

Research on the carbon emission reduction of internal combustion engines by reducing friction work

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Abstract. The increase in carbon dioxide emissions is a key factor leading to the warming of the Earth's climate system and the intensification of the greenhouse effect. Internal combustion engines have a significant impact on carbon emissions. For internal combustion engines, friction is the main cause of energy loss, which reduces fuel utilization and increases carbon emissions. Therefore, it is necessary to reduce friction work of internal combustion engine. This work focuses on the friction pairs of piston pins and liners in internal combustion engines, and optimizes the surface technology of piston pins by comparing carburized and nitriding processes. The results show that the friction work of the nitrided piston pin is 8.9% lower than that of the carburized piston pin, and the wear of the liner is reduced by 10%. Therefore, surface nitriding process of piston pin is an effective way to reduce friction work and carbon emissions of internal combustion engines.

1 Introduction

Carbon dioxide is one of the main greenhouse gases, which can absorb the heat emitted from the Earth's surface and prevent it from escaping into space, leading to global warming. Global warming can lead to an increase in extreme weather events, such as heatwaves, droughts, floods, etc., which in turn affect agricultural production, water resource distribution, sea level rise, and ecosystem balance. In order to reduce the negative impact of carbon dioxide, the international community is taking various measures, including reducing greenhouse gas emissions, improving energy efficiency, developing renewable energy, and implementing carbon capture and storage technologies. At the same time, governments around the world are also formulating relevant policies and goals to achieve emission reduction commitments and slow down the pace of climate change. Internal combustion engines are one of the main ways of emitting carbon dioxide. Due to their many friction pairs, such as the piston pin and liner, internal combustion engine has a higher amount of frictional work and greater thermal mechanical losses, resulting in low fuel utilization and an increase in carbon dioxide emissions. Therefore, it is necessary to study effective measures to reduce friction work, and thereby reduce the carbon emissions of internal combustion engines [1].

Many scholars have conducted researches to reduce the frictional work of piston pins and liners in order to reduce the emission of carbon dioxide. Allmaier et al. [2,3] built a bearing test bench, which could achieve a load force of 180kN and a sinusoidal loading frequency of 50Hz. At the same time, it could also detect

temperature rise during the test process, and verified the thermal elastohydrodynamic lubrication characteristics through experiments. Takeuchi et al. [4] installed an ultrasonic probe in the piston pin and measured the echo height to study the formation and cavitation behavior between the piston pin and the pin seat of an actual automotive engine cylinder block at low speeds. Etson et al. [5] designed and constructed a testing device using reciprocating angular motion to simulate the relative rotational motion of piston pins and liners. The testing machine could control the load, angular amplitude, reciprocating motion frequency, and lubricating oil flow rate, and the device could measure friction torque and surface temperature. Kong et al. [6] studied the effect of DLC(Diamond-Like Carbon) coating deposited on the surface of piston pins on friction and wear, and the results showed that depositing DLC coating on the piston pins of 2L engines could effectively improve their wear resistance performance. Other scholars have also deposited CrN coatings on the surface of piston pins. Compared with other anti friction and wear-resistant coatings, CrN coatings had significant advantages in the application of high-strength diesel engine piston pins due to their good toughness, low friction coefficient, high temperature resistance, good wear resistance, and high hardness [7-9]. Chen et al. [10] developed a swing type friction and wear testing machine that simulates the motion of piston pins and liners.

In this study, the friction coefficient and wear amount of carburized and nitrided piston pins were compared. By optimizing the surface process of the piston pin, friction work can be effectively reduced, thereby carbon dioxide emissions can be effectively reduced.

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2 Experimental details

2.1 Test specimens

A complete piston pin made of alloy steel is used in the experiment, as shown in Figure 1. The liner is cut into a 10mm wide circular specimen, as shown in Figure 2, the material of the liner is copper alloy.

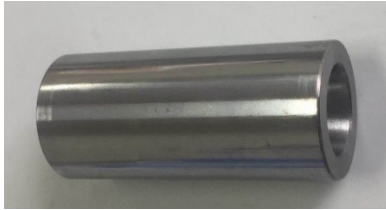


Fig. 1. Piston pin.



Fig. 2. Liner specimen.

2.2 Test equipment

A friction testing machine is used in the simulation experiment. Load is applied by a hydraulic cylinder in the vertical direction. The liner specimen is fixed in the fixture, and the motor drives the piston pin to rotate, as shown in Figure 3.

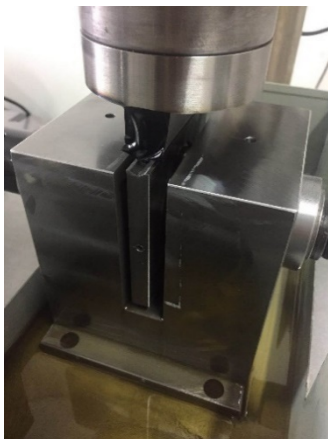


Fig. 3. Test equipment.

2.3 Characterization methods

The friction torques under different experimental conditions can be measured by the torque cell. The applied normal force can be achieved by a jack assembly and loading indenter, the sensor which fixed on the hydraulic cylinder of the jack assembly is used to measure the normal load. The rotation speed can be

adjusted between 1-1000 rpm. The friction pairs can be lubricated continuously by a peristaltic pump. According to the measured friction torques and normal force, the friction coefficient of the friction pairs can be calculated by the following equation:

$$\mu = T_n / (F_n \cdot R) \quad (1)$$

where μ is the friction coefficient of the friction pairs, T_n represents the average friction torque during the wear process, F_n is the applied normal force, R is the radius of the piston pin.

The liner sample is cleaned with gasoline and alcohol, and a precision electronic balance is used for weighing and recording. After the test, the liner sample is cleaned and weighed again. The difference in weight between the liner sample before and after the test is the amount of wear.

The experimental parameters are listed in Table 1.

Table 1. Experimental parameters.

Parameter	Value
Speed	100r/min
Temperature	Room temperature
Load	15MPa
Time	120min

3 Results and discussion

3.1 Characterization methods

The friction coefficient after the experiment is shown in Table 2. The friction coefficient of the carburized piston pin and liner pairing pair is 0.067, while the value of nitrided piston pin and liner pairing pair is 0.061. Compared to carburized piston pin, the friction coefficient of nitrided piston pin is reduced by 8.9%, which means the friction work decreases by 8.9%. The reduction of frictional work improves mechanical efficiency, enhances energy utilization, and thus reduces fuel consumption, thereby reducing carbon dioxide emissions.

Table 2. The friction coefficient after the experiment.

Carburized piston pin	Nitrided piston pin	Decreased value
0.067	0.061	8.9%

The wear amount of the liner after the test is shown in Table 3. The wear amount of the liner paired with the carburized piston pin is 6.4mg, while the wear amount of the liner paired with the nitrided piston pin is 5.7mg. Compared to the liner paired with carburized piston pin, the wear of the liner paired with nitrided piston pin is reduced by 10.9%. The use of nitrided piston pin can reduce the wear of the liner and thereby improve the lifespan of the mating pair.

Table 3. The wear amount.

Carburized piston pin	Nitrided piston pin	Decreased value
6.4	5.7	10.9%

3.2 Wear morphology

The macroscopic morphology of the worn pair of carburized piston pin and liner is shown in Figure 4, and slight wear marks can be seen on the surface of both carburized piston pin and liner. Microscopic analysis of the wear morphology of the liner is carried out using an electron scanning microscope, as shown in Figure 5. From the microscopic morphology, scratches along the sliding direction can be seen, with furrows and abrasive wear occurring.

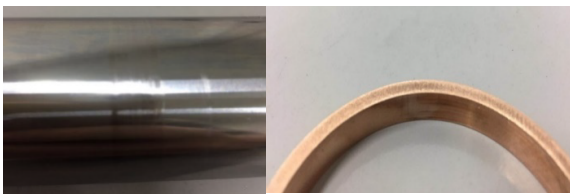


Fig. 4. Macroscopic wear morphology of carburized piston pin (left) and liner (right).

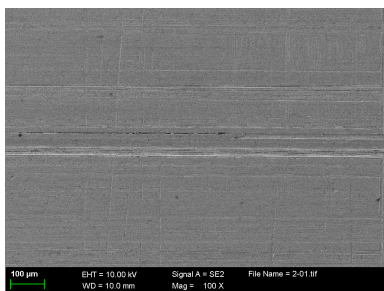


Fig. 5. Microscopic wear morphology of liner paired with carburized piston pin.

The macroscopic morphology of the worn pair of nitrided piston pin and liner is shown in Figure 6. Compared with carburized piston pin, the wear marks on the surface of nitrided piston pin and liner are relatively light and the color of scratches is lighter. Microscopic analysis of the wear morphology of the liner is carried out using an electron scanning microscope, as shown in Figure 7. From the microscopic morphology, it can be seen that there are slight scratches along the sliding direction. Compared to the liner paired with the carburized piston pin, the wear surface of the liner paired with the nitrided piston pin is smoother.



Fig. 6. Macroscopic wear morphology of nitrided piston pin (left) and liner (right).

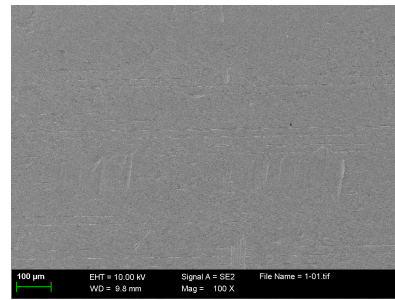


Fig. 7. Microscopic wear morphology of liner paired with nitrided piston pin.

4 Conclusions

The friction work of the nitrided piston pin is 8.9% lower than that of the carburized piston pin, and the wear of the liner is reduced by 10%. Therefore, surface nitriding process of piston pin is an effective way to reduce friction work and carbon emissions of internal combustion engines.

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