Application of CNC Boring Machine in Connecting rod Screw Hole Machining

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Abstract This paper expounds the shortcomings of the traditional drilling, expanding and reaming processing processing methods of connecting rod screw holes, and proposes a new technology for processing connecting rod screw holes using a special CNC boring machine. Then, this paper introduces the process method of CNC boring machine processing connecting rod screw hole and the design of tooling fixture, and through the example of programming and processing, it’s proved that the new technology greatly improves the quality of screw hole. While reducing the labor intensity of workers and improving the production efficiency, it also creates good economic and social benefits.

1. Introduction
Connecting rod is one of the four major parts in the engine. There are four very important holes on the connecting rod, big and small head holes, and two bolt holes. The connecting rod big-end hole is assembled by connecting rod body and connecting rod cover through connecting rod Bolt, which is used to connect the crankshaft of the engine. The small head hole is used to connect the piston pin to transmit the expansion gas pressure acting on the top of the piston to the crankshaft, so that the reciprocating linear motion of the piston is converted into the rotary motion of the crankshaft to output power. The two bolt holes are through holes through which combine the connecting rod body and the connecting rod cover with bolts. In the engine work, the connecting rod bears the action of alternating stress, therefore the connecting rod should not only have the sufficient strength and the rigidity, but also should guarantee the big head hole not to lose the circle. This requests the connecting rod bolt to have the certain strength and the correct installation position. The connecting rod bolt can only bear tensile stress when working. If the installation position, that is, the verticality of the bolt axis with the connecting rod body and cover joint surface is out of tolerance, it will cause the connecting rod Bolt to bear additional bending load, and the point contact will occur at the connection, stress concentration will connection, and fatigue fracture will occur in severe case. If the dimensional accuracy of bolt locating hole is out of tolerance, the connecting rod body and connecting rod cover may mismove along the joint surface and make the big head hole out of roundness. Therefore, it is necessary to ensure the dimensional accuracy of the screw hole and the tolerance of 0.04 verticality between the screw hole and the connecting rod and cover, as shown in figures 1 and 2.
2. Problems existing in drilling and reaming connecting rod screw hole

The connecting rod is divided into connecting rod Body and connecting rod cover for easy installation. The connecting rod Body and cover are assembled into connecting rod big head hole by bolt or screw combination, the combination of the connecting rod is composed of two parts: Positioning and connecting. At present, the commonly used positioning methods are positioning sleeve, connecting rod Bolt, connecting rod screw, tongue groove, anti-skid teeth and stop, etc. We discuss the use of a bolt or screw for orientation, where the bolt or screw serves both orientation and connection. The connecting rod bolts or screws are standard parts, so the machining quality of the connecting rod body and the locating holes on the connecting rod cover will affect the stress state of the bolts or screws. Therefore, the connecting rod positioning hole of the size accuracy, position, the hole axis and the vertical degree of the joint surface have higher requirements.

The traditional bolt hole processing technology adopts drilling, expanding and reaming. This process has been used for a long time and has accumulated rich experience in machining. However, due to the characteristics of the process, the quality is always unstable, and it has not been able to meet the high quality requirements of modern internal combustion engines.

2.1. Errors due to non-uniform positioning reference

In mechanical processing, we require the unification of process datum, design datum and measurement datum (three datum for short). But it can not be completely unified under special circumstances, which will result in the instability of quality. When machining the screw hole of the connecting rod body and connecting rod cover, the big end face of the connecting rod is generally used as the first positioning datum, and the small end hole (connecting rod cover: the bottom of the ear) is used as the second positioning datum, the lateral wall of the bolt hole is used as the third positioning datum. As shown in Figure 3 and Figure 4. In this way, the axis of the screw hole does not coincide with the three datum of the verticality of the joint surface, and the error of the datum does not coincide. There are two reasons: First, the connecting rod body, the cover of the end and the body, cover interface into the verticality error. Second, the outer dimension of connecting rod Body and cover has machining error, and under the action of positioning datum 3, the verticality error between the axis of screw hole and the joint surface is produced.
2.2. errors due to machining methods

In general, drilling, expanding and reaming are processed on ordinary drilling machines. The equipment accuracy is not enough, the drill sleeve is worn, the connecting rod hardness is not uniform, the sharp degree of each cutting edge of the drill bit is different and the technical level of the operator is different, etc., although the error is corrected by reaming and reaming. It is difficult to meet the requirements of the drawing stably, especially the verticality between the axis of the screw hole and the joint surface cannot be guaranteed, which affects the whole quality of the connecting rod, serious impact with the host plant supporting.

3. Application of numerical control boring machine

In order to improve the machining quality of the connecting rod screw hole and guarantee the matching with the main machine factory, the NC Boring Machine C26027 is specially designed for machining the screw hole. The main technical parameters of CNC BORING MACHINE: Double Boring head, two coordinate CNC system, processing aperture in 8 ~ 20mm, spindle speed 1000r/min, worktable maximum stroke 200mm, main motor power (double motor)2.2 kw, hydraulic motor power 1.5 kw, static motor power 1.5 kw, static pressure rated oil supply flow 10L/min, rated oil supply pressure 6.3 MPa. The bearing of boring head is hydrostatic bearing, the front bearing is radial and axial bearing, the restrictor is distributed, and the rear bearing is radial bearing. The numerical control system adopts GTC2B numerical control system. The rigidity of NC boring machine is good, the machining precision and the machining surface quality are high. It can meet the high precision machining requirement of general screw hole.

3.1. process improvement

The original drilling, expanding and reaming technology is changed into drilling, expanding and boring technology. Taking the processing of screw hole of connecting rod body and cover of 491Q gasoline engine as an example, the original processing technology is drilling φ8 through holes, reaming φ8.8 through holes and reaming φ9.2H7. The present technology is to change the reaming hole to boring hole φ9.2H7. Still retained the original drilling, expanding process, mainly through the hole expansion to correct the verticality error, while reducing the boring process of cutting. Because the technological rigidity of the boring system is relatively large, the form and position error of the screw hole formed after drilling and reaming can be effectively corrected by boring, and the size error can be controlled between φ9.2(0 ~ + 0.015), the verticality error between the axis of the screw hole and the joint surface is controlled within the tolerance of φ0.04, and the position error is controlled within the tolerance of 0.10. To ensure accuracy, the design of the boring bar is critical, as shown in Figure 5. Because it is a small boring bar, the boring bar diameter is relatively small, the boring bar must have enough strength and rigidity, otherwise the quality is difficult to guarantee, what is used here is a
diameter of φ6.45#, tempering hardness of HRC28 ~ 30, the boring bar must also have a certain toughness, the hardness can not be too high, otherwise in the stress prone to brittle fracture. The cutter is mounted in a longitudinal hole in the front end and is pressed from the front end with M3 screws.

3.2 harmonization of benchmarks
In the new technology, the positioning datum of connecting rod body and connecting rod cover is the same as in the original technology when drilling and expanding a screw hole. The main problem is that the drilling force is larger, and the clamping force when the end face is used as the datum is larger, so the base is the same when reaming.

In order to ensure the unity of the three datum, the joint surface is used as the first datum, the initial drilling and expanded screw hole is used as the auxiliary datum, which is used to fix the positioning of the movable Datum 2. Then the end face of the connecting rod body and cover is pressed with a press block, the cone auxiliary positioning pile is removed so that the process reference, design reference and measurement reference are completely unified. It can effectively correct the deviation of datum and the error of form and position caused by initial drilling and reaming, so as to ensure the quality of products. The positioning reference for the boring hole is shown in Figure 6 and Figure 7.

3.3. reduction of Labor intensity and improvement of production efficiency
The customized CNC boring machine for the double-head, the worktable can be horizontal and vertical two directions feed, horizontal driven by the screw rod, Vertical Ball Screw rod, are driven by stepping motor. The motion of the worktable is controlled by the program, and the repeating precision is high. A set of connecting rod body and cover screw hole can be finished by one time clamping. The operator only needs to clamp the connecting rod, unlike drilling, expanding, and reaming, which requires the operator to exert force, reducing the labor intensity.

Firstly, the connecting rod body and the connecting rod cover are positioned by screw hole positioning piles. Make the joint surface of the connecting rod body and the cover close to the joint surface positioning block 5, tighten the positioning screw of the side positioning device 6, and press it tightly by pressing the V-shaped block 9. Secondly, press the end face of the connecting rod body and
cover with the pressing block (not shown in the figure), then remove the screw hole cone positioning pile to complete the clamping of the workpiece. The schematic diagram of connecting rod mounting is shown in Figure 6. When processing, the worktable moves the tool setting and feeds, and the connecting rod body and the upper pair of screw holes on the cover are first processed. After finishing the processing, the worktable retreats, moves the two screw holes 62mm to a certain distance from the worktable longitudinally, the worktable transversely feeds, processes separately the connecting rod body and the cover under a pair of screw holes, after finishing the worktable retreats. Namely completes a set of connecting rod body, the cover screw hole processing. Then the next set of connecting rods is clamped and the next cycle begins.

1—Boring head;  2—Fixed Plate for locating pile;  3—Cone positioning pile with spiral hole (auxiliary positioning, removed during machining);  4—Positioning Plate;  5—Joint Locating Block;  6—Side positioning device;  7—Connecting rod Body;  8—Connecting rod cover;  9—Press the V-block;  10—Working Table;  11—Hydraulic clamping device

Figure 8 Boring Operation Diagram

4. Programming examples
This processing procedure is based on the 491Q gasoline engine connecting rod design, the preparation procedure is as follows:

N0000  G92  X-31  Z120  :  Cutter origin coordinates X-31, Z120
N0010  M03  M08  :  The main shaft is turning. Open the coolant
N0020  G00  U31  W-90  :  Boring head close to positioning plate
N0030  W-30  :  The boring head approaches the workpiece
N0040  G01  W-30  F100  :  Boring the first set of screw holes
N0050  G00  W60  :  The boring head quickly exits out of the locating plate
N0060  U-62  :  The worktable moves up the center distance of the two screw holes to the position of the next screw hole

N0070  G00  W-30  :  The boring head approaches the workpiece
N0080  G01  W-30  F100  :  Boring the second set of screw holes
N0090  G00  W60  :  The boring head quickly exits out of the locating plate
N0100  G00  X-31  Z120  :  The tool quickly returns to the starting point X-31, Z120
N0110  M09  M02  :  Coolant off. End of sequence

The Road Map of the table movement is as follows:
5. Conclusion
The CNC boring machine is suitable for machining connecting rod with bolt, screw or bushing. The machining precision of the locating hole is high and the tolerance of shape and position can meet the requirements, it improves the production efficiency, reduces the Labor intensity of the operator, improves the matching rate with the main engine factory, and produces good social and economic benefits.

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