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Research on discriminating partition laser surface micro-texturing technology of engine cylinder

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ABSTRACT

The effect of discriminating partition laser surface micro-texturing (LST) was investigated on engine comprehensive performance. The cylinder bore was divided into five different sections according to wear characteristics and lubricating performances and three schemes of LST partition were designed on the cylinder surface. The performance test bench shows that the diesel engine equipped with the three different LST cylinders have different decreasing amplitude in fuel consumption compared to the standard cylinder. The maximal oil consumption is decreased by 45.5%. A significant reduction in specific fuel consumption of the engine is observed with the laser microtextured cylinders compared to that of the standard cylinder. The comprehensive performance of the diesel engine fitted with LST-3 cylinder establishes the best performance.

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1. Introduction

Cylinder liner (bore) is one of the key parts of internal combustion engine, which has great influence on the power, economy and emission performances of the engine [1–5]. The surface topography affects friction, lubrication and sealing between the contact surfaces of the cylinder liner-piston ring friction pair significantly. Currently, conventional plateau honing technology is applied in the engine industry mainly to improve the anti-wear and lubrication performances of cylinder liner. With the development of the automobile industry and the increasingly stringent emission regulations, it is urgent to improve cylinder liner surface processing quality. Consequently, many researchers try to improve the comprehensive performances of IC engine by optimizing the microcosmic geometrical morphology of the contact surface between the cylinder liner and piston rings. Laser surface texturing (LST) which can significantly improve the tribological performances of friction pair surfaces [6–10], has aroused wide concerns of domestic and overseas researchers [11–13]. Therefore, many researchers [14–16] applied LST to the cylinder to improve the performances of IC engines. Duff et al. [17] found that the microdimples could act as oil reserves, resulting in the reduction of friction and the improvement of oil lubrication time. Brinkman et al. [18] found that the engine oil consumption of laser textured cylinder was smaller than that of the conventional honed structures.

Microcosmic geometrical topography of contact surface of cylinder and piston ring [19–22] has a smashing result on the comprehensive performances of IC engine. Therefore, many researchers have tried to optimize the surface topography parameters to improve the performances of IC engine. Zhou [23] developed the theoretical model for the optimal design of surface texturing on cylinder liner and investigated the effects of texturing parameters on the load bearing capacity and film thickness. The outcomes established that on cylinder liner, texturing with variable parameters in different velocity ranges could produce higher load carrying capacity and film thickness than that with invariable parameters. Zhu et al. [24] study the friction reduction effect of micro-round dimple textured surface with variable density in reciprocating motion and found that the topography parameter of lower density texture in the middle and higher density texture at both ends showed a better friction reduction.

The surface of cylinder-piston ring friction pair has typical characteristics of a partition. The method of partial texturing attracts some researchers' interests [25,26]. Etsion et al. [27] did a theoretical analysis on the effect of fully textured and partly textured piston rings on tribological behavior. The results showed that on the piston rings, partial texturing exhibited better surface tribological performances compared to full texturing. In addition, Etsion et al. [28] found that the partial LST piston rings exhibited

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up to 4% lower fuel consumption compared to the non-textured conventional barrel-shaped rings. Importantly, Green Corporation produced bag type oil storage tank only in the area of the top dead center (TDC) of the cylinder in order to increase oil supply of the lean region of the TDC and improve the lubrication conditions. However, the focus of current research is mainly on the lubrication mechanisms of textured surface by changing the parameters of micro-textured topography or partly texturing the friction pair, with few literatures on discriminating partition using laser surface texturing (DPLST) technology. Furthermore, most of the researches are confined to theory or experiments. Rahnejat et al. [29] combined numerical and experimental approaches to highlight the fundamental investigation of surface modification and coating and its impact on frictional performance. Yet, little research work has been carried out on energy conservation and emission reduction through the performance test bench.

Based on the requirements of wear characteristics and lubrication performances of IC engine, the DPLST technology is proposed in this paper. Through the performance test bench on the engine, the actual effect of cylinder liner DPLST technology is verified and the application and development of laser honing technology are further advanced.

2. Partition of the cylinder liner

During the functional operation of IC engines, insufficient lubrication contributes to some wear on the surface of the cylinder liner when the piston ring is running against the cylinder liner. Inhomogeneous distribution of temperature and pressure accounts for the uneven distribution of lubrication and thus results in asymmetrical distribution of wear on the surface of the cylinder liner. In general, wear on the inner surface of automobile engine cylinder is mainly mechanical and abrasive. On that point are four instances of wear, namely mechanical wear, grinding abrasive, corrosion wear and adhesive wear. Their characteristics are as follows:

2.1. Mechanical wear

When the IC engine is working, the piston ring is fired up and deformed, which is tightly pressed onto the inner surface of the cylinder liner due to its own elastic force. This results in some difficulties in the formation of lubricating oil film and thus causes serious wear in the upper area of liner surface. The odd distribution of pressure on the cylinder liner surface leads to inhomogeneous distribution of lubrication which results in uneven distribution of wear. In the upper part of the combustion chamber, the high air pressure causes high pressure between the piston-cylinder liner and develops local high temperature resulting in starved lubrication, which leads to excessive wear. This causes the liner to form a vertebral shape of big top and small bottom due air pressure at.

2.2. Grinding abrasive

The lubricating oil film is easily damaged by the tiny abrasive grain on the contact surface of cylinder liner and piston ring, resulting in grinding abrasive. The grinding abrasive is mainly distributed in the opposite surface of the intake valve.

2.3. Corrosion wear

Corrosion wear mainly refers to the loose formation on the inner surface of the cylinder caused by acidic gas generated in combustion process, which apparently reduces the effect of dynamic pressure lubrication. Corrosion wear is mainly distributed in the TDC area. Below the TDC, the rates of corrosion wear decreases rapidly.

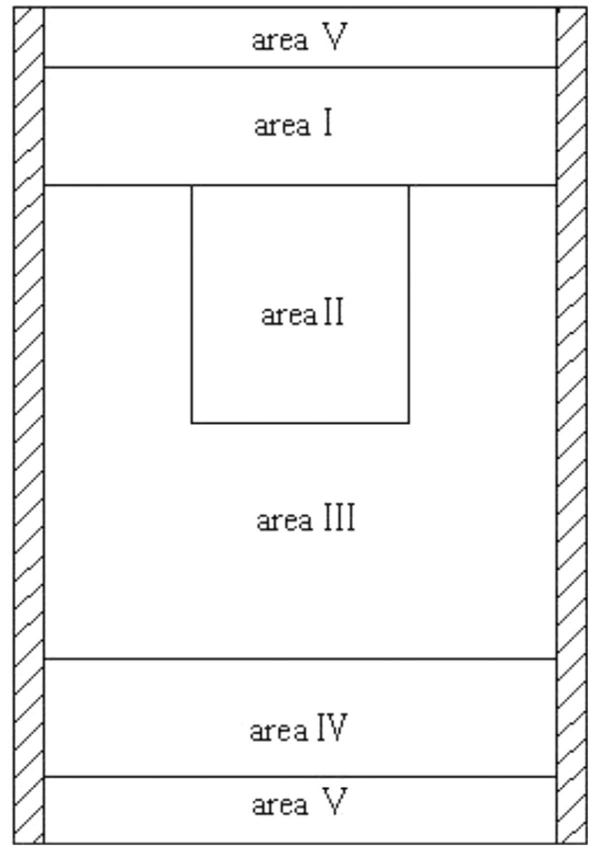

Fig. 1. Partition of cylinder bore.

2.4. Adhesive wear

For compression and power stroke in IC engine, the contact area of piston skirt and the cylinder encounter large lateral pressure when the piston reaches TDC, which makes it difficult for lubricating oil film to form and hold. Therefore, the surface is prone to be in the state of dry friction, which might lead to local high temperature, and thus metal contact surface melt and adhesive or peeling. Adhesive wear is mainly distributed in the main contact zone between the cylinder surface and the skirt area of the piston.

The inner-surface of cylinder liner is divided into five areas according to above wear characteristics, TDC area (area I), main contact area of skirt (area II), intermediate stroke area (area III), bottom dead center (BDC) area (area IV) and no texturing area (V) as shown in Fig. 1.

3. Laser texturing of cylinder bore

3.1. Equipment and methods

The LST patterns was carried out on the cylinder inner surface using the semiconductor sound and light pumped Nd:YAG laser shown in Fig. 2. The technical parameters of the equipment are shown in Table 1. The surface of the textured liner was measured by T1000 type roughness tester of German HOMMEL Company and polished by fine grinding equipment, as exhibited in Fig. 3. The test bench of laser microtexturing was carried out, as shown in

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