RESEARCH ON CORE TECHNICAL TRANSFORMATION OF CRANKSHAFT PRODUCTION LINE FOR MARINE INTERNAL COMBUSTION ENGINE

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Abstract. The traditional crankshaft production and processing technology has a low machining accuracy and a low process quality, so it is difficult to guarantee the product quality. In order to improve the quality and accuracy of crankshaft machining, the key process technology and equipment used in the production line have been improved according to the product structure characteristic of crankshaft and the technological process of production line design. Through research, the quality of the product is improved, and the effect of downsizing and efficiency is preliminarily achieved.

Keywords: internal combustion engine crankshaft; production line scheme; process route; key technology and equipment.

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Problem statement. Crankshaft is the key part of internal combustion engine to withstand the transmission power of impact load. It is the most difficult part to guarantee the processing quality in the five large units of the engine (cylinder block, cylinder head, crankshaft, connecting rod, and camshaft). At present, most of the internal combustion engine crankshaft production in China still uses the traditional technology introduced in 1980s, and the process is mostly rough finishing – semi-finishing – finishing. Rough machining adopts copying machine tools or multi-turning machine tools to process spindle neck, connecting rod neck and sector excircle. Semi-finishing and finishing are done by a crankshaft grinding machine, via rough grinding – semi-fine grinding – fine grinding, and then polishing. From the rough process to the finishing process, the crankshaft needs to be clamped and prepared several times, causing the workpiece to be knocked several times, resulting in poor reproducibility and poor process quality. Most of the equipment in the production line is usually hand-operated, thus depending on the experience of the workers with the possibility of random errors and unstable quality.

The traditional crankshaft production line is mainly composed of multiple ordinary machine tools and special machine tools processing complete crankshafts. It requires nearly 30 sets of equipment and personnel of about 30 people. Extensive production model wastes a lot of labor, material and equipment resources, thus, the business costs are not covered, and the benefits do not increase. The situation with the passive high-pressure market competition has not changed for a long time.

Basic material

1. Product structure characteristics and technical requirements

The crankshaft of the internal combustion engine is a single crank. The hardness of the spheroidal graphite cast iron is controlled

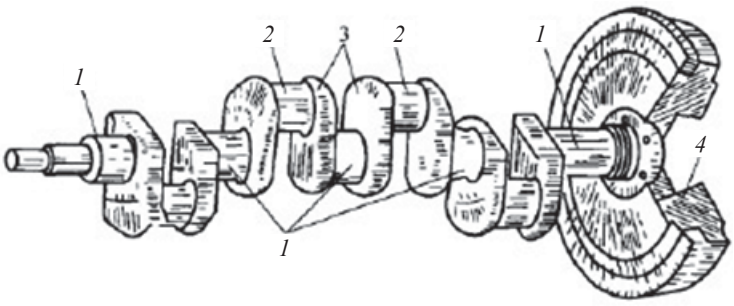

Fig. 1. Crankshaft structure:
1 — spindle neck; *2* — connecting rod journal; *3* — crankshaft arm; *4* — flywheel

in the range of 35-45 HRC; after being treated by austempering, the hardness difference in the same crankshaft is lower than or equal to 5 HRC. Surface roughness of critical parts is Ra 0.63, the radial dimension accuracy is 6, and the axial dimension accuracy is 8. The axial dimension of the crankshaft contains a chain of multiple dimensions, and the dimensional tolerances of the spindle shaft shoulder neck connecting shaft shoulder opening spacing, spacing, crankpin, and spindle neck spacing cannot be solved directly. The gross error, center hole error, shoulder error, feed error and process system error all affect the machining accuracy of crankshaft.

2. Determination of the production line scheme

To make full use of the site with minimal adjustments, according to the status of the site layout, the crankshaft production line layout equipment is brought in accordance with the pipeline. The workpiece is transported by overhead raceway, and the flow direction of parts reflects linearity. No crane is required for conveying parts between the processes, so as to save time and effort and avoid bruising. The distance between the operator and the working equipment is short, and operation of the upper and lower parts is simple, convenient and quick. At the same time, it is convenient to clean or cut the cutting fluid of the grinding machine. In the process of relatively large time quota, special station tools are designed to increase the reserve of parts. The distance between the machine tool, the wall and the operating space shall be formulated according to the standards stipulated by the state. The machine tool is arranged to comply with safety standards.

3. Development of a new crankshaft production process

The traditional production process of crankshaft has the following stages: blank casting or forging – heat treatment – end milling – center hole – rough machining of the long and short journal – rough machining of the joystick journal – fine machining of the long and short journal – fine machining of the connecting rod journal – drilling of the connecting rod journal lubrication hole – coarse grinding of the long and short journal – coarse grinding of the rod journal – milling of two keyways – fine grinding of the long and short journal – fine grinding of the connecting rod journal – drilling and hinging of bottom pin hole – nitriding – polishing, testing – cleaning, inspection and storage.

In this way, the machining accuracy is low. The crankshaft is clamped and operated many times, resulting in low quality and stability of the working procedure of the crankshaft, and it is difficult to guarantee a moderate machining allowance. The newly upgraded automatic production line is integrated with the crankshaft, rough and fine spindle neck. For example, the turning of the crank spindle neck and the short head, from the original two sets of ordinary machine tools (previously simple NC transformation) have merged in a CNC automatic lathe bed machining. The original K on the surface of the 2~φ10 taper pin hole, 4~M8*1.25 hole and fly cone has dispersed in many standalone processing respectively; it used to be integrated into the machining center. However, after years of practice examination, the production efficiency still does not increase, and it was decided to replace the two sets of vertical machining center with an eight-station hydraulic NC rotary table machine, a total of eight processes into one machine processing.

After the integration and transformation of the above processes, the technological route of the original crankshaft production will be changed into the following new technological route: blank casting or forging – heat treatment – end milling – center hole – rough and fine milling of the spindle neck, outer circle and short head – milling of the connecting rod neck with full NC external milling machine – coarse grinding of the spindle journal – (semi-precision grinding) – fine grinding of the connecting rod journal – machining of the deep inclined oil holes by using gun drills – milling of the K face, drilling, expansion and reaming of the 2~Φ10 cone pin hole in the eight position rotary table combination machine tool – drilling and tapping of the 4~M8*1.25 screw holes and orifice chamfering – nitriding – polishing, testing – cleaning, inspection and storage.

It is not difficult to see that in the new technology route compared with the original one, the number of equipment pieces has reduced by 30%, of the operators — by 25%. The automation level of the production line occupies the leading position in China.

4. Application of key process technology and equipment

4.1. The use of a fully automatic inclined bed CNC machine and a matching fixture

Crankshaft spindle length and its outer round are roughed; the original distribution is finished with two

general cars (already pre-CNC transformation), with the processing cylinder grinding allowance of 0.5 ~ 0.8mm. The thrust cone surface balance is generally retained at 0.3 ~ 0.4 mm; in order to guarantee the quality, only multiple grinding methods can be adopted, otherwise, the quality will be unstable and the efficiency will be low. Crankshaft spindle neck, long head and its outer roughing and finishing is one of the most advanced crankshaft machining processes, but the machining quality has been a serious issue.

This production line adopts a CNC machine with a fully automatic inclined bed and 630 specifications of machine tools. A 30° inclined lathe bed is equipped with a special turning tool for fixing the front and rear of the connecting rod neck, and two groups of tool holders are arranged on the two-way moving hydraulic slide table. The 1+1 double knife is employed before and after the simultaneous cutting method, and a full liquid elastic center clamp is used as well.

4.2. The use of an eight position hydraulic CNC rotary table combined machine tool

In the original K surface, the 2~φ10 taper pin hole, 4~M8*1.25 screw holes and a fly hammer hole were scattered in many single machine processing operations. Later, the seven processes were integrated into two vertical machining centers operated by one person. It has contributed to downsizing and increasing efficiency, but through the practice of several months, because the production section of 1.3 minutes cannot meet class production requirements of 500 pieces. Although the machining center has a high degree of automation, it still belongs to single tool cutting, and the crankshaft belongs to mass production. If the machining center has been working in a state of fatigue, the accuracy will be lost. Therefore, the production line uses an eight position fully liquefied CNC rotary table machine tool which integrates the eight processes of 2~φ10 taper pin hole, 4~M8*1.25 screw hole and a fly hammer hole.

4.3. The research and equipment for developing the crankshaft main journal, connecting rod neck, grinding process

At the crankshaft manufacturing enterprises, grinding of the spindle journal and the connecting rod neck of the crankshaft, heavy workload and unstable supply of the process have always been a difficult problem for enterprise development. At present, advanced crankshaft machining enterprises in China and abroad widely use the ST10-M and ST1-R CNC grinding machines produced by the VERECO company (Italy). The former is mainly a journal mill, and the latter is the connecting rod journal grinder. After a new grinding, the width of the grinding wheel is repaired to the width of the opening of the journal. During the grinding process in the future, only the outer circle grinding wheel is subject to correction on both sides of the fillet, the width is no longer fixed; in each journal grinding cycle, and the grinding wheel is only radially cut in and out. In addition to manual cutting, the machine is fully automated, including processing, measuring, grinding wheel correction and so on. It is controlled by CNC, and the SIEMENS 810l NC software is used for process control, size control, automatic positioning, clamping, indexing, trimming and so on. The automatic measuring device Mapos is used to measure the axial and radial dimensions during the processing, and the feedback information is automatically adjusted and compensated by centering grinding. Not only the axial dimension tolerance is ensured, but also the grinding quantity of the two sides is basically uniform. The grinding wheel can achieve a constant linear speed grinding. In each grinding cycle, the grinding wheel feed speed and the feed quantity are divided into stages, and the coarse grinding is completed at one time. The diamond grinding wheel is used to correct the grinding wheel and compensate automatically to correct the size. For such high-end configuration of CNC machine tools, research and development are difficult, and the project will be designated as a follow-up for development planning. At present, the key research problem is to produce 6 sets of fully hydraulic automatic fixtures on the existing CNC grinding machine. First, the quality of crankshaft grinding process will be stabilized gradually, then automatic grinding wheel balance will be provided, as will be the automatic tracking center, automatic measurement and other advanced devices; then the function of grinding wheel automatic correction will be realized.

Fig. 2. CNC full automatic inclined bed machine tool

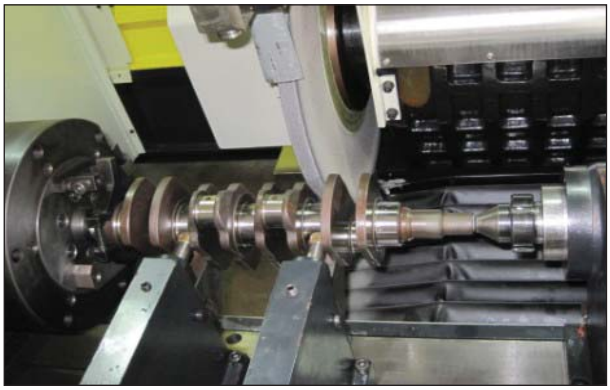

Fig. 3. Eight-station full hydraulic CNC rotary table combined machine

Fig. 4. Computer-controlled crankshaft gas soft nitriding

4.4. Crankshaft quenching equipment

A crankshaft quenching machine is mainly used for quenching of the crank shaft journal, connecting rod journal and thrust shoulder by means of rotation quenching method, uniform heating, uniform thickness of hardened layer, with application of CNC control. In addition to the upper and lower shaft, the rest are controlled automatically. CRT shows whether the axle neck has been quenched, which can meet the requirements of crankshaft heat treatment process and performance requirements. The process of self-heating by induction heating and liquid spraying cooling is adopted, and the inductor is not replaced during the whole process.

4.5. Axis neck polishing equipment

The crankshaft spindle neck, connecting rod journal, fillet, thrust surface and oil seal shaft neck are polished to improve the surface roughness and, consequently, the service life of the crankshaft. The production line adopts the Q/CGZJQOS-1400 grinding wheel polishing machine developed by Changchun 55 Research Institute of the former Ordnance Industry Department. The belt uses the Light Bujilin resin adhesive, corundum abrasive, and abrasive grain of size 320.

4.6. Computer technology control of crankshaft gas soft nitriding

At present, the commonly used soft nitriding method falls into the gas and the liquid soft nitriding methods. General enterprise production takes into account experience and test standards to control the nitriding process. Part of the surface of the nitriding layer is often subject to large fluctuations in the surface tissue, producing a large number of harmful substances and greatly reducing the service life of parts. The production lines use microcomputer control nitriding. The main designation of the process is to control the temperature and the nitrogen potential in the furnace through the sensor, as well as the nitriding process of the computer. It avoids the error of traditional manual operation, has the characteristics of energy saving, safety, product quality and easy to realize automation, greatly improving the quality and efficiency of the crankshaft surface.

4.7. Ultrasonic testing instead of magnetic particle testing

Magnetic particle testing is the use of electromagnetic phenomena on the uneven or irregular surface of the parts by means of the effective non-destructive testing methods. Magnetic particle test machine is magnetized after the appearance of magnetic marks, which indicates that the work surface has defects.

4.8. Design of the special fixture, application of advanced tools to ensure the accuracy of processing requirements

Originally in two ordinary machine tools for processing the surface of the main shaft long and short head, the clamping device used is an ordinary three jaw chuck and a dead thimble, and the spindle neck, the head axial dimension and the outer dimension of the spindle neck and the machining allowance are unstable. The production line makes use of a full hydraulic automatic centering clamp and elastic thimble to ensure reasonable processing allowance of the axial dimension and outer circle dimension of the long and short head.

Drilling deep oil holes in the past generally involved ordinary plus twist drills, and the classified feeding method was adopted. Gun drilling technology is now implemented; it increases the efficiency by more than 5 times, and the drill is not easy to break. In the past, drilling and expanding were used to process the hammer holes, whereas the U drilling technology can be applied once.

CONCLUSION. The newly reformed crankshaft production line has achieved the effect of downsizing and increasing efficiency through the organic integration of the process; successful development of the advanced, and fully automatic hydraulic fixture, which not only improves the effect of related machine tools, but also reduces the labor intensity and greatly stabilizes the quality of products. The production line has the characteristics of advanced design, high adaptability, and reasonable process arrangement. At present, the production line has the capacity of 40,000 annual output to meet the requirements of preliminary design.

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