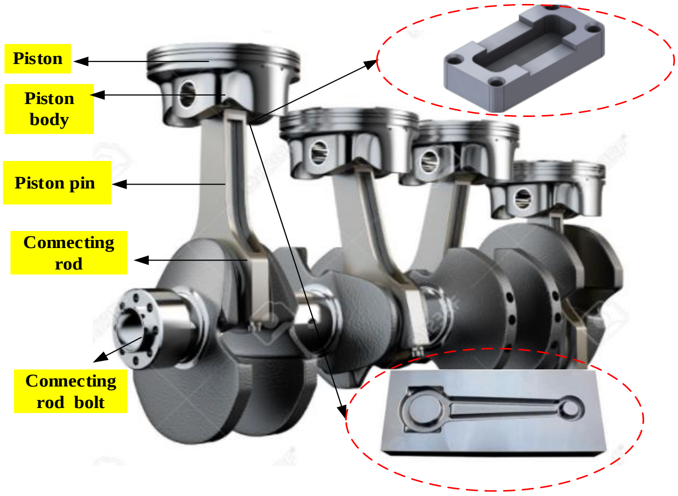

Figure 1: Typical link solid model.

The main steps for the design of the typical solid model of the connecting rod shown in Figure 1 are as follows:

(1) Create a "Part" file, select the positioning plane, draw a sketch of the part's section, use the "Extruded Boss" command to establish the base, and then use rotate, stretch, cut, and other commands generate the middle part of the connecting rod;

(2) Select a new datum plane, use the "Extrude Boss" command to stretch out the head and tail, and select the draft slope in the "Features" command, select the plane perpendicular to the parting plane, and set the draft, mold angle, generating slope;

(3) Use the "Cut" command to stretch out the grooves on the head and tail, and perform rounding. Finally, use the "array / mirror" command to mirror out the next part to generate the 3D solid shape of the connecting rod.

Under the Solidworks application software, the 3D solid model of the connecting rod is divided into two concave molds. After the design of the die is completed, the file is saved in IGES format for Mastercam to read in for CAM design.

2.3 Aided Manufacturing of Connecting Rod Mold

Mastercam is a computer-aided design and manufacturing software introduced by Deng et al[10] developed by CNC Software company in the United States. CAM is powerful and can provide graphical toolpaths and NC codes for multi-axis CNC machine tools, and can perform dynamic simulation of toolpaths. Use Mastercam9.0 to process the link entity and generate processing code.

(1) Roughing. The main steps of NC rough machining path generation are as follows:

a) Import the IGES format cavity file generated by Solidworks under Mastercam; b) Enter the surface machining entrance: Toolpaths (Surface machining), select Rough (rough machining) - Parallel (parallel milling) - Surfaces (select cavity surface) - Done (execute); c) Application parameter setting menu: Set tool parameters, surface parameters and roughing parameters (the main processing parameters are listed in Table 1. After the setting is completed, the computer starts to calculate the theoretical surface, the compensation surface and the tool trajectory, and finally generates the NC rough machining path.

Machining type	Tool size / mm	Spindle speed / (r / min)	Feed rate / (m / min)	Cutting time / min
Roughing	Flat knife	22.38	4.61	25.00
Finishing	Ball nose milling cutter	32.49	5.93	20.00
Kiyotane	Ball nose Cutter	48.61	9.61	15.00

Table 1: Processing parameters.

(2) Finishing

The main steps of NC finishing path generation are as follows, select Finish-Parallel (parallel milling)-Surfaces (select cavity surface)-Done (execute).The main parameter settings are shown in Table 1. CNC finishing path. The tool path is shown in Figure 3 (for the convenience of display, the tool path has been simplified). For small fillet parts that have not been partially cut off, the software automatically generates a secondary finishing (clearing) tool path to ensure the accuracy of the machining surface.

After all the toolpaths are generated, the post-processing module for high-speed machining in CAM is selected to convert the toolpaths into NC codes in high-speed cutting mode. Due to the large memory capacity of the HSM-600 high-speed milling machining center, the NC code can be entered at one time, and the tool path can be processed at high speed after the simulation is correct.

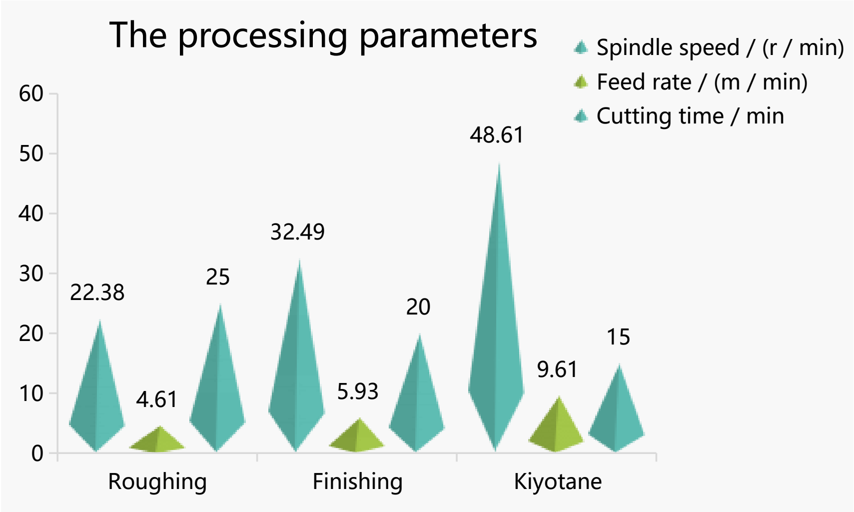

Figure 2: The main processing parameters.

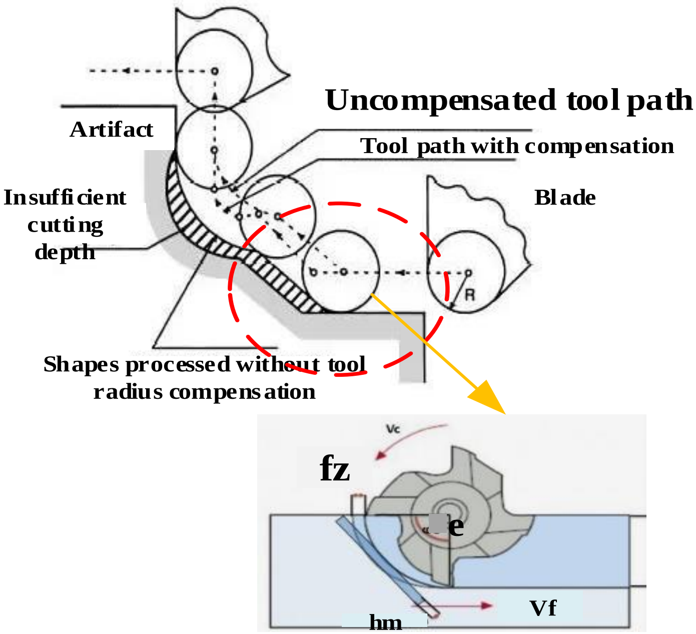

Figure 3: Roughing toolpath.

2.4 Improvement of Processing Technology of Connecting Rod Mold

(1) High-speed processing technology High-speed cutting (HSM) has the characteristics of high spindle speed, high feed speed, and high cutting speed. Chu et. al [11] said due to the increase in cutting speed, the mechanical structure of the cutting tool is changed, which improves the cutting conditions, reduces the cutting force and cutting temperature, and also reduces the transfer of heat to the workpiece, reduces the effect of thermal deformation, and helps improve machining

accuracy and surface quality. The improvement of cutting efficiency effectively shortens the processing time and reduces the processing cost. Figure 4 shows the difference between high-speed processing and traditional mold processing. The high-speed processing process eliminates the time for electrode modeling, processing, and cavity polishing in the traditional mold processing process, which improves processing efficiency.

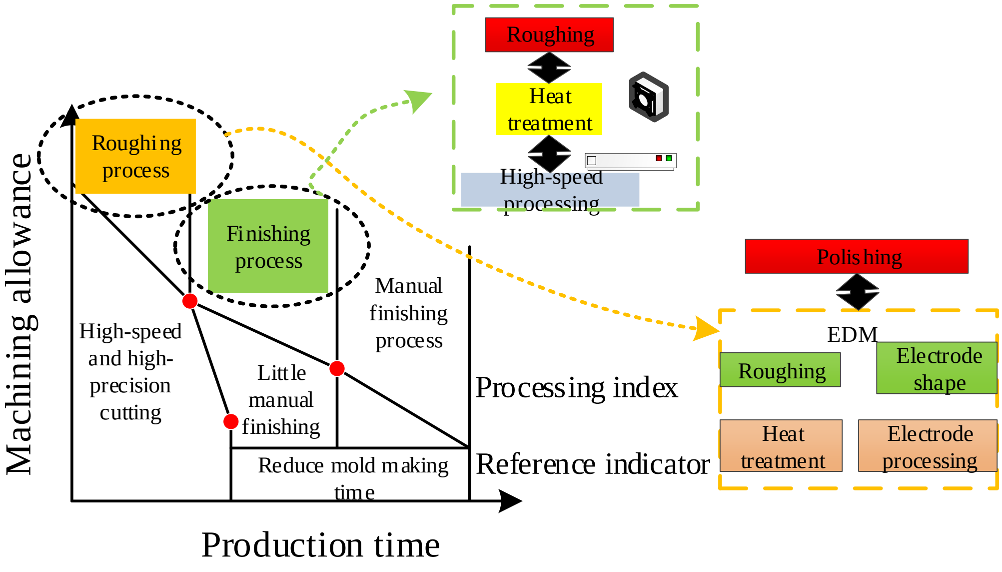

Figure 4: Difference between high-speed machining and traditional mold machining.

(2) Selection of cutting parameters for high-speed machining

The equipment used for the processing of this connecting rod is a high-speed milling machining center (the maximum speed of the spindle is 35000r / min, and the feed speed can be up to 35m / min). This places higher demands on the hardness and heat resistance of the tool. The tool selected for mold processing is a special high-speed cutting tool [4] produced by Sandvik.

Its main parameters are calculated using the following formula:

The data obtained from the lookup table are: V—finishing cutting speed

So—roughing feed per tooth

Selection of the rigidity correction factor K of the workpiece-tool-machine tool system. Machines with poor rigidity take 0.5, and in other cases, take a value between 1 and 0.5 as appropriate.

Take $V_R = 0.7V_P$, $S_R = 0.8S_P$

Calculating formula for cutting amount of flat-blade cutter:

$$D = 2sqr\left[Ap(d - Ap)\right] \tag{1}$$

$$n = \frac{1000 * V * K}{\pi * D} \tag{2}$$

$$V = n * S * Z * K \tag{3}$$

Where:D --- effective cutting diameter, mm; Ap --- cutting depth, mm; d --- tool diameter, mm; V --- feed rate, m / min; n --- spindle speed, r / min ; Z—number of cutter teeth.

3 COMPARISON OF ASSEMBLY AND OPERATION EFFECTS OF CAD / CAM TECHNOLOGY BEFORE AND AFTER CONNECTING ROD MOLD

Before and after applying CAD / CAM technology, real molds were made and put into production application. Statistics and records were made for each link, and a comparative analysis of assembly and operation effects was performed.

3.1 Assembly Effect Comparison

The optimized design of the previous model reduces the obstacles encountered in real assembly and accelerates the speed of real assembly. The real assembly results are basically the same as the software simulation assembly results. The comparison of real and virtual upper mold assembly results is shown in Figure 5. Using traditional mold design and manufacturing methods, the chain plate mold assembly is repeated three times on average, which takes about three days; after using CAD / CAM technology, the real assembly achieved a successful assembly, which was applied to production and commissioning took about half a day, time It has increased more than six times, greatly shortening the mold product development cycle.

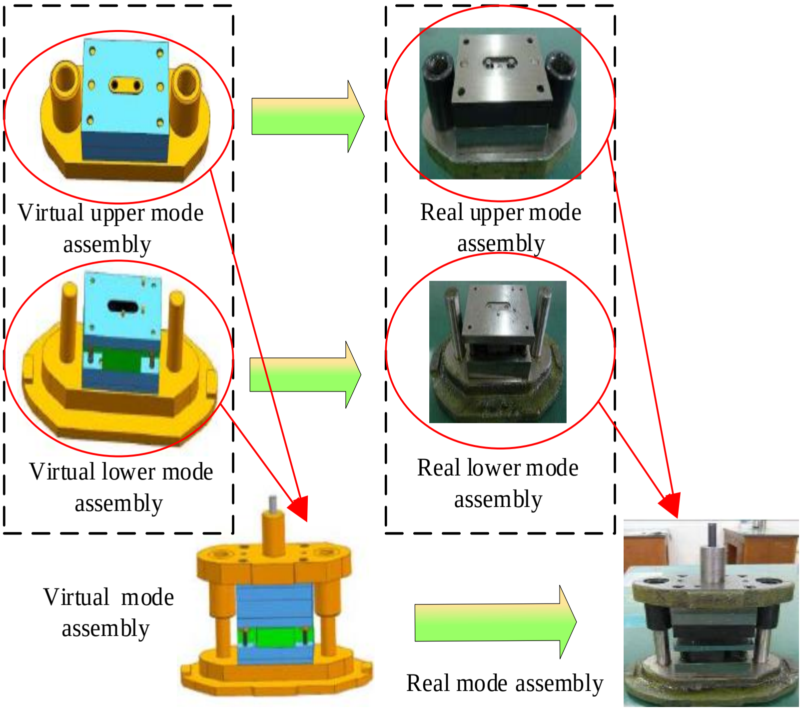

Figure 5: Comparison of real and virtual upper mold assembly.

3.2 Comparison of Mold Operation Effects

Through the previous assembly and motion simulation analysis, the problems that affect the final operation of the mold, such as component clearance, interference, and mold mounting height, are identified early and the mold design optimization is performed in advance. Before and after the application of CAD / CAM technology, the effect is obvious in the following two aspects.

(1) Save mold debugging time

The traditional design method is used to design the chain plate mold, relying on the designer's work experience and simple formulas, it takes a long time, and the actual mold operation effect is often far from the design. It needs repeated adjustments to achieve the best results. After applying CAE technology, the production process of mold design and manufacturing is shown in Figure 6. CAE software predicts possible defects in advance, and corrects and optimizes the process plan or mold mechanism design before mold processing, reducing the number of mold adjustments and repair time in the later stage, and greatly improving the production efficiency of mold design and manufacturing. Table 2 and Figure 7 show the comparison of parameters in the design and manufacturing process before and after CAD / CAM technology is applied to the chain plate mold.

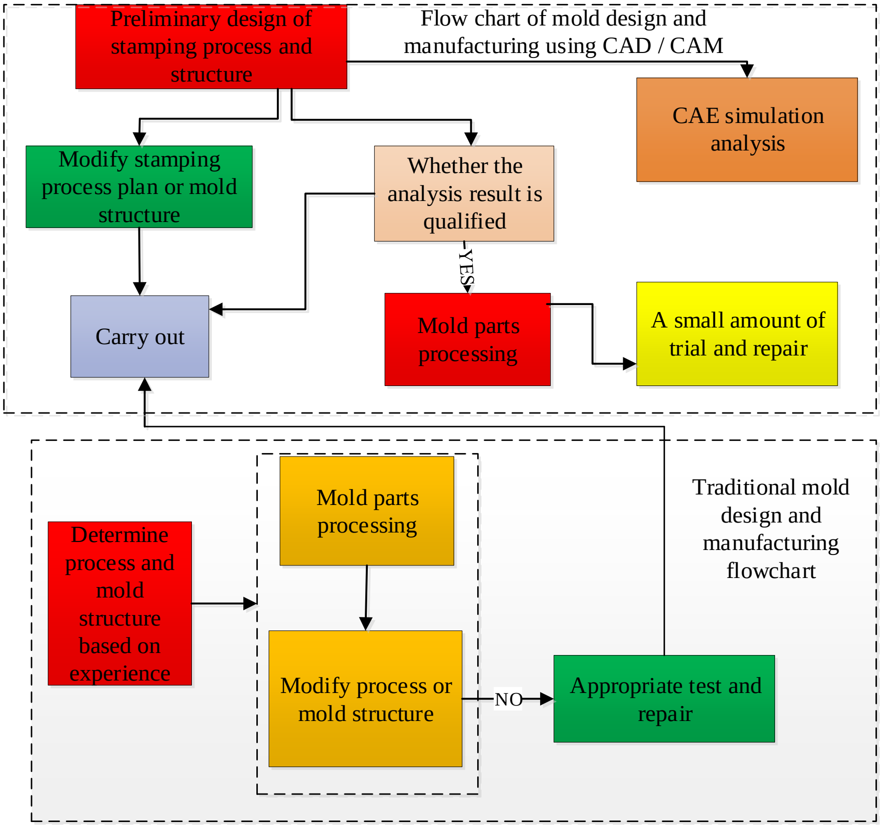

Figure 6: Flow chart of mold design and manufacturing using CAD / CAM.

	Design time (days)	Production time (days)	Debug times	Repair time (days)	Consumption of test template (sheet)
Before application	3.2	7	8	4	28
After application	3	4	2	1	4

Table 2: Comparison of production parameters before and after applying CAD / CAM.

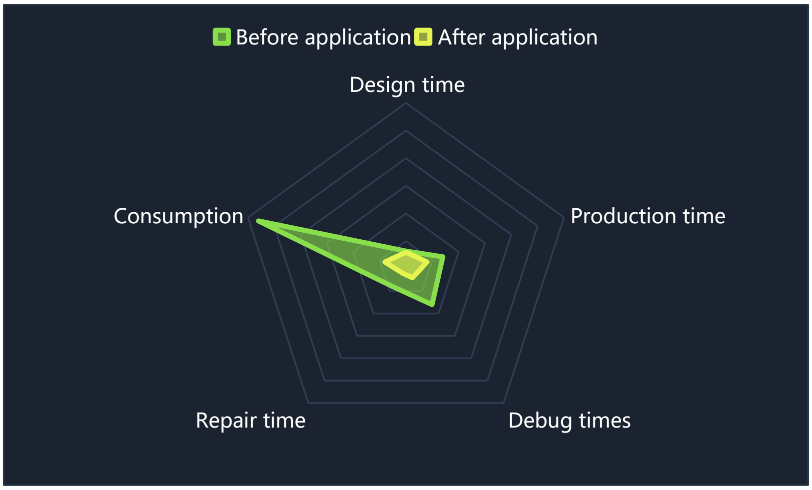

Figure 7: Comparison of production parameters before and after applying CAD / CAM.

(2) Improved the quality of punching parts and dies

After the molds with different design methods were put into production, the scrap product rejection rate and mold usage were statistically calculated. It was found that using traditional mold design and manufacturing methods, the stamping parts scrap rate of the chain plate mold was high, the number of mold failures was high, and the mold was used Short life. After adopting CAD / CAM technology, the scrap rate of punching parts is greatly reduced, and the number of die failures is reduced, and the service life is prolonged. The comparison is shown in Table 3.

	Punching scrap rate	Mold use failure times	Mould life
Before application	10%	4	12000
After application	3%	0	16000

Table 3: Comparison of the scrap rate and die quality before and after applying CAD / CAM technology.

4 CONCLUSIONS

The processing method of the connecting rod mold has been successfully applied. The entire machining process of the connecting rod mold only takes 85 minutes (the previous machining process took about 16 hours from the production of electrodes, EDM to polishing), which greatly shortened the processing cycle. For molds with complex shapes and high hardness after quenching, CAD / CAM system is used for 3D modeling and NC programming, and high-speed processing technology is used to complete the mold processing, which can shorten the production cycle of the mold and ensure the surface quality and mold quality. Machining accuracy has achieved good economic benefits. Finally, the assembly and operation results of the chain plate mold before and after the application of CAD / CAM technology were compared. It was found that the actual mold assembly and movement were basically the same as the software simulation. After using CAD / CAM technology, the efficiency of mold assembly and debugging was greatly improved. As a result, the quality of stamping parts and molds has also been improved. This shows that CAD / CAM technology can verify the rationality of mold design, assembly and movement in advance, avoid repeated mold repairs, improve mold quality, and greatly shorten the cycle of product development and improve product competitiveness.

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