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Design and Analysis of Machining Process for Motor End Cover Parts

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Abstract: As a crucial component of the motor, the motor end cover plays a vital role in the motor's performance and reliability. This paper mainly focuses on the design and analysis of the machining process for motor end cover parts. Firstly, it analyzes the structural characteristics and machining difficulties of the motor end cover parts, and proposes a reasonable machining process route. By selecting appropriate machining methods, including CNC machining, milling, turning, and hole machining, the machining accuracy and surface quality are ensured. Secondly, it conducts a detailed analysis of the key processes in the machining process, with a focus on exploring how to improve machining efficiency and the quality control measures for parts. This paper also introduces potential problems that may occur during the machining process, such as machining deformation and tool wear, and puts forward corresponding solutions. Through in-depth research on the machining process of motor end cover parts, this paper provides a scientific and reasonable theoretical basis and technical support for part machining in motor production.

1. Introduction

As a key component in mechanical equipment, the machining accuracy and quality of end cover parts directly affect the performance and service life of the entire mechanical system. End covers are typically used to seal and protect internal structures, and are widely applied in multiple fields such as aerospace, automobile manufacturing, and machine tools. Therefore, optimizing the machining process of end cover parts can not only improve their structural reliability, but also enhance production efficiency and reduce manufacturing costs.

In modern manufacturing, with the development of precision machining technology, the requirements for dimensional accuracy, geometric tolerance, and surface quality of parts are constantly increasing. The machining of end cover parts faces many challenges, such as the need for multi-process and multi-datum positioning, especially considering the economy of machining while meeting high precision requirements. For this reason, systematically designing a reasonable process flow, optimizing machining parameters, and matching with efficient fixture solutions have become key tasks in the machining process design of end cover parts.

Based on the specific structural characteristics of end cover parts and combined with actual production needs, this paper analyzes their machining difficulties and technical requirements, formulates a scientific and reasonable process route, optimizes machining parameters, and designs special fixtures to improve the machining accuracy and production efficiency of parts, providing technical support and theoretical basis for subsequent practical application

2. Analysis of the Part

2.1 Function of the Part

The motor end cover part plays a crucial role in the motor. As one of the key components of the motor, the main functions of the end cover are to enclose both ends of the motor, provide support for the rotor inside the motor, and ensure the sealing of the motor's internal structure. The design and processing of the end cover are directly related to the motor's stability, working performance, and service life.

As a supporting component of the motor, the motor end cover bears the motor's bearings and rotor. It fixes the bearings through the design of the bearing seat and ensures the precise fit between the bearings and the motor's main shaft, thereby guaranteeing the smooth rotation of the rotor. The structural design of the end cover needs to take into account force transmission and vibration suppression during operation, so the end cover must have sufficient strength and rigidity.

The sealing function of the motor end cover is of great importance. The design of the end cover needs to ensure that the electrical components inside the motor are isolated from the external environment, preventing the intrusion of dust, moisture, and other harmful substances. The heat dissipation process inside the motor also needs to be optimized through the design of the end cover to ensure that the motor does not overheat during long-term operation and avoid motor failures caused by overheating. Therefore, the material selection and processing technology of the end cover also need to consider good high-temperature resistance, corrosion resistance, and sealing performance.

In summary, the motor end cover plays a key role in supporting, sealing, and heat dissipation during the motor's operation. The rationality of its design and processing technology directly affects the motor's performance, reliability, and service life.

2.2 Process Design of the Part

During the process design of the part, it is necessary to ensure the integrity of the part's drawing views, the accuracy of markings such as dimensions and tolerances for the designed structure, and the completeness of technical requirements and processability requirements.

The material used for the designed part is HT150. The properties of this material can meet the application requirements. Compared with other materials, it has certain wear resistance and heat resistance, along with high elasticity, which enables it to buffer and reduce vibration—all of which meet the requirements of the end cover under working conditions.

When designing this part, based on its working conditions, emphasis must be placed on the technical requirements for the outer cylindrical surface of the right end face and the surface of the hole structure. Meanwhile, full consideration should be given to the machining process of the end cover part, as the quality of the process directly affects the part's quality and performance, as well as the production and machining costs. The specific machining dimensions are shown in Table 1.

Table 1. Machining Surface Dimensions and Machining Accuracy of Motor End Cover Parts

Item	Structure	Dimension	Roughness
1	Face	φ120mm、φ90mm Excircle＆Right end face	1.6μm
2	Ring groove	φ88mm Ring groove	3.2μm
3	Hole	φ52mm、φ40mm、φ26mmCenter hole	1.6μm
4	Face	φ120mm、φ60mm Excircle＆Left end face	12.5μm
5	Hole	φ40mm Center hole	3.2μm
6	Hole	φ9mm 6 holes distributed evenly	12.5μm
7	Hole	φ14mm 6 holes distributed evenly	12.5μm
8	Hole	M4 Threaded hole	12.5μm

2.3 Material Selection for the Part

The structure of the end cover part is relatively complex, including multiple outer cylinders, inner holes, annular grooves, chamfers, and threaded holes. These structural characteristics place high requirements on the machining process, which requires precise positioning and efficient machining methods to ensure the dimensional accuracy and surface quality of the part.

3. Casting Design

HT150 has good casting performance, wear resistance, and a certain degree of strength. This material performs stably in mechanical machining and can meet the application requirements of the end cover part. In addition, the price of HT150 material is relatively low, which helps to reduce production costs.

3.1 Casting Dimension Design

The part operates stably with low and evenly distributed stress under working conditions. The HT150 material exhibits good mechanical properties and machinability, along with low casting costs. The part is designed with a central hole structure and undergoes aging treatment after casting to reduce residual stress in the material and enhance its mechanical properties. Based on the empirical data analysis of castings with similar structures, the casting tolerance grade ranges from grade 8 to 10, and grade 9 is selected after comprehensive consideration. The machining allowance range of the part is from grade D to F, and grade F is chosen with reference to relevant factors. Casting structure optimization is shown in the figure 1，The specific dimensions of the casting are shown in the table 2.

Table 2. Dimensional Tolerance and Machining Allowance of Castings

Machining Surface to be Processed	Dimension/mm	Machining Allowance/mm	Blank Dimension/mm
Left outer circle	Φ60	3*2=6	Φ66
Right outer circle	Φ90	3*2=6	Φ96
Φ120outer circle	Φ120	3*2=6	Φ126
Height	34	6	40
Thickness	15	3	18
Center hole	Φ26	10	Φ 16

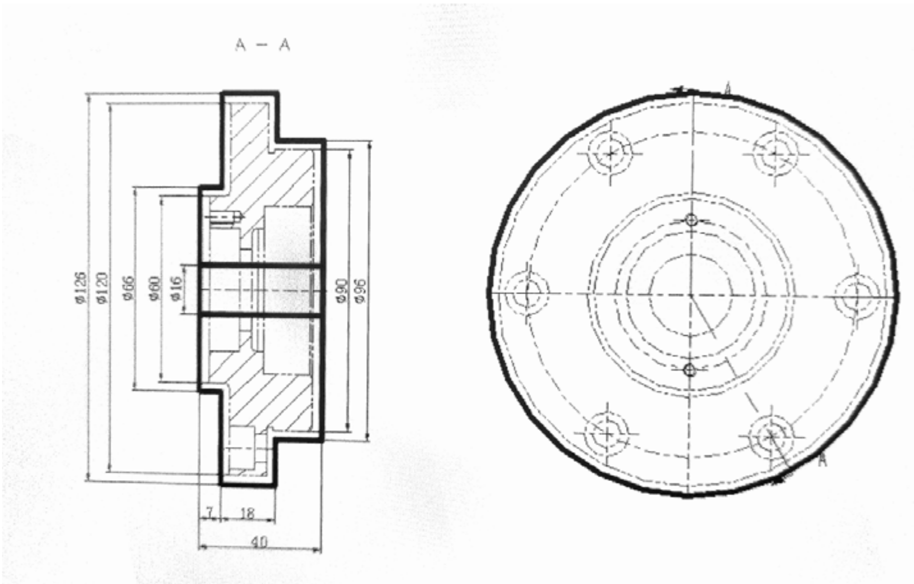

Figure 1. Blank Drawing of the Part

3.2 Heat Treatment of the Blank

The cast blank needs to undergo aging treatment to reduce residual stress in the material and improve the mechanical properties of the part. The temperature for aging treatment is usually selected between 180°C and 200°C, maintained for 4 hours, followed by natural cooling. After this treatment, the tensile strength reaches 150 MPa, the flexural strength reaches 330 MPa, and the Brinell hardness reaches 200 HBS.

4. Design of Part Process Flow

4.1 Design of Machining Datum for Part Positioning

The machining datum of the part is designed based on its structure and service condition requirements, to ensure that the dimensional accuracy of the part during machining meets the service requirements and improve the machining efficiency of components. The design of the datum surface is related to the stability of the entire machining process. Improper design will lead to many problems in production, processing and part performance, resulting in economic losses.

The design of the rough datum requires a certain degree of flatness, with no surface structural defects such as parting lines, flash, burrs on the surface. Based on the analysis of the design structure, it is finally determined that the left end face of the end cover and the outer circular surface of the end cover with a diameter of 60 are used as the rough datums for design and machining. The outer circular surface with a diameter of 60 is used as the rough datum to ensure the requirements for dimensional accuracy, perpendicularity and uniformity of the inner hole processed in the structure; the left end face of the end cover is designed as the rough machining datum to ensure the stability and accuracy of the part during the machining process. The right end face of the end cover and the hole structure with a diameter of 26 are designed as the fine datums. All other structures and surfaces on the component use these two surfaces as the datums for machining, which meets the principle of coincidence of design and machining positioning datums. The design of the fine datums meets the functional and machining requirements of the part, so as to ensure the dimensional accuracy and quality of the final product.

4.2 Tooling Design

To ensure the accuracy and stability requirements of machined parts, it is necessary to ensure the consistency of the relative positional relationships between different machined surfaces of the end cover parts. Since parts are machined using machine tools, it is necessary to position the components. The datums required in the positioning and machining process consist of three aspects: machining datums, datums, and measurement datums. According to the designed parts and process flow, the positioning scheme is given as shown in Figure 2. When the clamping device clamps the parts, the positioning components will wear out quickly due to factors such as part output and frequent disassembly. Therefore, the selection and implementation of positioning components must meet the requirements for interchangeable use, so as to reduce the time and cost of fixture replacement and maintenance.

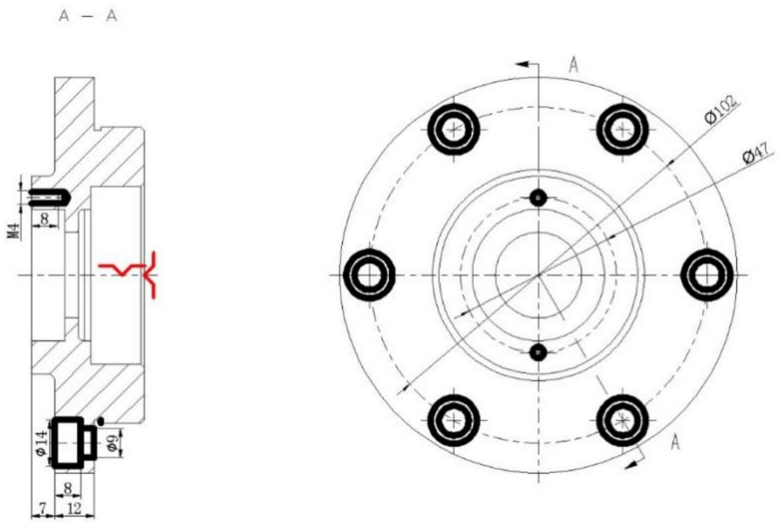

Figure 2. Tooling Design

4.2.1 Design of Fixture Positioning Mechanism and Its Calculation

The design of workholding fixtures[1] requires full calculation of the loads they bear to ensure stable and efficient machining processes, and to avoid incorrect or mistaken installation, The calculation is as follows:

(1) Fixture tool setting error Δ_T =0.064mm.
(2) Total fixture dimension error Δ_D= 0.03mm.
(3) Fixture installation error Δ_j =0 mm.
(4) Fixture processing method error Δ_a =0.12/3=0.04mm.

$$\sum\Delta = \sqrt{\Delta_D^2 + \Delta_T^2 + \Delta_J^2 + \Delta_A^2 + \Delta_G^2} \tag{1}$$

$$= \sqrt{0 + 0.064^2 + 0.03^2 + 0 + 0.04^2} = 0.081 \tag{2}$$

The precision calculation equation for machining is as follows: $J_C = 0.12 - 0.081 = 0.039$

After calculation, the deviation parameter is within the range of ±0.05 mm, which can meet the requirements.

4.2.2 Calculation and Design of Tooling Clamping Device

The structural and dimensional design of the clamping device must meet the design accuracy requirements of the machining process, as well as performance and structural requirements such as convenient and simple operation, simple structure, stable clamping, safe and stable structure, reasonable space and structural dimensions, and low maintenance and usage costs. Based on the working condition requirements, the calculated data of cutting forces during the machining process are as follows:

The calculation equation for cutting resistance is as follows: $F = 26Df^{0.8}HB^{0.6}$

The calculation equation for cutting torque is as follows: $T = 10D^{1.9}f^{0.8}HB_{0.6}$

Cutting Force Equation and Substitution of Relevant Parameters： $D = 62mm$

$$HB = HB_{\max} - \frac{1}{3}(HB_{\max} - HB_{\min}) = 255 - \frac{1}{3}(255 - 187) = 232 \tag{3}$$

$$f = 0.15mm \cdot r^{-1} \tag{4}$$

$$F = 26 \times 25 \times 0.15^{0.8} \times 232^{0.6} = 3755.2N \tag{5}$$

$$T = 10 \times 25^{1.9} \times 0.15^{0.8} \times 232^{0.6} = 26174N \cdot mm \tag{6}$$

The calculation formula for clamping force is：

$$W_0 = \frac{QL}{r' tg\varphi_1 + r_Z tg(\alpha + \varphi_2')} \tag{7}$$

After searching for the following parameters mentioned in the literature Handbook for Mechanical Machining Process Engineers, the result was obtained by substituting these parameters into calculation:

$$W_0 = \frac{35 \times 50}{4 \times (3^{\circ}10' + 9^{\circ}50')} = 1895N \tag{8}$$

By analyzing and designing the structural parameters and spatial matching status of the part, The tooling is as shown in figure 3 & figure 4. This structure adopts the principle of spiral clamping to secure the part, which can meet the fixture design requirements in machining and improve the efficiency of production and processing.

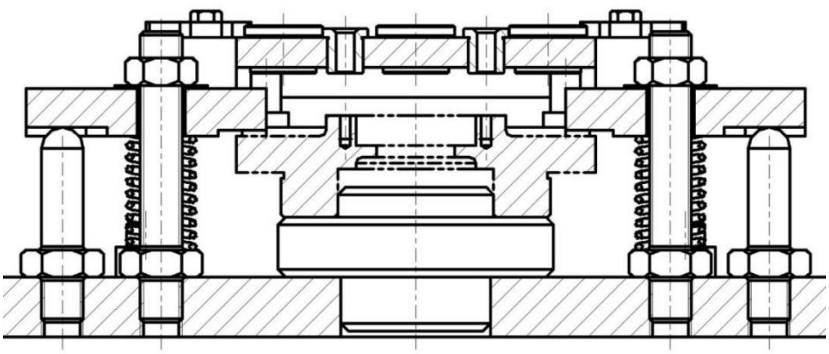

Figure 3. Clamping Mechanism Design

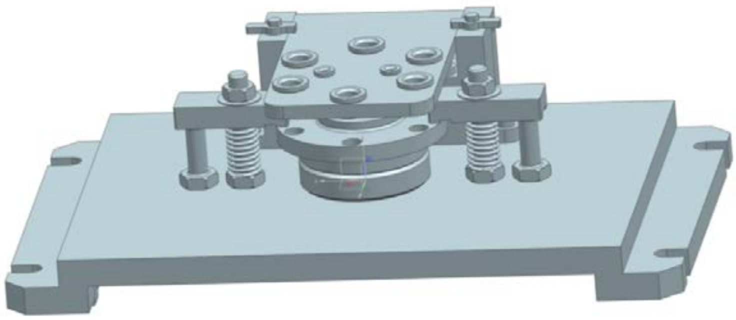

Figure 4. 3D clamping device

4.3 Design of Part Surface Machining Methods

The blank of this part is a casting, and the surfaces to be machined include end faces, inner holes, outer circumferential surfaces, internal and external chamfers, threaded holes, etc. The tolerance grade and roughness requirements shall refer to those specified in the part drawing. The design of machining methods is as follows:

End face machining: Milling is adopted to ensure the flatness and perpendicularity requirements of the end faces.

Inner hole machining: Drilling, reaming, or hole milling is used based on the hole diameter and length. Corresponding cutting tools and process parameters are designed for machining in accordance with the tolerance requirements.

Outer circumferential surface machining: Rough turning and finish turning are employed to ensure the dimensional accuracy and roundness requirements of the outer circumferential surfaces.

Internal and external chamfer machining: Chamfering tools are used for machining to meet the size and angle requirements of the chamfers.

Threaded hole machining: Tapping is adopted, and appropriate cutting tools and process parameters are selected according to requirements.

By selecting appropriate machining methods based on the specific requirements of different holes, the dimensional accuracy and surface quality requirements of the holes can be ensured while improving machining efficiency. For hole walls with high precision requirements, the process of rough boring followed by finish boring can ensure that the dimensional accuracy and surface roughness of the holes meet the requirements. For other holes, the drilling process can be selected for machining to meet their dimensional requirements. Through the rational selection of machining methods, the geometric shape and surface quality of the holes can be guaranteed to meet the design requirements.

4.4 Design of Process Content

In accordance with the machining principle of "datum first, others later", the surfaces and structures of the machining datums shall be machined first.

In line with the machining principle of "rough machining first, finish machining later", the rough machining process of the part shall be carried out first, followed by the finish machining process of the part.

According to the machining principle of "surface machining first, hole machining later", the end faces of the part shall be machined first, and then processes such as hole drilling shall be performed.

4.5 Process flow

Based on the material mechanical properties of the motor end cover, the process characteristics of the casting, and the existing process equipment level of the factory, a comprehensive analysis was conducted to obtain the process route shown in Table 3 [2].

Table 3. Process flow

Item	Process flow	Remark
010	Truning φ126x40	
020	Heat Treatment	
030	Rough Turning φ120、φ90 ＆Right end face	
040	Finish Turning φ120、φ90＆Right end face	
050	Truning ring groove φ88mm＆ chamfering C2	
060	Drill φ20mm	
070	Rough Turning φ26mm、φ40mm、φ52mm hole	
080	Finish Turning φ26mm、φ40mm、φ52mm hole	
090	Rough Turning φ120、φ60＆left end face	
0100	Finish Turning φ120、φ60＆left end face	
0110	Rough Turning φ40mm hole	
0120	Finish Turning φ40mm hole	
0130	Drill 6-φ9mm hole	
0140	Drill 6-φ14mm hole	
0150	Drill φ3.3mm hole	
0160	Tapping M4mm threaded hole	
0170	Deburs	
0180	Dimensional Check	
0190	Visual Inspection of Parts	
0200	Storage	

4.6 Cutting Parameters and Basic Time

4.6.1 Process 030

The purpose of rough machining is to remove the machining allowance, and the machining parameters need to achieve speed and efficiency [3].

(1) Determination of Cutting Depth and Machining TimesDuring machine tool processing, when designing the cutting depth of the tool, it is necessary to analyze the feed rate and cutting speed of the tool. The cutting depth (ap) is designed to be 1mm, and 2 turning operations are adopted to ensure that the accuracy meets the requirements.

(2) Determination of Feed RateBased on the information found in the literature "Practical Machining Process Manual", we conducted a preliminary analysis on the working characteristics of the end cover and selected a cutting feed rate (f) of 1.3mm/r, which can improve processing efficiency under the premise of ensuring processing quality. The selection of cutting feed rate is closely related to factors such as the tool, workpiece material, and machine tool performance. We selected this cutting feed rate through comprehensive analysis and reference to the process manual.

(3) Determination of Machine Tool Spindle Speed The spindle speed of the machine tool is selected according to the material and structure of the processed part. By looking up literature, we

obtained the operation manual of the CA6132 machine tool and checked the speed proposed in the manual. According to the information in the manual and the calculation result that 75r/min is within the relatively matching speed range, we selected a spindle speed of 80 r/min.

(4) Calculation of Process 030 DurationAccording to the machine tool parameters mentioned in the "Practical Machining Process Manual", y+ = 7mm, and L_total = 120×2 + 7 = 247mm. Substituting into the calculation, we get:

4.6.2 Process 040

Finish turning the outer circle structure of the end cover with a diameter of 120mm and the right end face with a diameter of 90mm, each with 2 turning operations. According to the designed part material, it is determined that during the finish turning process of the φ120mm outer circle and φ90mm right end face, 2 turning operations are performed respectively to ensure the processing accuracy requirements of each surface. The machine tool model used in this process is CA6132, and an external turning tool is used for processing. Through the analysis of the end cover material and size requirements, the external turning tool and its structure are designed. The tool material is cemented carbide YG6, which can meet the hardness and wear resistance requirements of the tool and is suitable for processing workpieces made of HT150 material. By selecting the appropriate working machine tool, tool structure, and tool material, we can meet the processing requirements of the end cover and improve processing efficiency and quality. At the same time, these selections also help to ensure that the dimensional accuracy and surface quality of the processed end cover meet the requirements.

Determination of Main Process Parameters

(1) Determination of cutting depth and machining times through the analysis of the working scenario and structural characteristics of the designed end cover, the cutting depth (ap) for tool processing is determined to be 0.5mm. Using 2 turning operations to complete the processing of this process can ensure processing accuracy.

(2) The process parameters of precision machining mainly ensure the machining accuracy and stability of parts, and reduce the defect rate, the range of cutting feed rate (f) is 0.3-0.35mm/r[1]. After analyzing the working characteristics of the end cover, we selected a cutting feed rate (f) of 0.325mm/r.The selection of cutting feed rate has an important impact on the processing efficiency and quality of the workpiece. By referring to the "Practical Machining Process Manual", we selected a suitable cutting feed rate for end cover processing to ensure that the processing quality and performance requirements of the final product are met.

(3) Determination of Cutting Speed and ToolBy comparing data analysis in the "Practical Machining Process Manual", the processing linear speed Vc is selected as 70m/min. We will sort out the above calculation results and substitute them into the formula to calculate the spindle speed. According to the processing linear speed Vc of the tool and the diameter D of the workpiece, the formula N = (1000NVc)/(/(formula N = (1000N = (1000of the workpiece, tN. Substituting the tool processing linear speed Vc of 70m/min and the workpiece diameter D into the formula, the spindle speed N can be calculated. Through this calculation, the theoretical speed is 185r/min, and according to the experimental results, the final spindle speed is selected as 200 r/min. This selection is based on a comprehensive consideration of the characteristics of the machine tool and the suggestions in the maintenance manual. By comparing with the calculation results, a matching speed is selected to ensure the stable operation of the machine tool and meet the coordination between cutting speed and spindle speed, so as to improve production efficiency and processing quality.

(4) Calculation of Process 040 Duration By looking up the parameter content in the "Practical

Machining Process Manual", we can get the result that y+ is 2.8mm. Based on this result, we can calculate that the value of L_total is 120 is 120g Process Ma

4.6.3. Process 050

Turning the φ88mm annular groove of the end cover, with 1 turning operation. After analyzing the material of the part and the structure of the annular groove with a machining diameter of t the value of L_total is 120cy and processing quality.ults, a matching speed is selected to ensure o ensure ensure is selected to ensure selected the suitable machine tool CA6132 for this process and a grooving tool to complete the processing of this process，which can meet the requirements of processing quality and efficiency.

Determination of Main Process Parameters

(1) Determination of cutting depth and machining times The processing flow of the annular groove structure needs to be designed in combination with process parameters such as the tool's feeding amount and cutting speed. The selection of cutting depth is crucial to the efficiency and quality of the process. Through the analysis of the working characteristics of the end cover, a cutting depth of 1mm is selected. This selection can not only simplify the manufacturing process but also ensure that the processing quality meets the requirements.

(2) Determination of Feed RateBy referring to the suggestions in the reference "Practical Machining Process Manual", the range of cutting feed rate (f) is 0.16-0.23mm/r. After verification and analysis, we selected a cutting feed rate (f) of 0.195mm/r, which can improve processing efficiency while ensuring processing quality.

(3) Determination of Cutting Speed and ToolBy looking up the parameter information given in the reference "Practical Machining Process Manual", the processing linear speed Vc of the tool is determined to be 21.96m/min. Next, we will sort out the above calculation results and substitute them into the formula to calculate the spindle speed.

According to the processing linear speed Vc of the tool and the diameter D of the workpiece, the formula N=(1000Vc)/(πD) can be used to calculate the spindle speed N.

Substituting the tool's processing linear speed Vc of 21.96m/min and the workpiece diameter D into the formula, we can calculate the spindle speed N=(100021.96)/(πD).

According to the parameter information in the reference "Practical Machining Process Manual", the tool life coefficient T=60min is obtained, and we take this value as a reference. Based on the above calculation results, we sorted them out and substituted them into the formula to calculate the tool's processing linear speed Vc as 21.96m/min. Now, we will sort out the above calculation results and use the formula (N=(1000Vc)/(πD)) to calculate the spindle speed. The diameter of the machined annular groove of the part is φ88mm, and the calculation result is 79.47 r/min. Considering the characteristics of the processing equipment and fixtures, after practical verification, the final spindle speed is set to 80 r/min.

(4) Calculation of Process 3.3 Duration

By referring to the parameter content proposed in the reference "Practical Machining Process Manual", we calculated that the value of y+ is 7mm. Based on this result, we can calculate that the value of L_total is 88×1 + 7 = 95mm.

5. Conclusion

This paper comprehensively introduces the key steps of the entire machining process, from part analysis to fixture design, providing engineers and production personnel with a valuable reference book. This paper conducts in-depth research on the function and processability of the part. This step provides important background knowledge for the subsequent process planning and fixture design, ensuring the scientificity and feasibility of the machining scheme. Understanding the characteristics of the part helps to accurately determine the selection of the blank, laying a solid foundation for the entire machining process. At the same time, it discusses in detail the selection of the blank, the determination of the blank size tolerance and machining allowance, and provides the drawing of the blank diagram. Determining the cutting parameters and basic time is to ensure the accuracy and efficiency of the machining process.

Finally, the paper concludes with fixture design, emphasizing the importance of fixtures in the entire machining process. By introducing the composition and function of fixtures as well as the scheme design of special fixtures, including positioning planning, clamping structure, and specific part design, the paper provides engineers with guiding principles on how to ensure the fixing and guiding of parts during the machining process. For engineers, designers, and production personnel, this is a valuable reference material that helps improve the efficiency and accuracy of end cover machining.

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