ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1136598

ANALYSIS OF THE WEAR OF PISTON RINGS PROTOTYPE IN TERMS OF TEAM ENDURANCE TEST

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Abstract

The article discusses the results of the wear of piston rings for internal combustion engines with self ignition. The research was a prototype multilayer ring sealing of the porous coating and the so-called chromium embankment diamonds [2]. 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 self ignition equipped with steel piston rings made in the technology for the embankment of the first groove and diamond also chrome coating 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 – steel piston ring barrel symmetrical with chrome coating.
Second piston groove – minute steel piston ring sealing the lower internal phase; standard.
Third Piston groove – oil piston ring with spiral spring steel chromed.

2, 4 cylinder:

First piston groove – steel piston ring of rectangular barrel symmetrical PCD coated.
Second piston groove – minute steel piston ring sealing the lower internal phase; standard.
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 self ignition type VW 1.9 tdi. 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 AVL Zollner production company is equipped with a brake that allows for continuous characteristics and the internal combustion engine with maximum power of 240 kW, for up to 6000 rpm and meets the requirements posed by the VW 1.9 tdi engine with a capacity of 100 kW at 4000 r/min (data taken from the service Manual for the engine).

Engine during the test was run on diesel fuel specific gravity 839.9 kg/m^3. The lubricant oil used was synthetic 5W/40 CASTROL EDGE. The coolant was MEYLE. 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.

Layout engine – elektro 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 VW. 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.

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	r/min %	r/min
1	0–5	2.5	0	0	30	1200
2	5–8	1.5	13	13	40	1600
3	8–25	8.5	35	35	60	2400
4	25–50	12.5	50	50	70	2800
5	50–80	15	70	70	90	3600
6	80–90	5	75	75	95	3800
7	90–100	5	100	100	100	4000

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 100 kW at a speed equal to 4000 r/min and maximum torque of 260 Nm in the range from 1600 to 3000 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.

On average, during the hour cycle engine it used in step 1 Cycle of about 780 cm^3 of fuel, in step 2 Cycle of about 3600 cm^3 of fuel, in step 3 Cycle of about 3850 cm^3 of fuel, in step 4 Cycle of about 3460 cm^3 of fuel and in step 5 Cycle of about 125 cm^3 of fuel. In total, during one cycle of the engine consumed an average of about 11820 cm^3 of fuel. In total, 1773 liters were used about of diesel fuel during the test of 150 cycles and about 230 liters of diesel fuel in the course of 50 running-hour cycle. In total, the engine used about 2003 liters of fuel during the entire 200-hour test. During the tests are listed lubricating oil with the oil filter. Moreover, were added 2.35 liter lubricating oil. The wear of oil is significant, but characteristic for VW 1.9 TDI diesel engine.

Tab. 2. Team durability test

Step	Time %	Time min	Power %	Power kW	Torque %	Torque Nm	r/min %	r/min	Measurement
1	16.7	10	0	0	0	0	100%	4000	Yes
2	25	15	68	68	100	260	Max. torque	2100	Yes
3	16.7	10	50	50	70	182	75%	3000	Yes
4	16.7	10	100	100	90	234	Max. power	4000	Yes
5	25	15	0	0	0	0	Idle	950	Yes

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 Tab. 4

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

No. of ring	Liner wear, mm										Z_{av} mm
	1	2	3	4	5	6	7	8	9	10	
1/1	0.003	0	0.006	0.001	0.006	0	0.001	0.001	0.003	0.008	0.003
2/1	0.003	0.005	0.006	0.003	0.005	0.004	0.005	0.005	0.006	0.002	0.004
3/1	0.006	0.001	0.005	0.006	0.007	0.005	0.007	0.005	0.007	0.008	0.006
4/1	0	0.002	0.005	0	0.006	0.004	0.006	0.01	0.007	0.003	0.004
1/2	0.037	0.025	0.038	0.034	0.031	0.038	0.039	0.031	0.029	0.033	0.034
2/2	0.042	0.019	0.029	0.03	0.031	0.027	0.023	0.028	0.018	0.032	0.028
3/2	0.041	0.02	0.021	0.03	0.03	0.028	0.031	0.029	0.013	0.039	0.028
4/2	0.027	0.014	0.03	0.02	0.03	0.026	0.028	0.022	0.024	0.037	0.026
1/3	0.01	0.011	0.014	0.007	0.01	0.003	0	0.021	0.01	0.008	0.009
2/3	0.007	–0.001	–0.001	0.021	0	0.001	0.004	0.021	0.059	0.009	0.012
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

No. of ring	Liner wear, mm										Z_{av} mm
	1	2	3	4	5	6	7	8	9	10	
1/1	0.009	0.009	0.006	0.005	0.009	0.005	0.005	0.008	0.008	0.006	0.007
2/1	0.002	0.008	0.005	0.005	0.009	0.007	0,007	0.008	0.007	0.004	0.006
3/1	0.01	0.007	0.008	0.007	0.01	0.01	0.009	0.01	0.012	0.011	0.009
4/1	0.007	0.009	0.01	0.009	0.009	0.012	0.011	0.01	0.011	0.01	0.010
1/2	0	0.003	0.001	0	0.005	0.001	0.003	0.003	0.004	0	0.002
2/2	0.002	0.005	0.006	0.007	0.005	0.005	0.003	0.004	0.004	0.003	0.004
3/2	0.004	0.003	0.003	0.002	0.001	0.004	0.001	0.003	0.005	0.004	0.003
4/2	0	0.004	0.001	0.003	0.002	0.003	0.001	0.003	0.001	0	0.002
1/3	0.001	0.001	0.001	0.004	0	0	0	0.004	0.004	0.003	0.002
2/3	0.003	0	0.003	0.003	0.004	0.003	0.003	0.001	0.004	0	0.002
3/3	0.005	0.006	0.002	0.004	0.005	0.005	0.004	0.003	0.005	0.002	0.004
4/3	0.005	0.003	0.008	0.006	0.004	0	0.005	0.005	0.006	0.001	0.004

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

Tab. 5. Change of mass of piston rings

No. of ring	Loss of weight, g
1/1	0.0322
2/1	0.0181
3/1	0.0268
4/1	0.0119
1/2	0.0327
2/2	0.0091
3/2	0.0147
4/2	0.0185
1/3	0.0212
2/3	0.0146
3/3	0.0158
4/3	0.0197

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

5.1. The first sealing rings

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

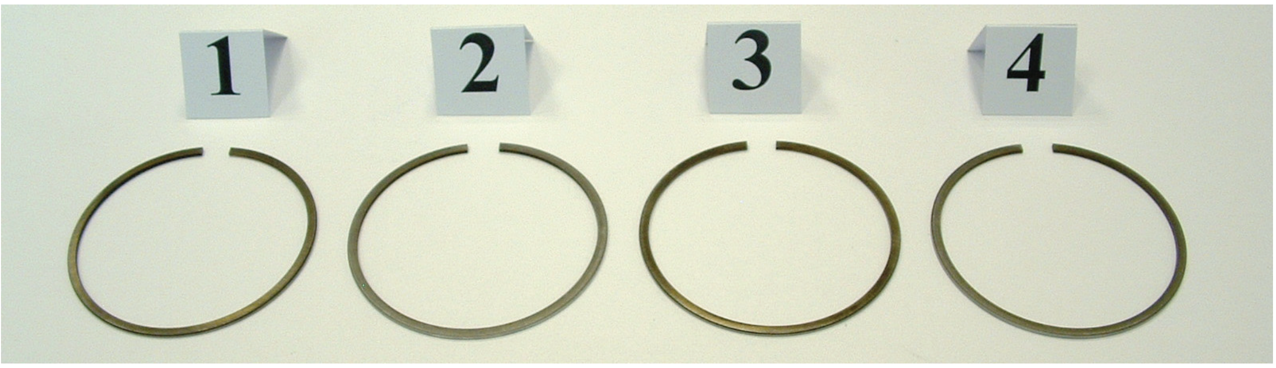

Fig. 1. The first sealing rings after the tests

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.

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).

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

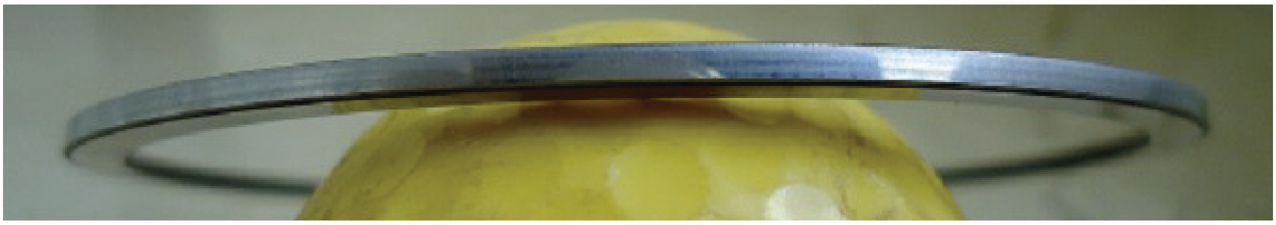

Fig. 3. View of side surface of the first ring of the cylinder No. 2

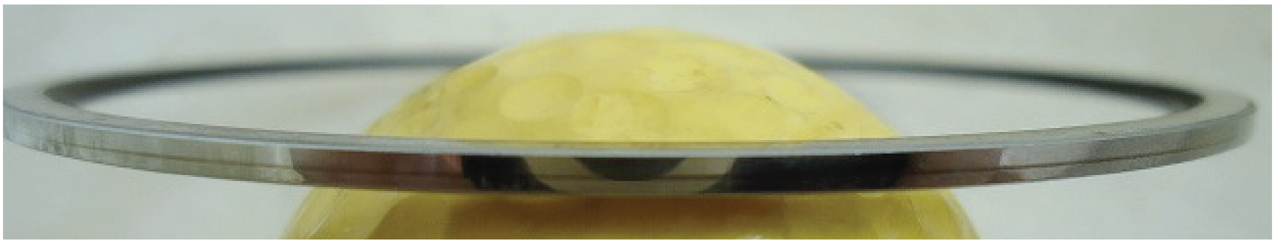

Fig. 4. View of side surface of the first ring of the cylinder No. 3

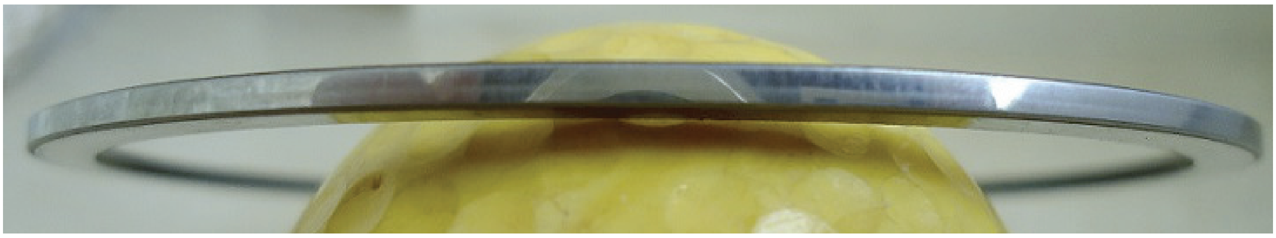

Fig. 5. View of side surface of the first ring of the cylinder No. 4

Average value of wear of the radial width of the ring 1/1 is equal to 0.003 mm. In all 10 measuring points on the circumference of wear ranging from 0.00 to 0.008 mm were measured. Also the rending of the axial high is equal to 0.007 mm were measured . Was measured the weight gain equal to 0.0322 g, 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 2/1 is equal to 0.004 mm. In all 10 measuring points on the circumference of wear ranging from 0.002 to 0.006 mm was measured. Average value of wear of the axial height is equal of 0.006 mm. Loss of weight of the ring 2/1 is equal to 0.0181 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 0.006 mm. In all 10 measuring points on the circumference of wear ranging from 0.001 to 0.008 mm were measured. Average value of wear of the axial height is equal of 0.009 mm. Was measured the weight gain equal to 0.0268 g, 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 4/1 is equal to 0.004 mm. In all 10 measuring points on the circumference of wear ranging from 0.00 to 0.007 mm was measured. Average value of wear of the axial height is equal of 0.009 mm. Loss of weight of the ring 4/1 is equal to 0.0119 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 0.1 mm.

In all cylinders between the TDC of the third ring, and the BDC of the first ring was found the occurrence of longitudinal features on both sides of the sleeve (Fig. 6) [4, 5].

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

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 found only a tiny imperceptible features on the piston surface in the section parallel to the axis of piston pin (Fig. 7).

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 lubricating oil consumption in VW 1.9 TDI engine (Fig. 8).

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 centered in the middle of their height (symmetrical barrel),
- The wear of cylinder in slots 2 and 4 qualify the engine block to the overhaul.
- Causes of excessive wear of cylinders 2 and 4 in ZZ and ring should be seen in coincidence impact PCD coating of the first ring and the upper internal undercut. The use of such relief causes rotation of the ring, resulting from the impact pressure of the exhaust gas around the axis of the free lower edge of the caller cooperation with the working surface of the cylinder.

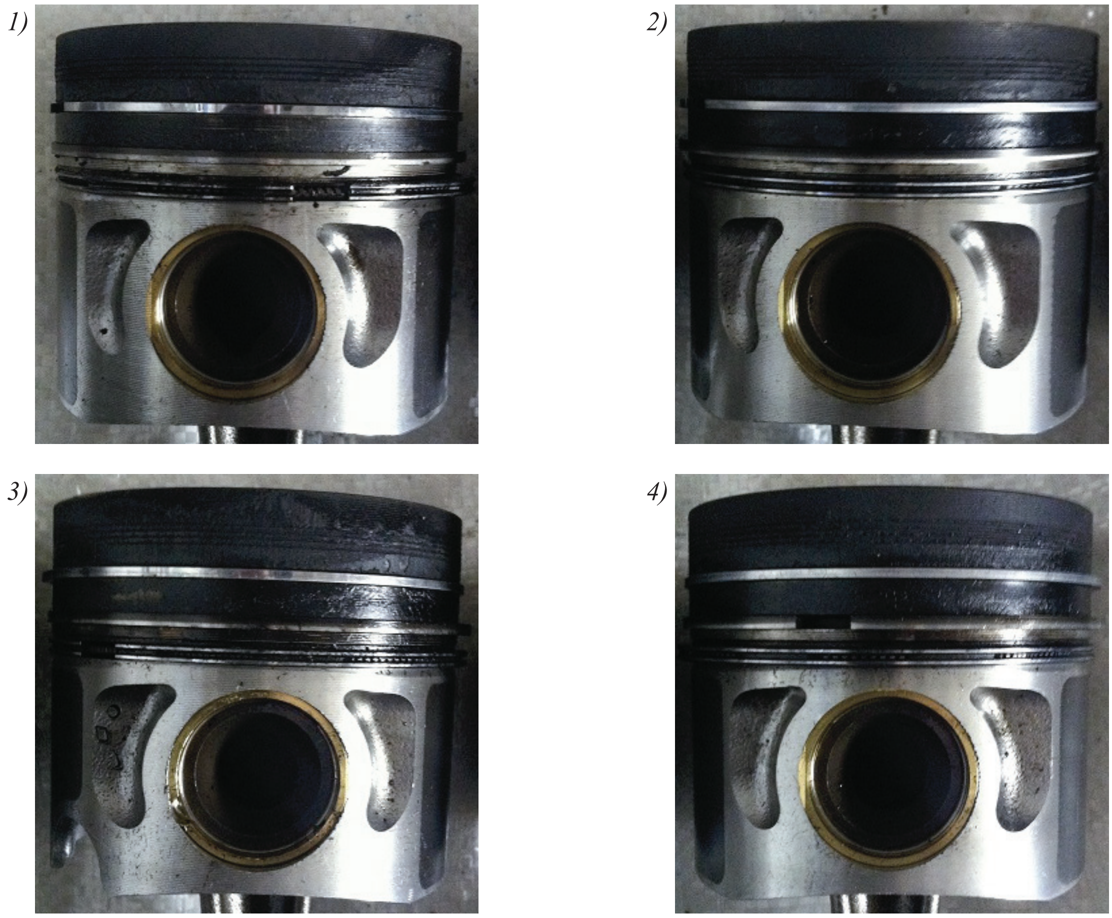

Fig.8. View of the pistons after tests

Such a turn hinders the formation of the lubricant wedge. In the case of the first O-ring is the solution wrong.

– The cause of a number of longitudinal cracks in cylinders 1 and 3 is to use an internal undercut the top of the first ring described in the section above.

References

[1] Kaźmierczak, A., Kaźmierczak, Ł., *Analysis of the Wear of Piston Ring Prototype of an Embankment of Diamond in Terms Endurance Test*, Journal of KONES Powertrain and Transport, Vol. 19, No. 4, pp. 283-289, 2012.

[2] Kaźmierczak, A., Kaźmierczak, Ł., Krakowian, K., *Badania prototypowych pierścieni tłokowych i analiza wyników*, Report No. S/21/2010, Wrocław University of Technology, Wroclaw 2010.

[3] Kaźmierczak, A., *Tarcie i zużycie zespołu tłok-pierścienie-cylinder*, Wroclaw University of Technology Press, Wroclaw 2005.

[4] Serdecki, W., *Wpływ pierścieni uszczelniających na kształtowanie filmu olejowego na gładzi tulei cylindrowej silnika spalinowego*, Poznan University of Technology Press, Poznan 1990.

[5] Sitnik, L., *Kinetyka zużycia*, PWN Press, Warszawa 1998.