

Wear Properties of Car Engine Shaft in Actual Engine Environment

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ABSTRACT

When evaluating the wear properties of slide bearings for car engines, it is a common practice to conduct long-term physical test using a bearing tester for screening purposes according to the revolution speed of the shaft, supply oil temperature and bearing pressure experienced in the actual use of engines. The loading waveform applied depends on the capability of the tester that is loaded, and it is often difficult to apply a loading waveform equivalent to that of actual engines. To design an engine that is more compact or lighter, it is necessary to reduce the dimensions of slide bearings and the distance between bearings. This requires loading tests on a newly designed engine by applying a loading waveform equivalent to that of actual engines to slide bearings and their vicinity before conducting a firing test.

We therefore conducted an engine firing test by attaching thin-film sensors to the slide bearing part of the engine and measured the actual load distribution. We then reproduced a loading waveform in the bearing tester to allow testing under conditions equivalent to those of actual engines.

Using this newly developed tester, we conducted basic tests on the relationship between the width and wear and between the oil temperature and wear of the slide bearing. As a result, we have found that wear decreases as the width of the slide bearing increases and wear increases as the supply oil temperature increases. Nevertheless, wear does not change linearly in this phenomenon, suggesting that the effective area under pressure and the decrease of viscosity are also relevant.

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INTRODUCTION

As we proceed with the CO₂ reduction and energy-saving, many efforts are in progress to reduce friction and wear in slide bearings used for car engine shafts.

Daido Metal et al. [1] have reported that friction can be reduced by devising a slide bearing with a surface structure called "multi-boring metal." Another example is that, friction has been reduced by adding a solid lubricant to an overlay. [2] In such cases, data are often collected for evaluation by installing a bearing on an engine and conducting a firing test. As the measurements of the coefficient of friction and the wear rate are often affected by sliding parts other than slide bearings, it is difficult to evaluate only the effect of slide bearings alone.

In the evaluation of wear, on the other hand, long-term engine firing tests are conducted to measure and predict the wear rate, as reported by Hoshi et al.[3] Although the wear data obtained by this approach are very precise, it is rather difficult to conduct such tests, which require significant time and labor.

High-precision testing on single slide bearings under conditions close to those of actual engines is therefore important in evaluating the lives and properties of slide bearings.

In the evaluation of slide bearings, tests are conducted by applying a sinusoidal load to the bearing by using an unbalanced shaft or weight as in Daido Metal et al.[4, 5], with the rotation speed, amount of oil supplied and oil temperature being consistent with those of actual engines. In this case, the loading waveform becomes broad compared with the sharp waveform observed at the time of firing, and therefore the overall load becomes significantly greater. In a strict sense, the formation of an oil film in the tester is different from that of actual engines because in the tester, due to its properties, the crank shaft surface that provides a load to the bearing always slides against different surfaces.

We have thus developed a new bearing test rig that allows us to synchronize the load distribution and the angle of rotation through a connecting rod used for actual engines to achieve the same loading waveform distribution as that observed at the time of firing. Using this test rig, we have verified the effects of bearing pressure and supply oil temperature on the wear of slide bearings.

SLIDING BEARING SIMULATED TEST APPARATUS

The new bearing tester consists of the proper tester (a drive motor, speed increasing gear and test chamber) and the amplifier unit including a hydraulic pressure source, lubricating oil supply unit and instrumentation equipment. Figure 1 shows a schematic representation of the sliding bearing simulated test apparatus.

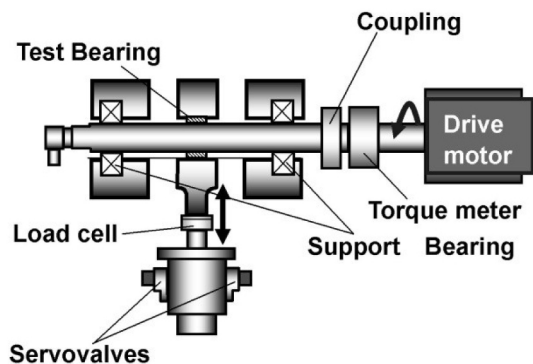


Figure 1. Schematic representation of the tester proper

A slide bearing specimen is set in the central part of the rotational shaft supported by bearing installed in the test chamber. The slide bearing specimen is installed on a connecting rod used for actual engines. The specimen, which is connected to the piston pin area of the connecting rod and to the servo actuator placed in the lower part of the test chamber, is loaded by the vertical motion of the servo actuator.

The servo actuator is capable of reproducing a pressure waveform corresponding to the cylinder pressure by operating multiple high-speed servo valves connected in parallel.

There is a rotary encoder installed at the end of the rotational shaft to allow the control of the angle of rotation.

Figure 2 shows thin-film sensors installed on the connecting rod to measure loading waveforms.

The sensors are arranged radially with five detection points. The slide bearing tested has an inner diameter of 58 mm, outer diameter of 62 mm and width of 19 mm. The film of the thin-film sensors was formed by physical vapor deposition (PVD) on a slide bearing of the same dimensions.

Figure 3 shows a loading waveform observed in an engine firing test using a slide bearing attached with thin-film sensors as well as a corresponding loading waveform reproduced by using the bearing tester. The thin-film sensors used in the engine test were used to perform the measurements with the bearing tester.

The black line represents a loading waveform acquired in the firing test of an actual engine, and the red line represents a corresponding waveform reproduced by the bearing tester.

The reproduced loading waveform mostly agrees with the waveform observed in the firing test of the actual engine. The blue line, which shows a sinusoidal load distribution, indicates greater loads compared with the loading waveform obtained from the actual engine.

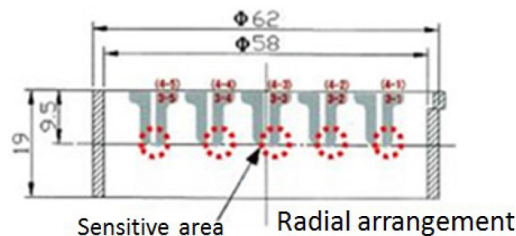


Figure 2. Thin-film sensors after testing (bearing tester)

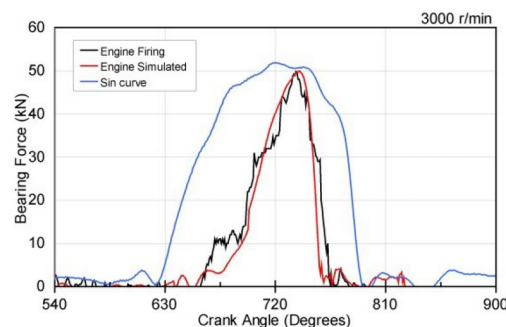


Figure 3. Loading waveform reproduced by the tester

The oil supplied from the oil supply unit (OPU) was temperature-controlled in the line heater, and a required amount of oil was supplied from the end of the rotational shaft to the slide bearing through the mechanical seal.

Figure 4 shows inside the test chamber of the new bearing tester.

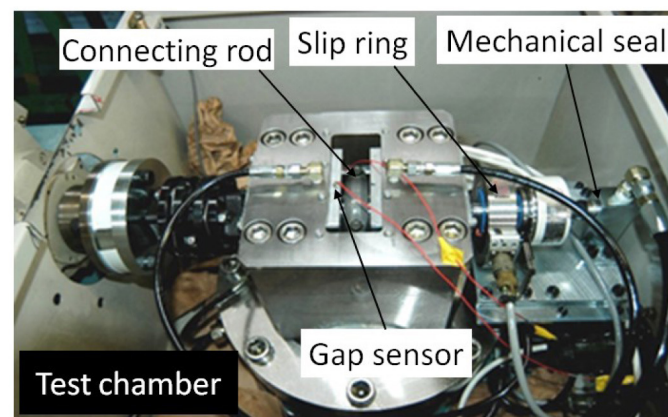


Figure 4. Inside the test chamber