ANALYSIS OF THE WEAR OF PISTON RING PROTOTYPE OF AN EMBANKMENT OF DIAMOND IN TERMS ENDURANCE TEST

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Abstract

The article discusses the results of the wear of piston rings for internal combustion engines with spark ignition. The research was a prototype multilayer ring sealing of the porous coating and the so-called chromium embankment diamonds. Technology of the rings is the deposition of multilayer coatings in the process of chromium plating. In times of chromium deposited from the bath, particles are technical diamond's shape, and granulation. This technology is a response to domestic factory piston rings to the needs of the automotive market and is an innovative development. Conducted engine tests consisted of a 50-hour cycle and to hour break-in team life cycle, which was repeated 150 times. Thus, the total duration of sample equal to 200 hours. Cycle life is a team containing a phase-hour cycle engine traffic load at maximum speed and maximum torque and maximum power of the tween partial load and idling. This cycle is repeated in the 200-hour test 150 times. During the measurement of key indicators were measured at the engine, the fuel consumption, coolant temperature and pressure of the lubricating oil. In order to calculate the wear of piston rings, the difference was calculated to measure the thickness and height before and after sample of 200 hours. In a similar way as the use of thickness and height of the rings was calculated by weight loss.

Keywords: combustion engine, piston ring, wear

1. Purpose and scope of work

The aim of the research work presented in this article was to examine the durability of the engine team with spark ignition equipped with steel piston rings made in the technology for the embankment of the first groove and diamond also nitrided steel oil rings. The object of this study was to verify the quantitative value of wear of piston rings studied. Scope of work included the implementation of 200-hour endurance test the engine team, the geometric thickness measurement, height and weight of the piston rings and the study of sensory surfaces of the cylinder liners and pistons, with whom they worked. This paper is a continuation of the stability studies of cyclic combustion engine TPC team, which is published in [1, 3].

2. Picking teams of piston rings

The piston rings have been installed according to the following completion:

- 1, 3 cylinder:
- first piston groove – piston ring sealing the rectangular steel nitrided barrel symmetrical about 1.2 mm,
- second piston groove – minute piston ring sealing the lower internal phase of iron K-12 standard,
- third piston groove – oil piston ring with spiral spring steel nitrided.
- 2, 4 cylinder:
- first piston groove - piston ring seal of rectangular steel barrel asymmetrical PCD coated with a height of 1.2 mm,

- second piston groove – minute piston ring sealing the lower internal phase of iron K-12,
- third piston groove – oil piston ring with spiral spring steel chromed.

3. Team durability test

After all the installation work was carried out test measurements of piston rings and other engine components cooperating with them in a combustion engine with spark ignition type 1170A1 046 CF2 900 SPI "BASIC S" POLONIA Seicento car 900 serial number 9888751. The engine is mounted on a test bed in the laboratory of the Department of Vehicle and Internal Combustion Engines of the Institute of Machine Design and Operation of the Wroclaw University of Technology. Function Dynamometer RSPU Raszyn production company is equipped with a brake that allows removal of water for continuous characteristics and the internal combustion engine with maximum power of 75 kW, for up to 6000 r/min and meets the requirements posed by the Seicento 900 engine with a capacity of 29 kW at 5500 r/min (data taken from the service Manual for the engine).

Engine during the test was run on petrol 95 Eurosuper of specific gravity 0.755 g/cm^3. The lubricant oil used was semisynthetic 10W/40 SELENIA ACT. The coolant was PARAFLU 11. In order to simulate actual working conditions and the need to ensure adequate thermal conditions introduced additional conditions simulating a fan blowing while driving the car and ensures proper cooling of the engine. However, in the lubricating system, due to very strict regimes hour endurance test team, there was a need for additional cooling of the lubricating oil.

Layout engine - water brake is equipped with all necessary equipment for the proper conduct of the test. The complete exhaust system made of two silencers (middle and last) and a catalyst such as mounted in the car Seicento. Exhaust gas was carried out with power exhaust fan in a way that after leaving the final exhaust silencer had to travel only the distance of about 3 meters in the level, after which they were placed in the exhaust stack with said fan. The system is designed so as not to interfere with their free course. Furthermore, the position is equipped with a system that allows the fuel supply consisting of a factory fuel tank capacity of 40 gallons in the vicinity of the bench.

Conducted engine tests consisted of a 50-hour cycle and to hour break-in team life cycle, which was repeated 150 times. Thus, the total duration of sample equal to 200 hours. Reaching the engine was carried out as in the statement below in Tab. 1.

Tab. 1. Test running of the engine

	Time [%]	Time [h]	Power [%]	Power [kW]	Rotations [%]	Rotations [r/min]
1	0-5	2.5	0	0	30	1650
2	5-8	1.5	13	4	40	2200
3	8-25	8.5	35	10	60	3300
4	25-50	12.5	50	14,5	70	3850
5	50-80	15	70	20	90	4950
6	80-90	5	75	22	95	5220
7	90-100	5	100	29	100	5500

The duration of the running cycle was equal to 50 hours. At the end of the running cycle, it was found that the engine has an output of 29 kW at a speed equal to 5500 r/min and maximum torque of 65 Nm in the range from 2800 to 3300 r/min. These data were consistent with the data of the engine and allowed the factory to determine the life cycle of team points shown in Tab. 2 Cycle life is a team containing a phase-hour cycle engine traffic load at maximum speed and maximum torque and maximum power of the tween partial load and idling. This cycle is repeated in the 200-hour test 150 times. During the measurement of key indicators were measured at the engine, the fuel consumption, coolant temperature and pressure of the lubricating oil.

Tab. 2. Team durability test

Step	Time [%]	Time [min]	Power [%]	Power [kW]	Torque [%]	Torque [Nm]	Rotations [%]	Rotations [r/min]	Measurement
1	16.7	10	0	0	0	0	100%	5500	Yes
2	25.0	15	68	20	100	65	Torque Max	3000	Yes
3	16.7	10	50	14	70	45,5	75%	4120	Yes
4	16.7	10	100	29	90	58,5	Power Max	5500	Yes
5	25.0	15	0	0	0	0	Idle Run	950	Yes

On average, during the hour cycle engine it used in step 1 Cycle of about 750 cm^3 of fuel, in step 2 Cycle of about 2300 cm^3 of fuel, in step 3 Cycle of about 1250 cm^3 of fuel, in step 4 Cycle of about 2300 cm^3 of fuel and in step 5 Cycle of about 230 cm^3 of fuel. In total, during one cycle of the engine consumed an average of about 6830 cm^3 of fuel. In total, 1024 litters were used about of gasoline during the life of 150 cycles and about 220 litters of petrol in the course of 50 running-hour cycle. In total, the engine used about 1244 litters of fuel during the entire 200-hour test. During the tests are listed lubricating oil with the oil filter. Moreover, were added 3.0 litter lubricating oil. The wear of oil is significant.

4. The values of piston ring wear

In order to calculate the wear of piston rings, the difference was calculated to measure the thickness and height before and after sample of 200 hours. The results of these calculations are shown in Tab. 3 and 4.

In a similar way as the use of thickness and height of the rings was calculated by weight loss. The results of these calculations are presented in Tab. 5.

5. The analysis of measurement results of investigation of wear rings

5.1. The first sealing rings

The first sealing rings are made in the technology of rolling of steel strip and subjected of the process of chroming (Fig. 1).

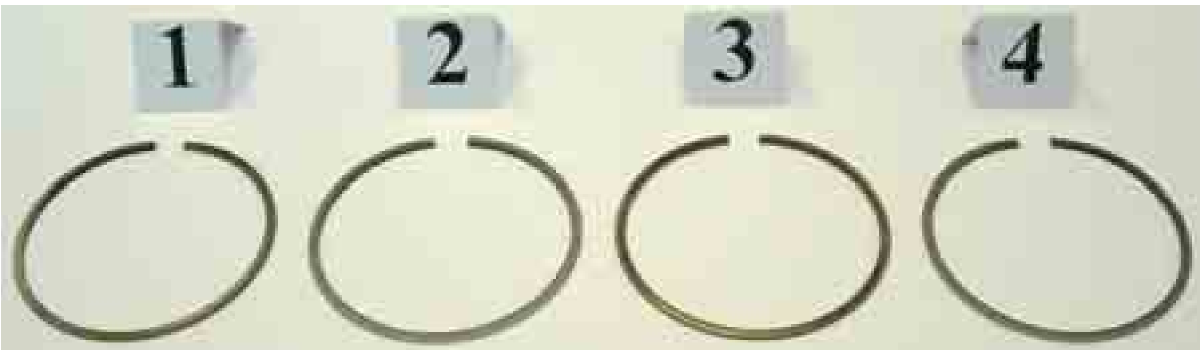

Fig.1. The first sealing rings after the tests

In all of the rings, traces of cooperation on the top shelf are concentrated around the perimeter of the entire width of the surface (Fig. 1). Lower shelf shows signs of cooperation around the perimeter of the surface. Partially vaguely visible signs of cooperation in the lower outer edge of the rings 1 and 3.

All of the rings shows the correct cooperation with the surface of the cylinders. The surface of the rings is evenly worn around the perimeter of the height of the rings (Fig. 2–5). In particular, the rings 1 and 3 were slightly consumption over the entire surface, at about 3/4 height from the bottom edge. 2 and 4 rings are worn on the entire surface, while maintaining a symmetrical barrel shapes.

Tab. 3. The wear of radial thickness of piston rings

Ring No.	Liner wear [mm]										Z_{av} [mm]
	1	2	3	4	5	6	7	8	9	10	
1/1	–0.009	–0.012	–0.02	–0.02	–0.011	–0.007	–0.002	0.000	–0.014	–0.009	–0.0104
2/1	0.001	0.000	0.005	0.002	–0.003	0.003	0.004	0.002	0.003	0.000	0.0017
3/1	–0.006	–0.003	0.001	–0.001	–0.01	–0.002	0.004	–0.004	0.003	0.002	–0.0016
4/1	0.002	0.003	0.000	0.000	0.002	0.002	0.001	0.001	0.000	–0.003	0.0008
1/2	0.011	0.004	0.009	0.002	0.009	0.008	0.005	0.000	0.005	0.020	0.0073
2/2	0.023	–0.002	0.006	0.004	0.003	0.000	0.013	0.010	0.004	0.012	0.0073
3/2	0.018	0.004	0.009	0.009	0.005	0.005	0.008	0.010	0.005	0.015	0.0088
4/2	0.014	0.007	0.003	0.000	–0.003	0.001	0.009	0.013	0.009	0.001	0.0054
1/3	0.02	–0.011	0.028	0.015	–0.002	0.014	0.006	–0.009	0.018	0.013	0.0092
2/3	0.007	–0.001	–0.001	0.021	0.000	0.001	0.004	0.021	0.059	0.009	0.0120
3/3	–0.004	0.009	0.024	0.014	–0.015	0.042	0.022	–0.003	0.023	–0.001	0.0111
4/3	0.039	0.014	0.002	0.013	0.024	–0.025	0.005	0.017	0.011	–0.004	0.0096

Tab. 4. The wear of axial high of piston rings

Ring No.	Liner wear [mm]										Z_{av} [mm]
	1	2	3	4	5	6	7	8	9	10	
1/1	0.000	–0.005	–0.005	–0.003	–0.004	–0.005	–0.004	–0.003	–0.003	–0.003	–0.0035
2/1	0.000	0.005	0.003	0.002	0.004	0.004	0.006	0.006	0.006	0.008	0.0044
3/1	–0.001	–0.004	–0.001	0.001	0.001	0.001	0.000	0.000	0.003	–0.002	–0.0002
4/1	0.010	0.010	0.010	0.011	0.013	0.012	0.008	0.008	0.008	0.014	0.0104
1/2	0.005	0.005	0.005	0.005	0.006	0.004	0.007	0.007	0.006	0.010	0.0060
2/2	0.008	0.006	0.003	0.006	0.008	0.008	0.007	0.006	0.002	0.006	0.0060
3/2	0.005	0.002	0.007	0.005	0.007	0.003	0.007	0.004	–0.001	0.006	0.0045
4/2	0.005	0.005	0.005	0.001	0.005	0.002	0.004	0.002	0.003	–0.008	0.0024
1/3	0.002	–0.003	–0.002	–0.002	0.000	–0.001	0.003	0.002	0.002	0.003	0.0004
2/3	0.001	0.004	0.002	0.004	0.003	0.005	0.005	0.006	0.005	0.006	0.0041
3/3	0.002	0.006	0.007	0.006	0.004	0.002	0.000	0.001	0.002	0.003	0.0033
4/3	0.007	0.007	0.005	0.005	0.003	0.004	0.005	0.005	0.005	0.008	0.0054

Tab. 5. Change of mass of piston rings

Ring No.	1/1	2/1	3/1	4/1	1/2	2/2	3/2	4/2	1/3	2/3	3/3	4/3
Loss of weight [mg]	–2.5	4.7	16.1	15.8	17.2	6.5	10.8	8.3	3.2	1.8	12.6	2.9

Fig. 2. View of side surface of the first ring of the cylinder No. 1

Fig. 3. View of side surface of the first ring of the cylinder No. 2

Fig. 4. View of side surface of the first ring of the cylinder No. 3

Fig. 5. View of side surface of the first ring of the cylinder No. 4

Average value of wear of the radial width of the **ring 1/1** is equal to –0.0104 mm. In all 10 measuring points on the circumference of increment widths ranging from –0.02 to 0.0 mm were measured. Also increase of the axial high – 0.003 Mm were measured. Was measured the weight gain equal to 0.0025 g, confirming increasing the size of the rings. Any discussion about the causes of this phenomenon requires detailed materials research

Average value of wear of the radial width of the **ring 2/1** is equal to 0.0017 mm. In all 10 measuring points on the circumference of wear ranging from -0.003 to 0.003 mm was measured. Average value of wear of the axial height is equal of 0.0044 mm. Loss of weight of the ring 2/1 is equal to 0.0047 g and it confirms the results of the wear of the width and height of the ring.

Average value of wear of the radial width of the **ring 3/1** is equal to -0.0016 mm. In almost all 10 measuring points on the circumference of increment widths ranging from -0.006 to 0.003 mm were measured. Also increase of the axial high -0.003 Mm were measured. Was measured the weight gain equal to 0.0161 g, confirming increasing the size of the rings. Any discussion about the causes of this phenomenon requires detailed materials research

Average value of wear of the radial width of the **ring 4/1** is equal to 0.0008 mm. In all 10 measuring points on the circumference of wear ranging from -0.003 to 0.003 mm was measured. Average value of wear of the axial height is equal of 0.0104 mm. Loss of weight of the ring 2/1 is equal to 0.0158 g and it confirms the results of the wear of the width and height of the ring.

6. The tests of the components cooperating with piston rings

6.1. Cylinder sleeve

Cylinder liners have a little wear except the sleeve 2 and 4. Honing features are not visible. On all surface of the cylinder above the TDC, I of the sealing ring and on the surface of the combustion chamber of the cylinder head were found deposits. Deposits have a thickness of about 0.3 mm.

In all cylinders between the TDC of the third ring, and the BDC of the first ring was found in a direction perpendicular to the motor cross the occurrence of longitudinal features on both sides of the sleeve (Fig. 6). It should be noted that the sleeves have 1500 hours engine traffic the total mileage (seven tests including one longer by 50%). In summary, the wear of the sleeve is the result of the 1500 hours work [4, 5].

6.2. Pistons

In this test was used a new custom pistons. The height the groove of the first sealing ring equal to 1.2 mm, and the standard height of the groove of oil ring equal to 2 mm.

Pistons organoleptic tests showed no significant wear. Cooperation with the piston rings, cylinder liners as well was fine. It was only found tiny imperceptible features on the piston surface in the section parallel to the axis of piston pin (Fig. 7).

Fig. 6. View of the engine block after test, removing the pistons and removing deposits

Fig. 7. The view of the piston groups after the tests

It was a large amount of carbon deposits on pistons bottom, which is the result of the increased by about 50% lubricating oil consumption compared to the normal wear (Fig. 8). This may be due to the reduced height of oil rings.

Fig. 8. View of the pistons after tests

7. Conclusion

- There has been little measurable wear the rings first. This applies mainly to the embankment diamond rings mounted in slots 2 and 4,
- Cooperation is the correct side surface around the perimeter of the first ring and cantered in the middle of their height (symmetrical barrel),
- The wear of cylinder in slots 2 and 4 qualify the engine block to the overhaul.

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