

Projection Behavior of Piston Rings in Cylinder Ports of a Two-Stroke Cycle Engine

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ABSTRACT

Two-stroke engine cylinders have ports to exchange gas. While the engine runs, the piston and its piston rings slide over these ports in the cylinder walls, and the rings may project into the ports. This paper explores this, first, by reporting a simple model of material mechanics that predicts rings might project into ports, and second, our experimental verification. We installed strain gauges on the bottom of the top and second rings, over the intake and exhaust ports, and ran signal wires out of the engine. We then examined the variations of strain while running the engine. Our analysis confirmed how the dimensions and the tension of the rings, and the dimensions of the ports, affect ring projection into ports as static displacements. Our measured ring strain suggests that, on the upward stroke, the top and second rings indeed project into the exhaust port; while the top ring catches in the upper side of the exhaust port, and the second ring catches in the upper sides of both intake and exhaust ports.

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INTRODUCTION

In two-stroke engines of the crankcase-compression type, the cylinder is pierced by intake, scavenge, and exhaust ports. To exchange gas through these ports during each engine cycle, the ports are opened and closed by the moving piston, as the piston and its piston rings pass over the ports. Due to the ring tension exerted onto the cylinder wall, rings may project into the ports. The ports may disrupt the oil film on the sliding surface of the rings, leading to ring scuffing. Successful ring design thus requires understanding the extent to which rings project into the ports. However, we have seen no full reports investigating ring projection into ports. So, in this study, we analyzed ring projection as static displacement using the beam model. We also installed strain gauges on the bottom sides of rings over the intake and exhaust ports, and then examined the ring projection in the ports using the variation in strain on the bottom of rings while running our engine [1].

ANAYSIS OF RING PROJECTION IN PORTS USING BEAM MODEL

Although previous studies have analyzed ring structure [2, 3, 4, 5, 6], none address ring projection in ports. Therefore this study first analyzes ring projection using a beam model.

In two-stroke engines, the positions of ring gaps are fixed with stop pins in ring grooves, keeping the ring gaps away from the ports. Looking at the ring in the port in cylinder circumference, the ring can be assumed to be a curved beam with a distributed load, with fixed support at the two port ends. However, the radius of the center plane in the ring is considerably larger than the ring thickness. Therefore, the curved beam can be replaced with a straight beam, providing a simpler model. In Fig. 1 [7], the deflection of the straight beam with its distributed load between the fixed supports at the two port ends (i.e., the ring projection into the port) can be expressed using Eqs. (1) and (2).

$$v = \frac{wl^4}{24EI} \left(\frac{x^2}{l^2} - \frac{2x^3}{l^3} + \frac{x^4}{l^4} \right) \quad (1)$$

$$v_{\max} = \frac{wl^4}{384EI} \quad \cdots \left(x = \frac{l}{2} \right) \quad (2)$$

Here v is the ring projection into the port [m], w is the force per unit length acting on the ring [N/m], l is the port length [m], x is the distance from the port edge [m], E is the elastic modulus of the ring [N/m²], and I is the moment of

inertia of the area in the ring [m^4] ($I = h_1 a_1^3 / 12$, where h_1 is the ring width [m], and a_1 is the ring thickness [m]).

Eqs. (1) and (2) show that ring projection into a port increases when the port length, and the force per unit length acting on the ring increase, and the elastic modulus, the ring width, and the ring thickness decrease. Ring thickness and port length have an especially great effect on the ring projection into the port.

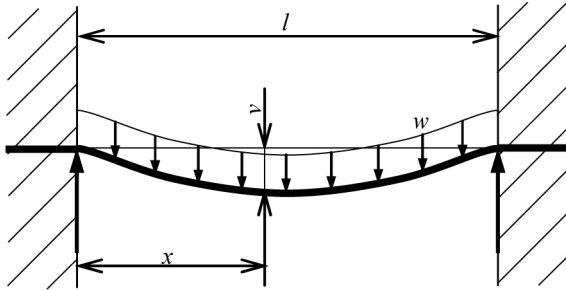


Figure 1. Beam model [7]

EXPERIMENTAL VERIFICATION OF RING PROJECTION INTO PORTS DURING ENGINE OPERATION

Experiment

Figure 2 shows our experimental apparatus, featuring a two-stroke air-cooled single-cylinder gasoline engine displacing 0.175L with a bore of 62mm and a stroke of 58mm. The cylinder includes 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, as shown in Figs. 3 and 4. Into the piston we installed two rings, as shown in Table 1. Each piston ring groove has a stop pin setting the gap positions of the top and second rings, as shown in Fig. 4.

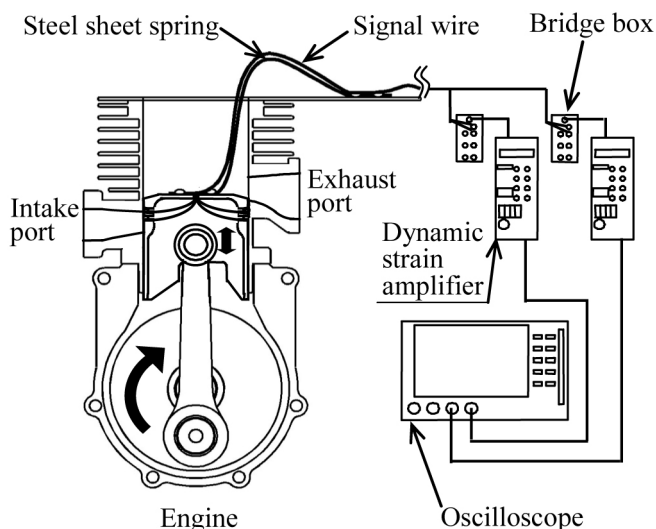


Figure 2. Experimental apparatus

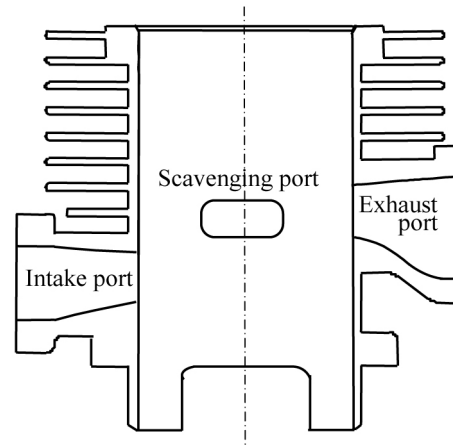


Figure 3. Experimental cylinder

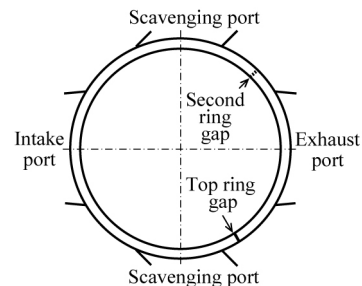


Figure 4. Positions of cylinder ports

Table 1. Specifications of piston rings

		[mm]
Top ring		End clearance 0.29
		Free gap 8.8
Second ring		Tension 11N
		Elastic modulus 95GPa
		Chrome plating
		Joint with side notch
Second ring		End clearance 0.37
		Free gap 9.0
		Tension 11N
		Elastic modulus 88GPa
Second ring		Phosphate
		Joint with side notch

Eqs. (1) and (2) predict that ring projection in ports increases with port length. So we investigated ring projection into the intake and exhaust ports, rather than the narrower scavenging ports. Ignoring gas pressure, our model predicts that the projection of both top and second rings into both the intake and exhaust ports is approximately $5\mu\text{m}$ at the center of each port length. We will verify this model calculation in the future.

We installed strain gauges on the bottom sides of the two rings, over the center of the intake and exhaust ports. We set terminals next to the strain gauges, and connected lead wires from the strain gauges to the terminals, and then heavy duty