

Application of Lean Manufacturing Technology in the Processing of Automotive Engine Connecting Rods

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Abstract: The engine connecting rod is a critical component in automobiles. Applying lean manufacturing techniques during its processing and production not only innovates the machining technology route but also optimizes the processing procedures, enhancing both efficiency and quality of connecting rod manufacturing. This, in turn, improves the assembly accuracy of the connecting rod assembly and enhances engine performance. This paper provides an overview of automotive engine connecting rods and discusses the application of lean manufacturing technologies in their processing, aiming to further improve the manufacturing standards of engine connecting rods and ensure vehicle driving safety.

Keywords: automobile, engine, connecting rod machining, lean manufacturing technology

1 Introduction

Lean manufacturing technology plays a significant role in improving processing quality and efficiency, and its application in the automotive industry contributes to industrial advancement. As people's living standards continue to rise, demand for automobiles is increasing. Since engine connecting rods are critical components of vehicles, their processing quality significantly impacts driving safety. To enhance the processing quality of engine connecting rods, shorten production cycles, and reduce manufacturing costs, automotive companies must focus on introducing and applying lean manufacturing techniques. Currently, lean manufacturing technology holds substantial potential for application and development in China. Automotive manufacturers should pay close attention to this trend, strengthen research into the technology, and ensure high-quality implementation in the machining of engine connecting rods [1].

2 Overview of Automotive Engine Connecting Rods

2.1 Automotive Engine Connecting Rod Structure

The connecting rod of an automobile engine mainly consists of the big-end and small-end holes, their respective end faces, the mating surfaces between the connecting rod body and the cap, and the positioning holes for the connecting rod bolts. The machining operations include the $\phi 65.5H6$ mm big-end hole and the $\phi 29.49$ mm small-end hole. The center distance between the two holes is (190 ± 0.05) mm. For the connecting rod component, the primary machining specifications are as follows: the $\phi 65.5H6$ mm big-end hole has a tolerance grade of IT6, with a surface roughness R_a not exceeding $0.4 \mu\text{m}$; the cylindricity tolerance for the $\phi 29.49$ mm small-end hole is 0.012 mm, corresponding to a tolerance grade of IT8, and its surface roughness R_a should be less than $3.2 \mu\text{m}$. After assembly, measurements revealed that the dimensional accuracy of the connecting rod meets design and process requirements. The dimensional accuracy of both the bushing press-fitted into the big-end hole and the upper end face of the small-end hole satisfies service requirements. Along the axis direction of the connecting rod, the parallelism tolerance between the two hole axes over a 100 mm length is 0.04 mm; the coaxiality between the top plane of the small-end hole and the end face of the big-end hole must meet the precision criteria specified in the technical conditions.

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Perpendicular to the connecting rod's central axis, the parallelism tolerance between the upper end faces of the big-end and small-end holes over a 100 mm length is 0.06 mm. The fillet radii satisfy the concentricity accuracy requirements during assembly for both the big-end and small-end holes. The center-to-center distance requirement between the two holes is relatively high, standardized at (190 ± 0.05) mm. To ensure product machining quality and improve production efficiency, inspections were conducted on the fillet radii of the shoulder regions of the two holes and the surface finish of the end faces. Additionally, only flatness of the connecting rod is required, with a tolerance of 0.025 mm [2].

2.2 Connecting Rod Structure Machining Method

The big-end bore must fit closely with the bearing shell and crankshaft, while the small-end bore must mate precisely with the piston pin. This close fit helps reduce the adverse effects of impact and facilitates heat transfer, thus requiring higher precision. Therefore, a machining sequence of reaming—rough boring—semi-precision boring—precision boring—diamond boring— honing should be adopted. For the small-end bore, the recommended process is drilling—reaming —reaming—precision boring—pressing in the bushing followed by another precision boring. Since both end faces of the big-end bore have high machining requirements, the same sequence—drilling—reaming—reaming—precision boring—pressing in the bushing followed by final precision boring —is applied. As for other secondary surfaces and side faces, they may be scheduled during or toward the end of the manufacturing process.

2.3 Connecting Rod Force Analysis

Under the influence of gas pressure, the axial force on the top of the automotive piston is transformed through the engine's piston-connecting rod mechanism. Affected by this mechanism, the axial force is converted into mechanical energy for crankshaft rotation. Meanwhile, under piston pressure, the connecting rod assembly undergoes motion, and combined with reciprocating inertial forces, this may lead to failure issues and eventually fatigue fracture. Therefore, when selecting connecting rods, preference should be given to those with low mass, high fatigue strength, and high rigidity. In automotive engines, bolts are used to connect the connecting rod and its cap, forming a single unit. From a stress perspective, the load on the connecting rod is significantly influenced by the position of the engine piston: when the piston is not at the midpoint, the connecting rod operates at a slower speed; when the piston reaches the midpoint, the connecting rod's operating speed gradually increases. Consequently, during the piston's repetitive up-and-down motion, the resulting inertial forces may adversely affect the connecting rod. When the piston-connecting rod assembly moves in synchrony with the piston, operators must monitor the stress conditions on the connecting rod and promptly replace it if damage is detected to prevent disruption of engine operation.

2.4 Connecting Rod Processing and Manufacturing

Metal powder and forged steel are commonly used materials in the manufacturing of automotive engine connecting rods. These two materials differ not only in processing techniques but also in production costs and quality. Metal powder generally has a slightly lower manufacturing cost than forged steel. Moreover, compared to connecting rods made from forged steel, those produced from metal powder exhibit higher fatigue strength, lack machining defects, achieve greater precision and superior overall mechanical performance, and offer longer fatigue life. Therefore, metal powder materials offer significant economic advantages and high value, and are widely [3] used in the international automotive manufacturing industry.

Since connecting rods are fundamental components of automotive engines, their manufacturing quality and performance are critically important. With continuous advancements in technology and the economy, China has achieved significant technological innovation in automobile manufacturing, and the industry is developing positively. Particularly in the processing and manufacturing of engine connecting rods, high levels of precision manufacturing technology have been applied, resulting in superior processing hardness and product quality. Furthermore, when machining connecting rod components for automotive engines, enterprises should focus on improving the quality of rod processing, enhancing overall rod performance, and increasing the intelligence and refinement of the

manufacturing process. This approach will improve the efficiency of connecting rod production, increase the success rate of manufacturing, and reduce processing costs.

3 The Significance of Lean Manufacturing Technology in the Processing and Production of Automotive Engine Connecting Rods

The application of lean manufacturing technology in the machining and production of automotive engine connecting rods significantly improves processing quality and production efficiency. With the same production volume, increased efficiency reduces production time and lowers manufacturing costs. Currently, compared to domestic development, lean manufacturing technology is more mature abroad, particularly in Japan. In China, as automotive manufacturing technology gradually advances, automakers have increasingly focused on applying and researching lean manufacturing techniques. Through extensive experimentation and innovation, significant achievements have been made in integrating lean manufacturing into the automotive industry—especially in the machining of engine connecting rods, where innovative technological applications have yielded remarkable results. Practice has shown that applying lean manufacturing technology to the production of engine connecting rods greatly enhances the assembly accuracy of connecting rod assemblies and provides technical support for integrated machining of connecting rods and rod caps. Furthermore, it improves the precision level of connecting rod machining, thereby increasing processing efficiency and the economic benefits of automotive operations, ultimately strengthening corporate competitiveness.

4 Application of Lean Manufacturing Technology in Automotive Engine Connecting Rod Processing

4.1 Precision Manufacturing of Connecting Rod Head Hole by Honing Process

4.1.1 Traditional Honing Process

In the manufacturing process of automobiles, engine connecting rods are high-speed rotating components, thus requiring strict manufacturing standards—particularly in terms of precision for the dimensions and shapes of the big-end and small-end holes. After precision boring, workers must perform honing to ensure that the rod's shape and hole dimensions meet automotive production standards, thereby preventing quality defects. During the honing process, the honing tool enters through the big-end and small-end holes of the connecting rod and rotates within the bore to complete the grinding operation. This process is relatively slow. To improve honing effectiveness, workers may employ the double-honing technique, which, although more costly, delivers excellent results. Alternatively, single-honing can also be used; both techniques effectively maintain the dimensional accuracy and surface quality of the connecting rod. However, regardless of the method used, the grinding efficiency of the rod bore remains low, and the stability of the process is generally poor.

4.1.2 Lean Manufacturing Honing Process

The lean manufacturing honing process is a technique used in the machining of connecting rod head holes. In practice, it requires the use of honing reamers and honing stones, with the tool tip made of hydraulic blocks and the grinding strips composed of steel substrates coated with diamond. During processing, the honing reamer enters the workpiece by rotating and performs reciprocating motion. This process can be subdivided into fine honing, semi-fine honing, and rough honing operations. At the beginning of workpiece machining, guide elements are used to ensure precise positioning of the honing reamer. With support from automated measurement and compensation technologies, increasing the reciprocating speed of the honing reamer improves processing efficiency and reduces machining time. Furthermore, honing achieves results similar to reaming, but with higher efficiency. Therefore, the honing process enables one-step completion of the connecting rod head hole machining. Additionally, before the honing head enters the workpiece, the dimensions of the connecting rod's head hole already meet design specifications, and the rigidity of the honing reamer also complies with design requirements. To ensure high-quality machining of engine connecting

rods, operators must properly control both circumferential and reciprocating speeds. Moreover, the automatic measurement and mold compensation functions in connecting rod manufacturing technology not only promote innovation and development in engine connecting rod machining processes but also enhance the precision of head hole machining.

4.2 Lean Manufacturing of Connecting Rod Splitting Process

4.2.1 Swelling and Breaking Process

There are two traditional methods for processing connecting rod blanks: integral and split types. In the integral blank processing method, separating the connecting rod cap from the connecting rod requires techniques such as sawing, grinding, and broaching. To connect the rod and cap afterward, bolts are used—first machining the bolt holes, followed by precision boring of the big-end hole. This approach is relatively complicated and difficult to ensure high manufacturing accuracy. Therefore, automotive manufacturers can adopt lean manufacturing technology, specifically applying a lean manufacturing process known as "expansion-breaking" at the separation surface of engine connecting rods. This technique directly breaks the connection between the connecting rod and its cap, achieving effective separation. When joining the rod and cap, an expansion-breaking device is used to machine the groove line at the designated breaking point on the big-end hole. The device applies radial force onto the big-end hole, causing cracks to form along the groove line. Over time, these cracks gradually extend until they fully separate the rod cap from the rod, enabling clean breakage. From the perspective of connecting rod processing alone, the application of this expansion-breaking technique simplifies the manufacturing process, improves processing efficiency, and increases the success rate of rod separation.

4.2.2 Technical Specifications

Under normal circumstances, the simplification of connecting rod assemblies can be achieved with the support of relevant technologies. For example, the application of the split-forging process for connecting rod separation surfaces not only achieves the goal of simplification but also ensures the integrity of the mating surface between the connecting rod cap and the connecting rod. At the same time, it prevents damage to the connecting rod cap and rod after separation, which could otherwise affect subsequent use. Additionally, specific machinery is required when machining the separation surfaces of the connecting rod and its cap. To streamline the machining process, workers can employ a lean manufacturing split-forging technique for the connecting rod separation surfaces, thereby simplifying certain processing steps in the assembly of connecting rod components.

4.3 Connecting Rod Horizontal Double-Surface Lean Manufacturing Grinding Process

4.3.1 Comparison of New and Old Processes

Traditional vertical dual-axis surface grinding processes primarily involve combining two vertical single-axis milling machines to perform grinding operations, during which the workpiece on the disc remains in a free state. Due to the influence of the workpiece's own weight, after connecting rod machining is completed, the grinding amounts on the upper and lower surfaces may become unbalanced, easily reducing machining accuracy. The lean manufacturing horizontal double-end face grinding process is a new technique commonly used in automotive engine connecting rod manufacturing. It mainly involves reciprocating motion of the connecting rod between combined grinding wheels while they rotate together, thereby completing the grinding operation. During grinding, the horizontal combination of dual grinding wheels rotates synchronously, allowing the workpiece to reciprocate within the wheel grooves, enabling automatic measurement and compensation, effectively improving connecting rod processing speed. Additionally, under this new process, there are two feeding methods for the connecting rods: one is the disc-type method, suitable for automated loading and unloading; the other is the reciprocating type, suitable for manual loading and unloading. Compared with traditional grinding techniques, the new grinding process offers more significant advantages—higher precision, faster speed, and greater reliability—and has now been widely applied in the manufacturing of automotive engine connecting rods.

4.3.2 Grinding Quality of New and Old Processes

The analysis of grinding quality between new and old processes primarily involves the two end planes of connecting rods. Typically, quality evaluation and analysis consist of three main aspects: parallelism of the two end planes, bending deformation of the complete connecting rod assembly, and flatness conditions. Compared with traditional techniques, the application advantages of lean manufacturing horizontal double-end face grinding technology are more evident. This technology ensures that the connecting rod remains in a free state while held in the fixture. At the same time, it maintains the radial grinding forces on both sides of the connecting rod consistently stable throughout the grinding process, effectively preventing deformation and improving the uniformity of material removal on both end faces. Additionally, the wear on the two end grinding wheels is approximately equal, which to some extent guarantees consistent machining results on both ends of the connecting rod.

5 Conclusion

With the continuous development of the economy and science and technology, the automotive industry is experiencing favorable growth. To further ensure the stability and efficiency of this development, the application of lean manufacturing techniques is essential—particularly in the machining process of engine connecting rods. These techniques not only guarantee the quality of rod processing but also enhance the production efficiency of engine connecting rods. In actual manufacturing, workers must design and produce connecting rods based on the stress conditions they will endure, while also emphasizing standardized implementation of lean manufacturing practices. This ensures that the full potential of lean manufacturing is realized, thereby improving the overall production standards for engine connecting rods.

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