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Design of the New Type Piston Ring Grinding Process

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Abstract:

Among the numerous components of an engine, piston rings are an important part, and their machining quality has a significant impact on the performance of the engine. There are a small amount of burrs on the surface of the piston ring after processing. Traditional deburring equipment, similar to grinding machines, has problems such as high labor intensity and low automation level, which cannot meet the production needs of modern enterprises. This article proposes a new intelligent production line solution that achieves full process automation control based on PLC from feeding to brushing and grinding to final cutting. A dual objective optimization model for grinding energy consumption and time is established, and the optimal process parameters are determined. This design can solve the problem of continuous processing while achieving unmanned and automated processing, avoiding the decrease in accuracy and production efficiency caused by secondary clamping, and improving the profit margin of the enterprise.

Keywords: *piston ring; automated grinding*

1 Objective and Significance

As a metal elastic ring that moves in the axial, radial, and rotational directions inside the engine, the piston ring, when assembled into the ring groove inside the engine cylinder block, will reciprocate together with the piston, providing power support for the engine. High quality piston rings are crucial for engines as they serve multiple functions such as guiding support, ensuring airtightness, and achieving lubrication. In the machining process of piston rings, burrs are inevitably generated on their surfaces. Large and sharp burrs can cause serious particle wear, which can have a slight impact on the service life of the engine. In severe cases, it can lead to engine failure or even damage.

Figure 1 Piston Ring

The six types of burrs shown in Figure 2 are common defects on the machined surface of piston rings. The essence of burrs is the sharp protrusions generated by extrusion on the surface of the piston ring (i.e. the machined surface) after machining due to insufficient selection of machining parameters, machining allowances, and tool types during metal processing. The difficulty of handling burrs varies among different materials. For K1 series materials, due to their low toughness, burrs are easily removed. However, for ductile iron, due to its high toughness, the burrs formed are not easily removed and are very sharp. If we don't remove the burrs before assembling the piston rings into the engine, larger burrs will fall off after installation, causing wear during reciprocating motion and accelerating the damage of the engine piston rings and cylinder liners, resulting in the engine not working properly.

At present, there are various techniques for removing piston ring burrs in the industry, such as ultrasonic deburring, centrifugal grinding, magnetic grinding, etc. However, these methods are relatively expensive, have low processing efficiency, and have a narrow application range. Most companies use single

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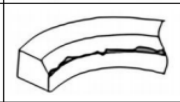
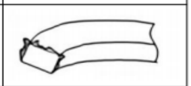
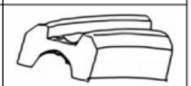
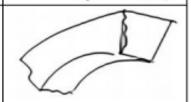
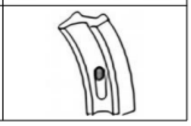
Serial Number	Burr form	Schematic diagram
1	Sharp burrs on the outer edges and corners	
2	Internal edge burrs	
3	Open end face burrs	
4	Burrs at the opening of the oil tank	
5	Burr on the open end of the ladder surface	
6	Oil hole burrs	

Figure 2 Six forms of piston ring burrs

Figure 3 Physical images of existing external brush equipmen

station brush equipment with a structure similar to an external cylindrical grinder for deburring operations (refer to Figure 3). This device is easy to operate, cost-effective, and has strong adaptability. However, this mode of operation relies heavily on manual loading and unloading, resulting in high labor intensity. Not only is the production pace slow, but there are also differences in manual clamping force, leading to poor product consistency. And due to the single station nature of the machine, which can only be operated by one person, continuous processing is not possible, which consumes a lot of time in process connection and results in low production efficiency. In response to the above issues, an intelligent upgrade design has been carried out this time, introducing robotic arms and automation control technology to replace traditional manual single station operations, and establishing a continuous intelligent production line including material picking, clamping, brushing, grinding, and unloading. This has important engineering application value for eliminating quality hazards and improving the core competitiveness of enterprises.

2 Design Plan

2.1 Design of multi-station seeding tooling

The traditional single-station operating equipment, with only one feeding ring, affects the processing progress. This production line is equipped with three horizontally placed feeding racks, where workers place the piston rings after sorting them. When the production line starts working, it requires circular feeding to ensure that there is always material on the feeding racks to complete the processing process. This realizes an automated processing process of feeding, operating, processing, and collecting materials simultaneously, significantly improving efficiency.

2.2 Design of intelligent production line

This design scheme establishes a fully automated control system based on Siemens PLC, achieving seamless connection from material loading to unloading: processes such as material retrieval by robotic arm → material pushing → clamping → grinding → unloading. The PLC part is designed using the SIEMENSE system, and equipped with industrial vacuum cleaners and hydraulic stations. It includes the following structures:

① Feeding rack *3 (effective length 720mm);
② Material pushing mechanism;
③ Feeding mechanism part;
④ Part of the workstation for clamping;
⑤ Clamp the feeding mechanism part;
⑥ Clamping and rotating mechanism part;
⑦ Brushing and grinding mechanism part;
⑧ Material feeding and grasping mechanism part;
⑨ Lower cooking ring mechanism part.

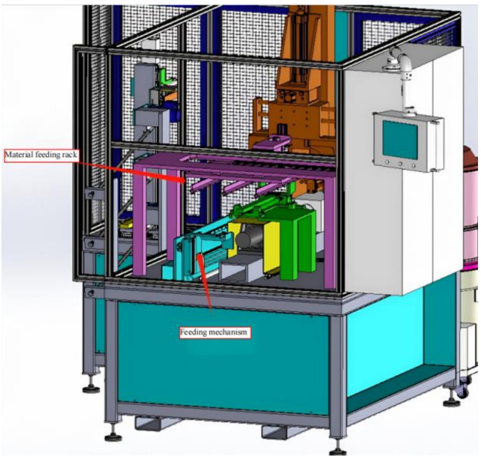


Figure 4 Schematic of the loading rack

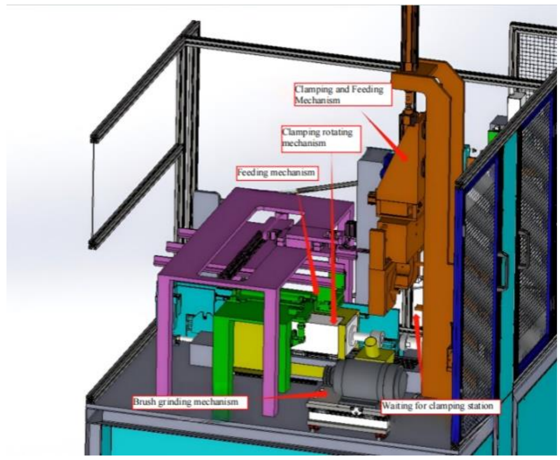


Figure 5 Schematic diagram of the designed production line structure

After the system is initiated, the feeding mechanism takes the lead in action, utilizing a dual-guide rod cylinder in conjunction with an electric cylinder to advance the piston ring on the feeding rack forward. Once the workpiece reaches the predetermined grasping point, the feeding gripper immediately intervenes to transfer it to the waiting clamping area. Immediately thereafter, the clamping feeding mechanism descends to pick up the workpiece and, in conjunction with the movable spindle box of the clamping rotating mechanism, completes the hydraulic locking of the workpiece. During the processing stage, the brushing mechanism performs surface treatment on the piston ring through a compound motion of longitudinal feed and lateral swing. Finally, the unloading grasping mechanism is responsible for removing the finished product, which is then organized by the ring sorting device and returned to the unloading rod, achieving full-process automation.

3 Design of the Brushing and Grinding Mechanism

This solution, based on the core function of the outer cylindrical grinding machine spindle rotation drive, replaces the original grinding wheel assembly with a dedicated brush wheel. It is equipped with a workpiece positioning system, cleaning liquid supply system, and protective recovery system, achieving automated and low-damage brushing of the piston ring's outer circumference, end face, and groove. This system is suitable for batch piston ring cleaning of carbon deposits and oil contamination.

① Brush selection and configuration: When selecting brush filaments for piston rings made of different materials, we need to conduct differentiated comparisons. For example, for gas rings, we need to choose nylon 612 filaments with a Shore hardness of

Table 1 Brush Wheel Assembly

Component Name	Specification parameters	Selection criteria
Brush material	Ring: nylon 612 brushed wire (Shore hardness 70-80); Uncoated ring: soft stainless steel brushed wire (wire diameter φ0.08-0.1mm)	The nylon bristles exhibit excellent flexibility to prevent coating scratches; the soft steel bristles effectively remove stubborn carbon deposits without damaging the metal substrate.
Brush wheel structure	Integrated hub with detachable brush ring, featuring an inner diameter compatible with grinding machine spindle (e.g., φ80mm/φ100mm)	Facilitates rapid replacement of worn brushes, reducing maintenance costs
Brush length and density	Brush length 15-20 mm, density ≥80 roots/cm²	Ensure full contact with the piston ring surface while preventing excessive bending of the brush hairs to avoid incomplete cleaning.
special accessories	Ring groove brush head: Customized elongated strip brush (width 2-5mm), mounted on the grinding machine tool holder via an extension rod	To meet the deep cleaning requirements of piston ring grooves, replace manual pointed brush operations

70-80 to prevent damage to the coating during brushing. For piston rings without a coating, we use soft stainless steel filaments with a diameter of 0.08-0.1mm, which can maximize the removal of carbon deposits without damaging the coating. The length of the brush filaments is set to 10-20mm, and the density is controlled to be above 100 filaments per cm to ensure sufficient contact.

② Speed and process control: Adjust the spindle speed via inverter from the original grinding machine's 1000–3000 r/min to 200–500 r/min. In terms of process, air ring cleaning is performed at low speed (200–300 r/min), while stubborn stain removal is carried out at medium speed (300–500 r/min) to prevent workpiece deformation.

③ Improvement of fixture: Replace the traditional three-jaw chuck with a pneumatic collet combined with polyurethane soft jaws, with clamping force controlled at 0.1–0.3 MPa, which protects the workpiece surface while ensuring a coaxiality accuracy of ≤0.02 mm.

4 Conclusion

The core practical significance of this design lies in promoting intelligent upgrading of the engine component industry, thereby enhancing enterprise competitiveness. By establishing a new intelligent production line featuring multi-station material loading, full-process coordination, and energy-saving optimization, this project successfully achieves an automated and continuous production model for piston ring external brushing. This innovation not only improves production efficiency and machining accuracy but also significantly reduces labor and energy costs. It effectively addresses the issues of low efficiency and poor precision inherent in traditional single-station equipment, fundamentally eliminating the potential risk of engine failures caused by burr detachment, and well aligns with current demands for efficient and high-precision manufacturing.

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