Optimization of Machining Craft of Engine Block Based on Numerical Control Process Technology

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Abstract: This paper introduces the general and numerical control machining technology of the important surface of the engine block, and focuses on the relevant methods and measures to ensure the quality of high-speed milling and boring. Some methods and measures of optimization based on NC machining technology are proposed. The application of optimization in engine block machining cases is briefly listed. To ensure the quality of the engine block, improve its efficiency, and reduce its cost, opinions and suggestions that can be used for reference are provided.

1. Introduction
The engine is the heart of engineering machinery and equipment. It bears the important task of providing motion and power for the normal work of the equipment. The engine block is a key part of the engine. The quality of its processing directly affects the performance of the equipment. How to improve the quality of engine block and reduce its cost has become urgent problems. Numerical control machine has the characteristics of high precision, fast speed, high efficiency, and easy control of accuracy. Combined with the advantages of CAM software, sophisticated testing equipment is used to serve the of engine block, while increasing the supervision of the manufacturing. It is beneficial to the requirements of the engine block. Equipment, tools, and software are necessary for ensuring the requirements of parts. Technology is the soul of the manufacturing and the core of requirements. Different engine blocks have different structures and techniques. Only by combining the specific conditions and requirements with corresponding optimization can better guarantee its requirements, improve efficiency and reduce costs.
2. Engine block structure and common machining method for important surfaces

Figure 1 Engine block structure

The common engine block structure is shown in Figure 1. The shape of the engine block is complex, and the thickness of the block is not uniform with low hardness. There are more ribs and cooling channels inside with many holes on the plane. The main machining surfaces of the block are planes and holes. The important machining surfaces are the main bearing and piston holes, camshaft holes, mounting surfaces, block and head joint surfaces, etc. The hole size accuracy can reach IT6 and the surface roughness can be up to Ra0.4. The roundness and cylinder of the hole, the flatness of the plane, the perpendicularity, and the parallelism also require higher form and position tolerances, and the clamping of the cylinder block is difficult, which brings greater difficulties to guarantee the requirements of the block.

Important planes are generally processed by rough milling → fine milling → grinding to achieve dimensional accuracy and surface quality. The cylinder bore adopts rough boring → semi-fine boring → fine boring → honing, and the main bearing hole adopts the method of semi-fine boring → fine boring → honing to ensure its dimensional accuracy, surface quality and hole pitch accuracy. The dimensional accuracy processed needs to be manually adjusted to ensure that the position and size compensated by mechanical micro-compensation devices. The efficiency is low, and the accuracy is difficult to guarantee with high defective rate. Shape and position tolerances are guaranteed by fixture or corresponding measures.

3. Numerical control machining technology of engine block

The accuracy of numerical control machining tools can generally reach 0.005 ~ 0.01mm with stable quality and reliable and highly flexible. The unidirectional positioning accuracy is 0.02mm and the repeatable is at least 0.008mm. Therefore, the numerical control machining is basically used. The cutting speed of high-speed can be 5-10 times faster than ordinary machining. It has the characteristics of high machining efficiency, reduced cutting force, small thermal change of the workpiece, small machining vibration, and the ability to process various difficult-to-machine materials with precision and surface quality. The main CNC machining of the engine block adopts high-speed milling and boring process.

3.1. High speed milling CNC machining

High-speed milling has high requirements on cutting speed and feed velocity. The spindle speed of the machine tool should be at least 10000 ~ 30000r / min, and the feed velocity should be at least 2 ~ 25m / min, and the high speed can reach 60 ~ 80m / min. The milling width should be determined in conjunction with the feed amount \( f_z \) per gear. When \( f_z \) is smaller, a larger \( \alpha_e \) can be selected, otherwise generally \( \alpha_e \) is smaller. The milling depth \( \alpha_p \) is determined by factors such as the tool diameter D, the length-to-diameter ratio \( L / D \), and the hardness of the material. It is generally taken as \( \alpha_p \leq 0.05D \). It is advantageous to choose a \( \alpha_p \) than a larger \( \alpha_e \). The use of small cutting depth, high
cutting and large feed can effectively reduce the cutting force that the cylinder body bears. And it can reduce the heat brought by cutting, which can greatly improve the processing efficiency, and reduce the thermal deformation and others caused by the force. The impact of accuracy requires the machine tool to have a high speed and high feed velocity with good dynamic balance performance. The current spindle speed of CNC milling machines / machining centers is generally 8000r / min, and the high speed can reach 100,000r / min. Therefore, the use of CNC milling can fully meet the conditions of high-speed milling.

When high-speed CNC milling is used to process the cylinder surface, the process system must have good rigidity to avoid vibration and motion interference. The workpiece must be clamped firmly and stable, the overhang of the tool must be as short as possible, and the cutting must be continuous. When milling the cylinder surface at high speed, the machining allowance must be uniform, while avoiding shock and vibration. The high-speed milling will cause the vibration of CNC machine tools, which will easily increase the cutting error of the boring tool. It is necessary to control the range of equipment vibration, so that this process is better used[1].

The use of high-speed CNC milling can greatly reduce the stress and heat deformation of the workpiece, and can well ensure the flatness requirements of the plane. The dimensional accuracy can be effectively controlled by program preparation and tool radius and tool length compensation, and the guarantee of dimensional accuracy is more convenient and fast.

3.2. High-speed CNC boring process

The important holes on the engine block are usually precisely bored to improve the dimensional accuracy, reduce the surface roughness and correct the inclination of the axis of the holes. The holes on the engine cylinder block have small length diameter ratio and large length diameter ratio. It is bored on one side to meet the requirements, while the holes with large length diameter ratio or far distance on the same axis are bored by turning head. At present, the technology of turning and boring is one of the most common ways to use high-speed boring technology for engine block with a developing trend in the future[2]. Turning boring can effectively shorten the length of boring bar, increase its rigidity, avoid the boring bar too long and take special technological means to increase rigidity, reduce the manufacturing difficulty and cost of boring bar, small processing activity area and more safety. Workpiece rotation is achieved by the fixture, which requires high precision in the manufacture of the fixture. It will increase the structural difficulty and manufacturing cost of the fixture. The rotation of the worktable is achieved, and the indexing accuracy of the worktable directly affects the coaxiality of the hole.

Using a machining center with a rotary table or a CNC machine has high indexing and positioning accuracy. It can also be compensated by the error compensation function of the CNC system, which can well guarantee the coaxiality requirements and operate easily. The boring bar cantilever can avoid the influence of insufficient rigidity of the boring bar on the cylindricity error and improve the cutting speed with short elongation and good rigidity. It is beneficial to improve the dimensional accuracy and reduce the surface roughness value, and promote the cutting efficiency. In terms of advantages, the dimensional accuracy of the hole can be controlled by programming. It can be compensated by the tool radius compensation function of the CNC system, which can effectively control the machining dimensional error of the machined hole, avoid human factors adjustment and control to affect the machining efficiency and dimensional accuracy.

4. Optimization of machining craft based on numerical control machining technology

Many factors need to be considered for optimization. By optimizing the process, not only can it effectively guarantee the quality of parts, improve production efficiency, reduce processing costs, but save energy and reduce emissions[3]. Therefore, more enterprises pay attention to the process optimization problem[4]. Different enterprises have different situations and optimization.
4.1. Optimization of engine cylinder block processing route

Engine cylinder body has many machining surfaces and contents on each surface. When the process route is designed, CNC milling machine / center / multi-axis CNC machine is used as the processing equipment. The process should make full use of the advantages of CNC machining equipment and follow. The principle of concentration and plane first, then hole, rough first then exquisite, master first, then second, benchmark first, and uniform balance, etc., can arrange the procedures, and complete as many surfaces as possible in one clamping.

The process of engine cylinder body is changed as follows: datum plane→main plane rough→main plane semi-finishing→secondary surface→main hole semi-finishing→main surface high-speed finishing→important hole high-speed finishing. High-speed cutting on important surfaces is arranged after high-speed cutting. This arrangement can ensure the important surface machining allowance is uniform and create conditions for high-speed cutting. The hole adopts the boring process of turning, which can ensure the precision machining and surface quality of the block. The precision machining of important surfaces uses CNC machine with high accuracy and speed. Once clamping is completed, it is beneficial to ensure the shape and position tolerance requirements of the cylinder body. The rest can be completed by general CNC machine/ machining centers, which can greatly reduce the number of processing equipment.

4.2. Optimization of engine block machining program and cutting path

The processing methods are compiled by manual and automatic programming. The starting cylinder has a complex structure and a large amount of processing. Manual editing is a large workload, and the probability of manual calculation of node errors is high. Generally, it is rarely used. CAM manufacturing software is widely used in enterprises for automatic programming, through which 3d modeling is used to define the machining blank, the tool and determine the movement mode of the tool, input the machining parameters, develop the machining surface, generate the tool path, and automatically generate the NC machining program after the post-processing[5]. The machining process can also be simulated by CAM, and the cutter path that affects the machining efficiency and interference can be optimized by combining the generated tool path, and the reasonable cutter path can be obtained by the first trial cutting.

4.3. Optimization of engine cylinder processing parameters

Processing parameters directly affect the quality, efficiency and cost of parts. Key technology is the core of the enterprise, no matter what theoretical method is optimized. It finally must be proven by practice, so it is the most direct way to practice verification. According to the existing technical conditions, the NC machining parameters are suitable for enterprises with the lowest cost, and the highest efficiency can guarantee the requirements. Then input the corresponding parameters in the CAM software, which can be applied to the actual manufacturing.

4.4. Optimization of the quality assurance system of engine block machining

Product quality is the life of the enterprise, and quality control is an important part of the processing. To strengthen the supervision of engine cylinder, processing quality is also an important measure to optimize. In terms of quality inspection, a combination of ordinary inspection and precision instrument inspection is adopted. The commonly required surfaces are ordinary inspection methods. Important dimensional accuracy, flatness, perpendicularity, coaxiality, roundness, cylindricality, position, etc. Adopting a three-coordinate measuring instrument for on-line and off-line inspection can timely grasp the quality information, and provide improvement directions for further optimization of the technology[6]. In terms of quality control, the comprehensive promotion and implementation of the ISO9001 standard will be throughout the whole process of cylinder processing, including safe and civilized production and processing parameters of the implementation of testing means and methods. As long as every link of cylinder processing is supervised, it can ensure the quality of high cylinder processing.
4.5. Application examples

Figure 2 Schematic diagram of cylinder block processing of an engine

Figure 2 is a schematic diagram of machining a cylinder bore of an engine. After three-dimensional modeling by CAM software, the tool path is generated, and the processing program is generated by post-processing. Then the software is used to simulate to optimize the tool path. It is finally determined that the boring tool feeds 3.5mm downward during semi-fine boring, and the cutting position of the semi-fine boring tool is 180 ° at the workpiece plane, and the non-cutting position of the fine boring tool is 30 °. During fine boring, the boring tool feeds 3.5mm upwards. The non-cutting position of the semi-fine boring tool is at 0 °, and the non-cutting position of the fine boring tool is -150 °.

In terms of machining accuracy, after the length and radius are accurately determined on the counter outside the machine, input the length and radius in the offset setting interface of the numerical control system. After the first piece is cut and processed the quality inspection, the size compensation enter the length and radius compensation values of the tool in the offset setting interface. Then the processing parameters are optimized according to the machining accuracy, surface quality and machining efficiency, and the optimized parameters are re-entered in the parameters setting interface of CAM software. By strengthening the quality control of the machining accuracy of the cylinder block, the processing technology can play its due role, and the cylinder block is more in line with the requirements[7].

5. Conclusion
The CNC machine tool is used to process the engine block by adopting reasonable technology and using automatic programming software. The CNC system is used for error compensation. The external tool setting instrument is used to measure the length and radius of the tool. While increasing the monitoring of the entire engine block processing, on-line and off-line testing makes the guarantee of engine block quality more simple, convenient and reliable with stable quality.

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