

Scuffing Test Rig for Piston Wrist Pin and Pin Bore

Rong Zhang, Qian Zou, and Gary Barber
Oakland University

Ben Zhou and Yucong Wang
General Motors

ABSTRACT

In practice, the piston wrist pin is either fixed to the connecting rod or floats between the connecting rod and the piston. The tribological behavior of fixed wrist pins have been studied by several researchers, however there have been few studies done on the floating wrist pin. A new bench rig has been designed and constructed to investigate the tribological behavior between floating pins and pin bore bearings. The experiments were run using both fixed pins and floating pins under the same working conditions. It was found that for fixed pins there was severe damage on the pin bore in a very short time (5 minutes) and material transfer occurs between the wrist pin and pin bore; however, for the floating pin, even after a long testing time (60 minutes) there was minimal surface damage on either the pin bore or wrist pin.

CITATION: Zhang, R., Zou, Q., Barber, G., Zhou, B. et al., "Scuffing Test Rig for Piston Wrist Pin and Pin Bore," *SAE Int. J. Fuels Lubr.* 8(1):2015, doi:10.4271/2015-01-0680.

INTRODUCTION

The mechanism of surface damage from lubricant starved wear known as scuffing has been a research topic of great interest for many years. However, the question of how scuffing is initiated and the factors that contribute to its occurrence are still not fully understood. In general, it can be said that scuffing manifests itself as sudden failure in mechanical equipment operating under extreme conditions of load and speed. When scuffing occurs, there is a sudden rise in friction force accompanied by noise and vibration; severe wear and plastic deformation are commonly observed on the damaged surface.

Much work has been devoted to the failure of lubricant layers and a number of scuffing criteria have been suggested (W. F. Bowman and G. W. Stachowiak, 1996; SI C. Lee and Huanliang Chen, 1995; Kenneth C. Ludema, 1984; Jeng Haur Horng, 1998; J. Castro and J. Seabra, 1998; J. Hershberger et al., 2005; Young-Ze Lee and Byung-Ju Kim, 1999; B. Zhu et al., 1987). However the phenomenon of scuffing failure is so complicated that none can be said to be a universal criterion applicable over the entire range of operating variables. Any one of the criteria may be used only with certain operating conditions and materials.

Being at the heart of an engine, the piston assembly, consisting of a piston, rings, connecting rod and wrist pin, may be subjected to extremes of thermal and mechanical loading, as well as poor lubrication. Under such severe conditions, scuffing may occur. Compared with the piston pin being fixed to the connecting rod, a design where the piston pin floats is expected to effectively enhance the scuffing resistance. In the floating pin design there are two types

of bearing systems: one is the piston wrist pin and the piston pin bores; the other is the piston wrist pin and the small bearing of the connecting rod. When scuffing initiation occurs on either bearing, the higher friction force will stop the pin's rotational motion relative to that bearing; however, the other bearing can still operate effectively. On the scuffed bearing, due to no sliding motion, the working condition becomes less severe and scuffing may not propagate due to a halt of the sliding motion. The piston wrist pin will fail only if both bearings scuff. The scuffing behavior of fixed pins has been studied by several researchers. However, there have been few studies related to floating pins. Zhang et al. (2003-2004) described a test rig to study the scuffing behavior of fixed piston wrist pins and pin bores. The test rig attempted to simulate the piston assembly operating conditions as close as possible. In their design the pin was driven by a motor to produce reciprocating rotation, hence it was not a floating pin condition. Etsion et al. (2006) designed a simple machine to test the effect of various surface treatments on piston pin scuffing resistance. The pin was also driven. Therefore, it also was not a floating pin. Tadahiro et al. (1997) built a machine to analyze the lubrication conditions of piston wrist pin boss bearings. They placed a needle bearing between the small end of the connecting rod and piston wrist pin to minimize the friction between them; hence it was semi-floating pin. In particular, no studies have been conducted to study the tribological performance of floating pins using a test rig. In the current work, a new bench rig has been developed to investigate the scuffing behavior of floating pins. After the rig was constructed, tests were run and the scuffed pins from the rig were compared to scuffed pins run in fired engines.

BENCH TEST RIG

The bench test rig consists of loading system, drive system, synchronization system, data acquisition system and specimens. A schematic drawing of the main frame of the bench rig is shown in Figure 1. The loads on the piston pin are produced by a PZT (Piezoelectric Transducer) actuator which is held in a linear bearing. A load cell measures the dynamic loading during the test. The load is applied to the pin by the small end of the connecting rod, hence on each of the piston wrist pin and pin bore bearings there is half of the load. In the bench test rig, the piston is placed top side down. With such configuration, there will be more contact area between piston and piston holder which increases the stiffness and hence aids in producing a load on the piston wrist pin during operation. In engines, during the combustion phase, the pressure is on the top surface of the piston which is also the case in the bench test rig. On top of the PZT (Piezoelectric Transducer) actuator, there is a fine pitch screw to apply a preload on the piston wrist pin. In order to prevent rotational motion of the actuator, an anti-rotation ring is used. At the bottom of the main frame, a rod swing mechanism was designed to simulate the rod swing motion in an engine. A synchronization system was built to detect the loading position and match the load signal and rod rotation signal. More details will be shown in the next few sections to introduce these individual systems in the bench rig.

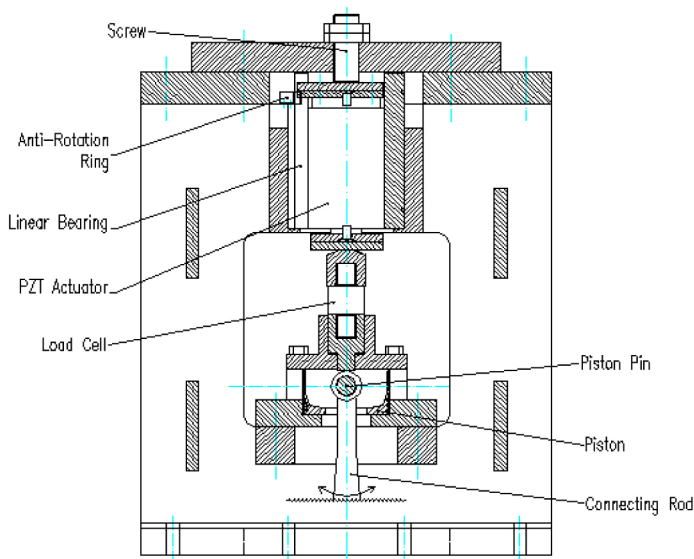


Figure 1. Schematic of the bench rig

LOADING SYSTEM

In a combustion engine, there are four phases during two cycles of crankshaft rotation. This includes intake, compression, power and exhaust. The peak pressure in the piston occurs in the power phase and the pressure returns to atmospheric pressure sharply (Figure 2). In the other three phases, the pressure in the piston is slightly above atmospheric pressure. Hence the load applied in the piston assembly is correlated with the rotating position and cycle of the connecting rod. The Piezoelectric transducer is a solid-state ceramic actuator which converts electrical energy directly into linear motion (mechanical energy) with high resolution. The PZT (Piezoelectric Transducer) actuator itself has very high stiffness for compression

(66 kN/60 μ m). Due to its stiffness at both ends of the PZT (Piezoelectric Transducer) actuator, even a small displacement can generate a high load. In the schematic drawing (Figure 1), the PZT (Piezoelectric Transducer) actuator is in contact with the load cell components at one end. On the other end a fine pitch screw is utilized to apply a preload on the piston. The compression force generated by the actuator is applied on the small end of the connecting rod; hence on each side of the piston wrist pin and pin bore there is only half of the compression load. The response time of the PZT (Piezoelectric Transducer) actuator is 100 ms (Figure 3); thus the actuator needs 100 ms to increase to its maximum range and also needs 100 ms to return from the maximum range to the original position. The maximum force depends on the stiffness of the entire structure. In the bench test rig, the maximum force obtainable is 1.5-1.6 kN.

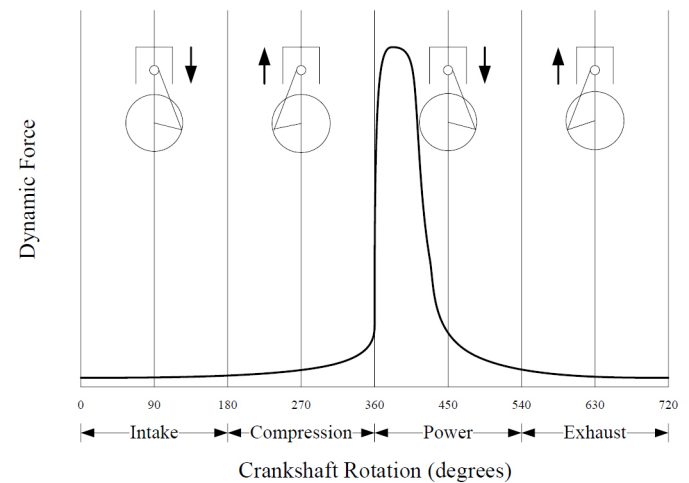


Figure 2. Schematic of cylinder pressure vs crankshaft angle

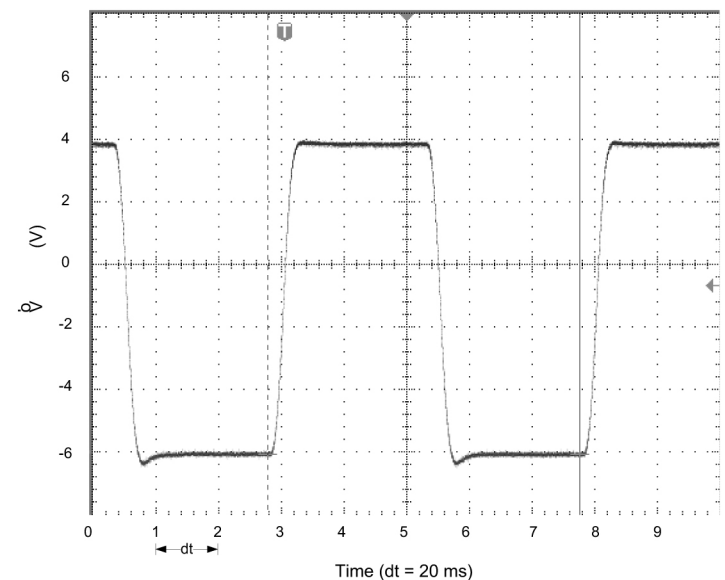


Figure 3. Response curve of PZT (Piezoelectric Transducer) actuator

ROD SWING SYSTEM

A crank mechanism (Figure 4 and 5) was designed in the bench test rig to simulate the swing motion of the connecting rod. The rotational motion is driven by an AC motor and the crank mechanism transfers