Wear 400–401 (2018) 207–212

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

The effect of plateau honing on the friction and wear of cylinder liners[☆,☆☆]

Eun-Seok Kim, Seung-Mok Kim, Young-Ze Lee*

School of Mechanical Engineering, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea

A R T I C L E I N F O

Keywords:
Cylinder liner
Plateau honing
Friction and wear
Boundary lubrication

A B S T R A C T

In case of the diesel engine, the optimal control of interacting surfaces for improving the performance of engine becomes important more than before, especially in designing the surfaces of cylinder liners. The plateau honing technology has been developed on the cylinder liners of the large ship engines and the automotive engines. A plateau honing is a kind of metal removal process, which leaves a substantially flat or plateau finish with much greater bearing area, while maintaining a cross hatch pattern of valleys for oil retention. However, the valley produced by honing functions as an oil repository has a fatal role in the formation of fluid dynamic pressure on interacting surfaces.

The friction and wear tests with reciprocating motion were performed to compare the lubricity of sliding cylinder liner surfaces with each different mark of plateau honing. The friction and wear of surfaces with each different depth of profiles, which were used as the honing mark of the marine diesel engine, were compared with those of randomly ground surfaces. From the tests with the deep-grooved honing marks, it was found that the severe interactions due to asperity contacts and the formation of relatively thin films produced larger amounts of wear volumes than the test with the shallow-grooved ones.

1. Introduction

The loss of the energy in the internal combustion engine may happen due to the problem of high frictional forces and wear amounts in interacting surfaces of mechanical components. According to Tung, Only 12% of the energy is used for the actual power and the others go to waste. 15% of energy loss occurs in the mechanical parts, and the waste of energy is mainly related with the friction losses. If the friction losses, which are kind of mechanical losses, can be reduced by 10%, it can be possible that the fuel and oil consumption can be reduced by 1.5%. Among those losses in engine, the most of losses are resulted from the piston assembly and the interfaces between piston rings and cylinder liners [1].

In order to increase the fuel efficiency of the marine diesel engine, the optimal control of interacting surfaces for improving the performance of engine becomes more and more important, especially in designing the surfaces of cylinder liners. Recent trends in the development of high-speed engine require the engine with higher performance, lighter weight, less fuel consumption and lower exhaust gasifier than before [2]. Also it should be more durable to severe loading, which requires reducing the amount of wear. One method to do that is the process to make some grooves on surfaces for lubricating purpose and to control the contact surfaces. The plateau honing technology has been developed on the cylinder liner of a large ship engines and automotive engines [3]. A plateau honing leaves a substantially flat or plateau finishes on the sliding surfaces with much greater bearing area, while maintaining a cross hatch pattern of valleys for oil retention [4,5].

To control the friction between the piston rings and cylinder liners, the surface texturing has become one of valuable technologies. Honing and laser surface texturing on cylinder liners attracted attention to reduce the friction [6,7]. The valley produced by honing functions could act as an oil repository, and at the same time the valley is a fatal role in the fluid dynamic formation [8].

☆ This paper was presented on WOM17 in Long Beach.
☆☆ This article was submitted 21st International Conference on Wear of Materials.

* Corresponding author.
E-mail address: yzlee@skku.edu (Y.-Z. Lee).

http://dx.doi.org/10.1016/j.wear.2017.09.028
Received 2 September 2016; Received in revised form 17 March 2017; Accepted 28 September 2017

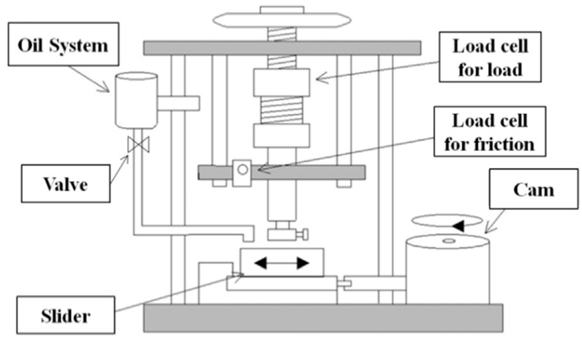

Fig. 1. Reciprocating wear tester.

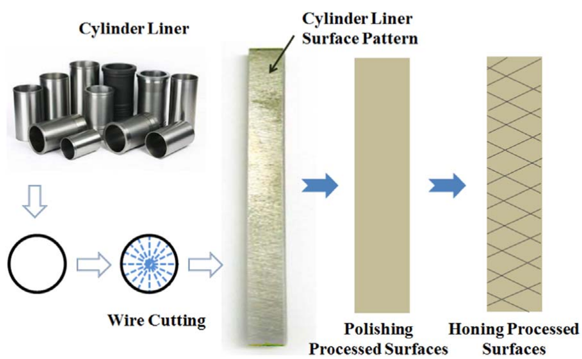

Fig. 2. Procedure of cylinder liner machining.

In the present study the friction and wear tests were performed to compare the lubricity of sliding cylinder liner surfaces with each different mark of plateau honing. The depths of profiles were changed from 0.035 μm to 0.78 μm in Ra, which was usually used honing mark of the marine diesel engine. Also, these surfaces were compared with randomly ground surface with the surface roughness of 0.12 μm and 0.2 μm in Ra.

2. Experiment details

2.1. The test apparatus

The tribometer with reciprocating motion was used to investigate the friction and wear characteristics of cylinder liner surfaces with different honing mark against piston ring surfaces. The liner specimens were prepared from the commercial engines. Ball specimen was fixed on the upper part of the tester connected with loading device and friction sensor as shown in Fig. 1. The liner specimen has the reciprocating motion the stroke of 50 mm. The spring was installed on the device for transmitting the vertical load in order to minimize the changes of vertical loads due to vibration. A device for lubricating oils was attached in order to implement the lubrication environment. The frictional force between the ball and the cylinder liner was transmitted to the rotating shaft and was monitored by the load cell on the upper part.

2.2. Sample preparation

Specimens were produced by wire cutting process from cylinder liners as shown in Fig. 2. The Liner specimens were prepared by polishing and scratching process to have different honing depth, which showed the surface roughness of 0.035 μm, 0.12 μm, 0.2 μm, 0.46 μm and 0.78 μm in Ra (Fig. 3). The five kinds of honing marks were produced to evaluate the effect of honing mark on the friction and wear of contacting surfaces. Fig. 2 shows the procedure for preparing the specimen. The surface roughness of the commercial cylinder liner was 0.78 μm in Ra (Rk 3.602, Rpk 0.878, Rvk 2.219) (Fig. 4) on the surface processed by long-stroke honing. Also two surfaces were produced by random grinding without honing marks. The values of surface roughness were 0.12 μm and 0.2 μm in Ra. The material of the cylinder liner was cast iron (GG26Cr), AISI 52100 steel balls were used as counter surface instead of piston ring for reproducibility and contact condition to be controlled.

All liner specimens were mounted on a reciprocating tester after cleaning with acetone. The load of 100 N and the speed of 120 rpm were used. One hour was enough to evaluate the friction forces and the amount of wear at the test condition. The grade of oil was ISO VG 68 @ 40 °C. The amounts of wear were measured by tracing the specimens with a surface roughness tester before and after the tests. SEM and the optical microscope were used to investigate the worn tracks on the surfaces.

3. Results and discussion

3.1. Friction test

Fig. 5 shows the friction coefficient of specimen which were produced by different surface process. Overall, the honing processed surfaces have lower friction coefficients than the surfaces with grinding process with similar surface roughness. The friction performance of the surface roughness of 0.78 μm in Ra makes no difference to those of smoother surfaces, but the polishing processed surfaces show the highest friction coefficient.

3.2. Wear resistance

The wear volumes of cylinder liners with different surface roughness are shown in Fig. 6. The surfaces with the honing marks of 0.1–0.2 μm in Ra produced the least wear volume, and the surface with the roughness of 0.78 μm in Ra produced the most wear volume. The wear volumes were increased as increasing the surface roughness from 0.2 μm, because the abrasive effects were increased by colliding of the jagged asperities. On the other hand, the wear volumes were increased as decreasing the surface roughness from 0.1 μm, because the increase of real contact area between cylinder liner and steel ball causes more severe wear by adhesion.

Comparing the wear volumes of two machined surfaces, randomly ground surface shows similar or better wear resistance than honing processed surface. It is indicated that the valleys of the surface disturb the maintaining hydrodynamic pressure of lubricant film, so that those lead to partially metal to metal contact and plastic deformation by interacting asperities.

3.3. Surface analysis

In Fig. 7 the honed surfaces with varying surface roughness were