EXPERIMENTAL STUDIES OF SCUFFING MECHANISM IN OIL LUBRICATED PISTON-RING /CYLINDER SLIDING CONTACTS

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Experiments have been conducted to investigate scuffing mechanism in oil lubricated piston-ring /cylinder sliding contacts. Samples were extracted from actual components to simulate the real contact geometry and other influencing conditions. A standard test machine, with some modifications, has been used for the investigation of the effects of surface temperature, load and sliding velocity. Preliminary tests were carried out to find the critical temperature of scuffing using gradient temperature under a constant load, reciprocating frequency and stroke. The experimental and analytical results show that a transition from lubricated contact to adhesion, accompanied by the phenomena such as material transfer between the two sliding surfaces, local contact welding and temperature rise, and sharp increase in friction coefficient, appears to contribute to the final failure of scuffing.

Keywords : Scuffing, Piston-ring/Cylinder, Adhesion

1. INTRODUCTION

The tribological behavior of piston rings has been long recognized as an importantfactor that influences the performance of internal combustion engines in terms of power loss, fuel consumption, oil consumption, blow-by and harmful exhaust emissions. Especially, piston ring and cylinder bore scuffing during running-in is a problem which has become a matter of concern to all manufacturers of engines and lubricants[1].

Scuffing is a complex phenomenon, involving mechanical, thermal and chemical interactions among the contacting materials, environment, lubricant, etc. The biggest mystery of scuffing lies in the unpredictability and catastrophic nature of the failure. Machinery is likely either to fail early or to last a long time, with few failures at intermediate duration.

A comprehensive review on scuffing investigations was given by Ludema[2]. Recent developments on this research area have been discussed in literatures, including those of Sheiretov et al[3]. Great efforts have been devoted to the investigation, improving our understanding of the phenomenon, but the mystery of scuffing remains unsolved, and design engineers have to largely relay on their experience to prevent the disastrous failure.

2. EQUIPMENT AND TEST METHOD

2.1 Geometry of contact and specimen

The SRV oscillating-type wear-testing machine (Optimol Model) was used in the experiment. The sliding system consists of an oscillating upper specimen and a stationary lower specimen.

The specimens used in tests were cut from cast iron cylinder bore and barrel profile chrome coated cast iron top compression ring, respectively, for simulating the actual contact geometry and typical operation conditions. The cylinder bore specimen was made in rectangular form of 24 mm by 12mm, 7 mm thick in its center, which was pressed against a piece of piston ring 15 mm in length. A specially designed holder was assembled on the moving head of SRV machine, to clamp the ring segment tightly in the vertical plane, while the cylinder bore specimen was fixed to another specially designed holder located below the upper specimen. An electrical heater was attached beneath the lower holder. A detailed sketch view of the specimens and the arrangement are shown in Fig. 1.

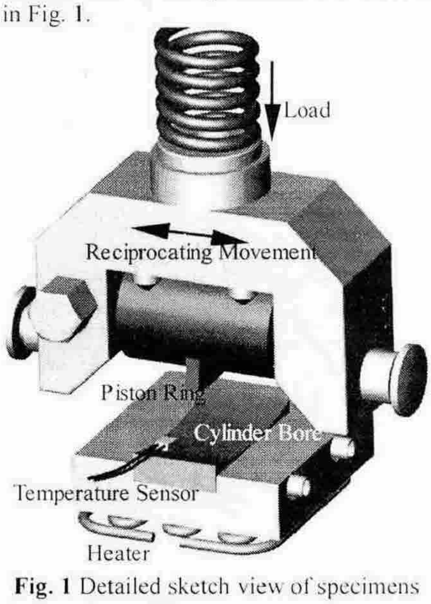

Fig. 1 Detailed sketch view of specimens

2.2 Experimental conditions

The operational parameters include load, reciprocating frequency, stroke, and temperature. In this study, the reciprocating frequency was set at 20 Hz and the stroke at 2 mm. Load was 50 N during the running-in stage and then increased and kept at 100 N or 200 N during the scuffing test stage. Heater temperature ranged from room temperature up to 300℃. Outputs include friction coefficients and the temperature in the region near the contact surfaces.

Before each test run, specimens were cleaned carefully with acetone in an ultrasonic bath, dried in a hot air stream, and then set in the apparatus. The sliding speed was held constant throughout the run, but the loads were increased to the predetermined value after running-in and kept constant thereafter. After running-in stage at 100℃ and 50N, the test was switched to the regular experiment of scuffing.

There are two groups of experiments. In the first group, a running-in was carried out for 10 minutes at a temperature of 100℃, then the specimen was heated in a stepwise manner

(150 ~ 300℃). The test went on, for 8 minutes at each temperature with the normal load unchanged, till a failure took place. The second group of experiments was conducted under constant load and a continuously increasing temperature with a gradient of 5°C/min. This method was also adopted by Galligan et al[4].

The lubricant used was HVI 75N base oil with kinematic viscosity 3.12 mPa · s at 100℃ approximately. Before test, we injected 0.05ml oil. As the test progressing, however, the contact surfaces were under starved condition due to the consumption of lubricant.

3. RESULTS AND ANALYSIS

In scuffing tests, the onset of adhesion is characterized by a rapid increase in the friction coefficient. Failure is considered to have occurred if the friction coefficient exceeds 0.35.

3.1 Typical testing results

Some typical testing results, which show the friction coefficient changes with time under certain temperature and load, are given in Fig.2 and Fig.3.

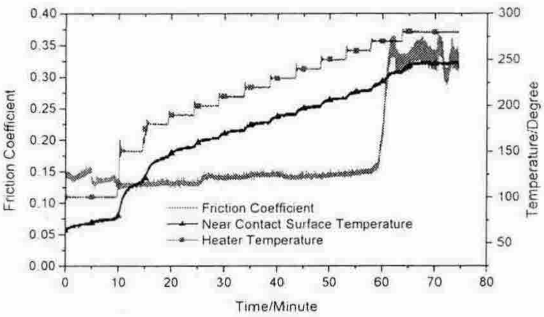

Fig. 2 Typical test result under stepwise heating

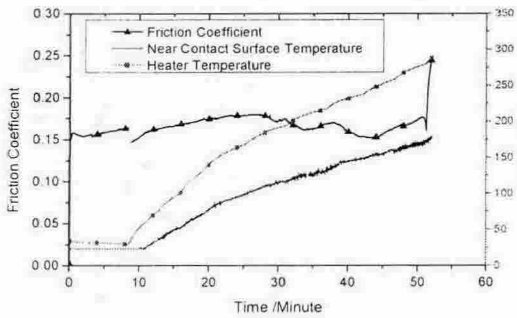

Fig. 3 Typical test result under temperature gradient

As observed from test results, scuffing occurs shortly after the environment temperature reaches 220-250℃. Lubricant may failure to prevent metal-to-metal contact because of evaporation and degradation under such high temperature.

3.2 SEM analysis

The transfer of material was observed at ring and cylinder surfaces in different degree. On piston ring, the main feature in SEM photos is the apparent adhesion zone(Fig.4) while on cylinder bore, there is a clear manifestation of large plastic deformation(Fig.5). The discrepancy is believed resulting from the difference in hardness of the materials (chromium vs. cast iron) used for piston ring and cylinder bore [5].

Elemental content survey using Energy Dispersive X-ray Spectrometer system can give us clear evidence about the transfer of material. From Fig.6 we can see that at the adhesion zone of piston ring the content of Fe has a very high value. This validates the transfer of material from cylinder bore to piston ring.

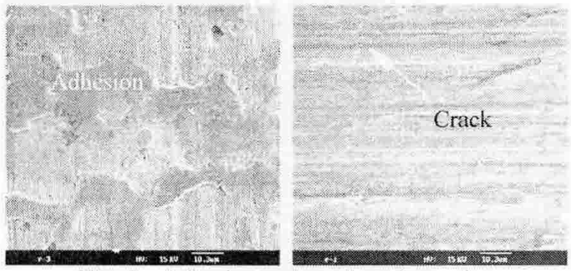

Fig. 4 Adhesion and crack at piston ring

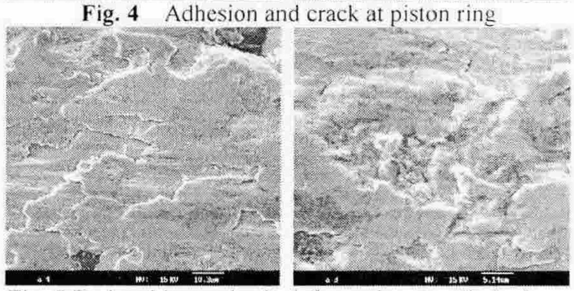

Fig. 5 Peel and large plastic deformation at cylinder bore

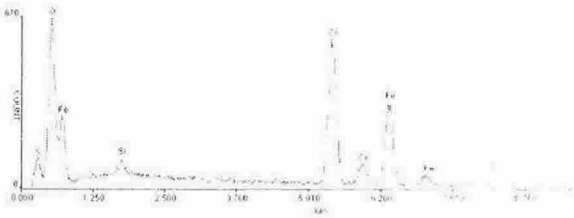

Fig. 6 Elemental survey of adhesion zone at piston ring

4. CONCLUSION AND DISCUSSION

(1) The transfer of material and large plastic deformation are observed on contact surface in scuffing tests.

(2) Scuffing occurs when temperature reaches a critical range under particular combinations of material, load, velocity and lubricant.

(3) High temperature can affect the properties of lubricant and materials significantly, and plays an important role in the initiation of scuffing.

5. REFERENCES

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