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Behavior of piston rings passing over cylinder ports in two-stroke cycle engines†

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Abstract

In two-stroke cycle engines, the piston and piston ring slide over not only the cylinder wall but also the cylinder ports. This study investigates whether piston rings project and get caught in the cylinder ports. We installed strain gauges, on the bottom sides of piston rings, over the intake and exhaust ports, and plotted the variation of strain per cycle, while running the engine. By examining the variation in strain on the bottom of the piston ring, we clarified that our piston ring indeed became momentarily caught in the cylinder ports.

Keywords: Cylinder port; Piston ring; Strain; Two-stroke cycle engine

1. Introduction

In a two-stroke cycle engine, the piston and piston rings heat up due to combustion as the crankshaft rotates. The piston and piston ring slide over not only the cylinder wall but also the cylinder ports. Scuffing may occur on the piston rings as it slides over the cylinder ports because the ports can disrupt the oil film on the sliding surface. Further, we hypothesize that piston rings can project and get caught in the ports (except piston ring gaps), causing further scuffing. As far as we can tell, no experiments have reported on the measurement of the extent to which piston rings project and get caught in the ports. In this study, we installed strain gauges, on the bottom sides of piston rings, over the intake and exhaust ports and plotted the variation in strain per cycle, while running the engine. Examining the variation in strain per cycle, we investigated whether piston rings do in fact project and get caught in the ports.

2. Experimental apparatus and procedure

Fig. 1 shows our experimental apparatus. We used a two-stroke air-cooled single-cylinder gasoline engine with a bore of 62 mm and a stroke of 58 mm. In this engine, the cylinder has an intake port on the thrust side, an exhaust port on the anti-thrust side, and scavenging ports on both the front and rear sides. In this piston, we installed two rings: a barrel-faced half keystone top ring on top and a taper–faced rectangular second ring below it. Both rings had a width of 2.0 mm, a thickness of 2.8 mm, and a tension of 11N. The ring grooves in our piston use stop pins to prevent rotation of the rings under engine operation. Fig. 2 shows the positions of the intake and exhaust ports around the top and second rings. In order to measure the strain on the bottom sides of the rings as they slid over the ports, we used a strain gauge with a grid width of 0.84 mm and a grid length of 2.0 mm. We attached the strain gauge on the bottom sides of our rings over the center of port width. To protect the lead wires of our strain gauge from breaking, we set terminals next to the strain gauge, then connected our lead wires and heavy-duty signal wires via terminals, as shown in Fig. 3. In order to prevent the strain gauge from damping, the strain gauge was covered with silicone sealing, as shown in Fig. 4. We ground and drilled the ring grooves and the piston crown, as shown in Fig. 5, then installed the rings and strain gauge, and finally drew signal wires from the strain gauge through the inside of the piston, and out of the piston crown. To prevent the signal wires from breaking under engine operation, we attached the signal wires to a steel sheet spring [1] with epoxy adhesive, as shown in Fig. 6. Signals from the strain gauge were sent via a bridge box to a dynamic strain amplifier, and finally displayed and recorded on an oscilloscope.

In each experiment, we applied sufficient two-stroke oil to the cylinder wall at the engine bottom dead center (BDC), and then calibrated a ring strain of zero at the engine top dead center (TDC). We then ran the engine while measuring ring strain throughout the engine cycle. Experiments were carried out at room temperature with engine speeds of 100, 200, 300, and 400 rpm.

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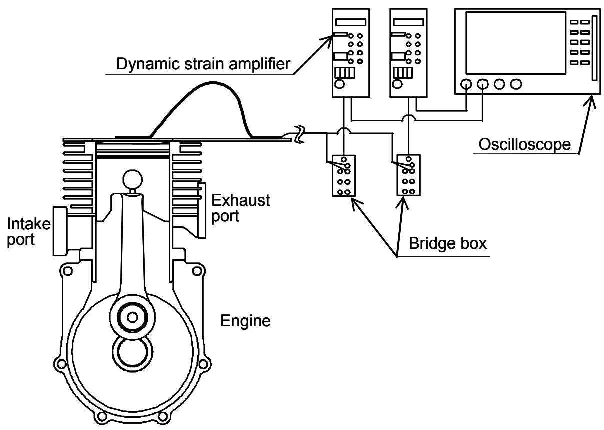


Fig. 1. Experimental apparatus.

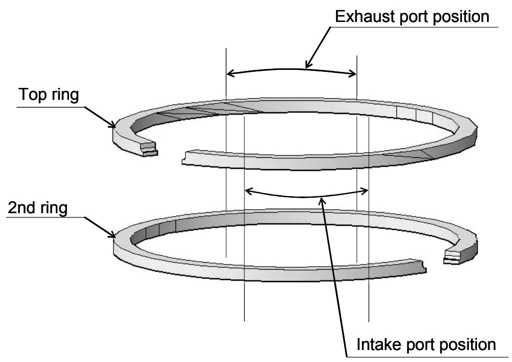


Fig. 2. Positions of the intake and exhaust ports around the top and second rings.

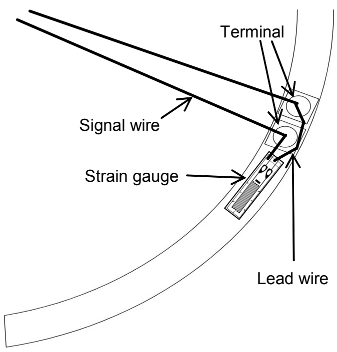


Fig. 3. Strain gauge and signal wire at the bottom of the piston ring.

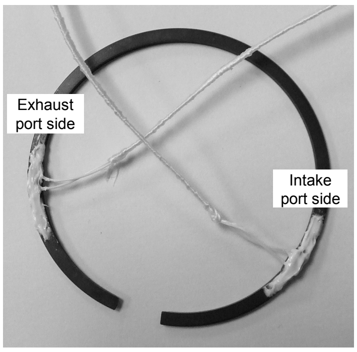


Fig. 4. Strain gauges and signal wires at the bottom of the second ring.

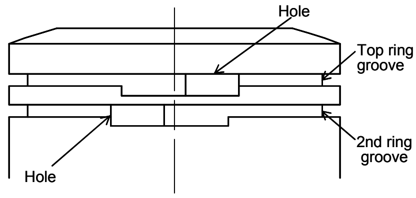
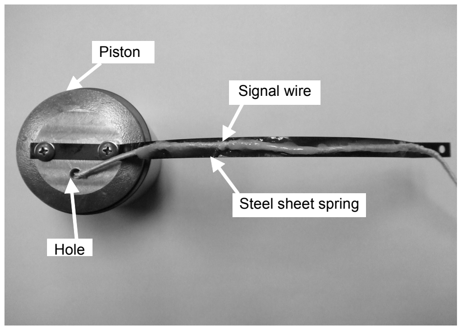
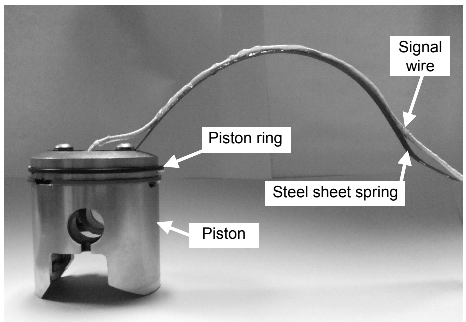


Fig. 5. Ground and drilled piston ring grooves and piston crown.



(1) Top view



(2) Side view

Fig. 6. Signal wires installed on the steel sheet spring.

3. Results and considerations

Figs. 7 and 8 show typical examples of our strain measurements from the bottoms of the top and second rings, respectively, as they move above and over the intake port, while the engine ran at 300 rpm. At the bottom dead center (BDC), the top ring is located above the intake port, and the second ring is located over the intake port.

Fig. 7 shows that the bottom of the top ring had a positive strain during the downward stroke and a negative strain during the upward stroke. However, the strain did not increase instantaneously in either the downward or upward strokes, because the top ring did not pass over the intake port. Part "A" of Fig. 8 shows the second ring strain increasing during the downward stroke while moving past the intake port to BDC. We surmise that the second ring projected into the intake port there. Then part "B" of Fig. 8 shows strain instantaneously increasing immediately after the second ring moved upward from BDC. Evidently, the second ring gets caught in the intake port.

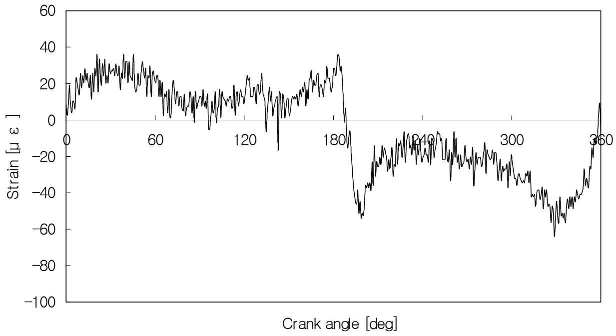


Fig. 7. Strain at the bottom of the top ring above the intake port at 300 rpm; Crank angles of 0 and 360º represent TDC, and 180º BDC.

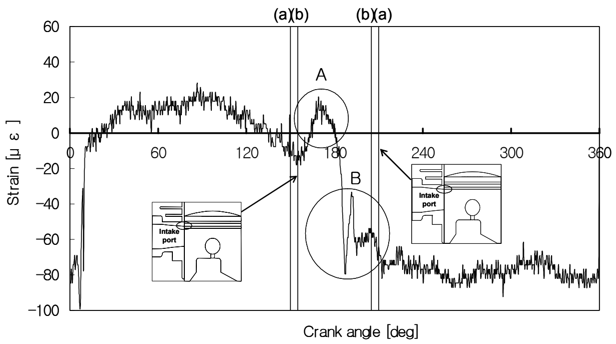


Fig. 8. Strain at the bottom of the second ring over the intake port at 300 rpm; (a) represents the position where the bottom side of the ring is located at the upper side of the intake port, and (b) the position where the upper side of the ring is located at the upper side of the intake port.

Figs. 9 and 10 show typical examples of our strain measurements from the bottoms of the top and second rings, respectively, as they move over the exhaust port, while the engine again ran at 300 rpm. Both top and second rings pass over the exhaust port.

Fig. 9 shows no strain increase when the top ring moved over the exhaust port. However, part "C" of Fig. 10 shows instantaneous strain increase in the upward stroke when the second ring moved to the bottom side of the exhaust port. It seems that the second ring also gets caught in the exhaust port.

Each engine speed showed these phenomena.

Next, we analyzed the piston behavior using the simulation software "AVL EXCITE Piston & Rings." We created an analysis model with conditions corresponding to our experimental apparatus and conditions. The results indicated that in the downward stroke, the piston moves from the exhaust port side to the intake port side, and then it moves along the intake port side. Immediately after the piston moves upward from BDC, it moves from the intake port side to the exhaust port side, and then continues moving along the exhaust port side. It appears that the second ring projects and gets caught in the ports when the piston moves along the intake and exhaust port sides, and it moves from the intake port side to the exhaust port side.

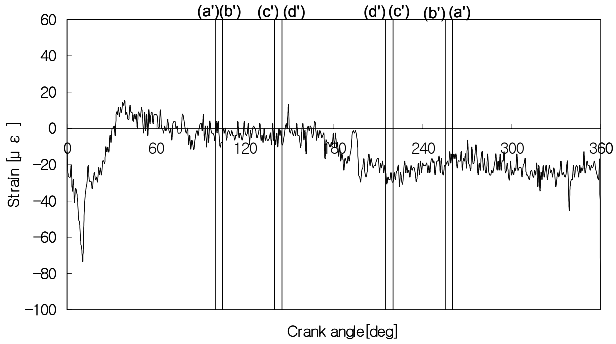


Fig. 9. Strain at the bottom of the top ring over the exhaust port at 300 rpm; In Figs. 9 and 10, (a') represents the position where the bottom side of the ring is located at the upper side of the exhaust port, (b') the position where the upper side of the ring is located at the upper side of the exhaust port, (c') the position where the bottom side of the ring is located at the bottom side of the exhaust port, and (d') the position where the upper side of the ring is located at the bottom side of the exhaust port.

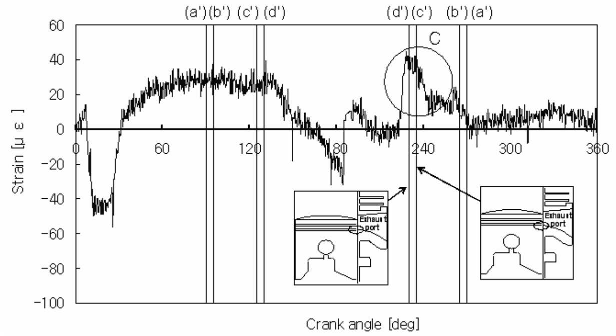


Fig. 10. Strain at the bottom of the second ring over the exhaust port at 300 rpm.

In our experiment, only the second ring projected and got caught in the ports. It seems that it is easier for the second ring to project and get caught in the ports than the top ring, probably because the contact width of the second ring with its taper-face is narrower than that of the top ring with its barrel-face.

4. Conclusion

We investigated whether piston rings project and get caught in the ports by examining the variation in strain on the bottoms of the rings while an engine is run. The result indicated that the second ring indeed projected and got caught in the intake and exhaust ports.

Acknowledgment

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References

[1] M. Yamamoto and O. Tsutsui, Experiment and evaluation technology of tribology to solve problem, *The 39th Tribology Advanced Course*, Tokyo, Japan (1994) 91-108.

Kohei Nakashima received his Ph.D. degree in Mechanical Engineering from Meijo University, Nagoya, Japan in 1996. He is currently an Associate Professor at the Department of Transportation Engineering at Meijo University. Dr. Nakashima's research interests include engine tribology, engine cooling, and fuel cell.