COMPARATIVE RESEARCHES OF LUBE OIL CONSUMPTIONS ENGINE WOLA S12-U WITH COMPOSITE PISTONS

Jerzy Kołomecki

Mechanical Manufacturing Plant PZL WOLA, Siedlce Ltd. "WOLA" Factory
Fort Wola 22, 01-258 Warsaw, Poland
tel.: +48 22 6344489, fax: +48 22 6344499
e-mail: jkolomecki@pzl-wola.pl

Abstract

An object of the paper are test results of the lube oil consumption in reference to two versions of standard and novel pistons worked out within the framework of the project of developmental No. O R00 0052 05 under the title "The elaboration of the modern technology of composite materials of the novel generation to uses on the pistons of combustion engines to military uses". The project was coordinated by Institute of Aviation; a project manager was Antoni Jankowski. Unique properties, which are characterized by worked out novel material, mainly high hardness and strength, the low hysteresis and coefficient of thermal expansion α create many novel opportunities. As one of essential evaluation criteria of the novel piston, is lube oil consumption what is the object of the paper. The researches of the pistons were performed in WOLA S12-U engine. Novel solution of the pistons lets on the optimization of the shape of the piston and decreasing of the clearances between piston and cylinder. This causes decreasing of the lube oil consumption, decreasing of blowthroughs to the crank case, decreasing of the noise level and the vibration and the emission level of harmful components of exhaust gases; the improvement of the durability and dependability of the work of the engine and the pistons; increasing of mechanical loads , the pressure increasing combustion , and to the same opportunities increasing of the engine power and the BSFC decreasing.

Keywords*: combustion engines, diesel engine, composite pistons, lube oil consumption, engine tests*

1. Introduction

Researches of the lube oil consumptions of the WOLA S12-U engine were performed in the framework the realization of the project of developmental No. O R00 0052 05 under the title "The elaboration of the modern technology of composite materials of the novel generation to uses on the pistons of combustion engines to military uses". The project was coordinated by Institute of Aviation, a project manager was Antoni Jankowski. Unique properties, which worked out novel composite material has , chiefly high hardness and strength, small hysteresis and small coefficient of thermal expansion α create many new opportunities consisting among other things on:

- the optimization of shape of the piston and decreasing clearances between piston and cylinder, what causes decreasing of the lube oil consumption, decreasing of blowthroughs to the crank case, decreasing of the noise level and vibration and emission level of components toxic exhaust gases;
- improvement durability and dependability work of the engine and the pistons;
- increasing of mechanical loads, pressure increasing combustion, and consequently opportunity increasing engine power and decreasing BSFC.

As one of essential evaluation criteria novel piston, performed from composite material is lube oil consumption, which is the object of the paper. Researches of the pistons performed on engine test bench with WOLA S12-U engine.

2. Description current state of works

The WOLA S12-U WOLA S12-U investigated engine is a powertrain unit of the PT-91 HARD tank. This engine is the following developmental version for which starting point was W-2 the engine applied in the last age in T-34 tank. W-2 the engine came into being based on the air-engine Hispano-Suiza. The air-origin of this engine was reflected in the construction the W-2 engine. The

W-2 engine was at that time a compression-ignition engine. This is reflected in all following developmental versions, in this also at the WOLA S12-U engine. The WOLA S12-U engine is compression-ignition engine, a twelve-cylindric engine, with direct-injection, cooled liquid, mechanically re-charged, multifuel, of stroke capacity 38.88 dm^3 and the maximum power of 625 kW, at the rotational speed 2000 rpm. Moreover, because of the air-origin, WOLA S12-U engine has a very compact and light construction, thanks body and all body elements made with aluminium alloy. However, this engine contemporarily is not too stiff. Steel-thin-walled cylinder liners can have big deformations, what causes the necessity of the use relatively big piston clearances in cylinder. This on one hand gives the work safety and the resistance on seizing, even in case of large and nonuniform deformations of the piston, which is exposed on high thermal, and mechanical loads. Such high clearances are reasons of high lube oil consumption. Finally, high concentrations of harmful substances in exhaust gases take place. Declared by the producer specific lube oil consumption is contained within the range from 2.5 to 7.0 g/kWh. In all following versions of engines from the family "W", it the lube oil consumption was comparable, though with tendency of decreasing.

The lube oil consumption is measured during standard industrial tests for every piece of the engine. Measurements of the lube oil consumption are performed under lasting of 45 minutes researches, at the rotational engine speed 1800 rpm on the maximum torque characteristics, at constant temperature of lube oil on the inlet and the outlet of the engine.

3. Project of the novel piston

The construction of pistons applied in engines of the family "In" in the last period was an object of many changes. Modifications of the construction of the pistons concerned both material, though always this be forged part with the alloy of aluminium, the shape of the combustion space and the compression ratio and system and number of piston rings. Least changes had the shape of the piston skirt. Below ring-shaped zone the piston, this shape was a cylinder, however above ring-shaped zone the piston this shape this was a cone.

Applied at WOLA S12-U the engine the standard piston 3304-05-24.01BX was performed also from forged part from material PA12. The shape jacket had here a shape of the barrel. The shape of the piston in section longitudinal for specific diameters dimensioning the shape of the piston is presented on Fig. 1. The oval of the piston skirt in section transverse causes that piston during work exposed on variable and unsymmetrical thermal and mechanical loads could fit in with the cylinder liner considerably better. Signs interaction with the cylinder liner, observed during demounting of many engines, unmistakably on this indicate. Though declared by the producer the specific lube oil consumption still contained within the range 2.5 – 7.0 g/kWh, it, in contrast with earlier versions of engines, where the specific lube oil consumption are within the range high allowed values of the lube oil consumption.

As opposed to 3304-05-24.01BX standard piston performed from forged part, semi-manufactured product 1304-05-1 novel composite piston is mould. 3D computer model mould of the novel piston (see Fig. 2) was worked out in UNIGRAPHICS NX2 system. The project of the novel piston is based on 3304-05-24.01BX standard forged part.

Based on the model mould, 3D the computer model of the ready piston was worked out. Assumption was accepted that in regard of the building in the engine it should be exchangeable from 3304-05-24.01BX standard pistons. This means that same are combustion chamber, system and the number of rings, the position and hole diameter of the piston pin. During works design optimizations the shape of the piston was an object of the detailed analysis. Assumption that 3304-05-24.01BX standard piston under conditions of the work of the engine within the range rated has correct and giving a safe work clearance in the cylinder. Such the same value clearance should have design for 1304-05-1 novel composite piston. Characteristic diameters dimensioning the novel shape of the composite piston are introduced on Fig. 3.

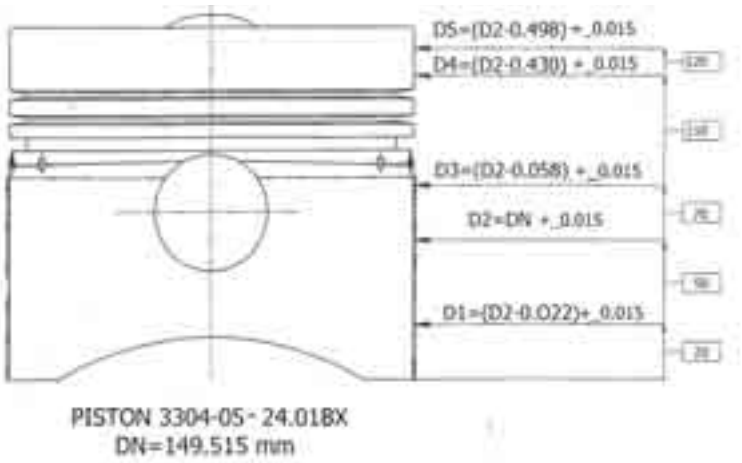

Fig. 1. Design of the 3304-05-24.01BX standard piston

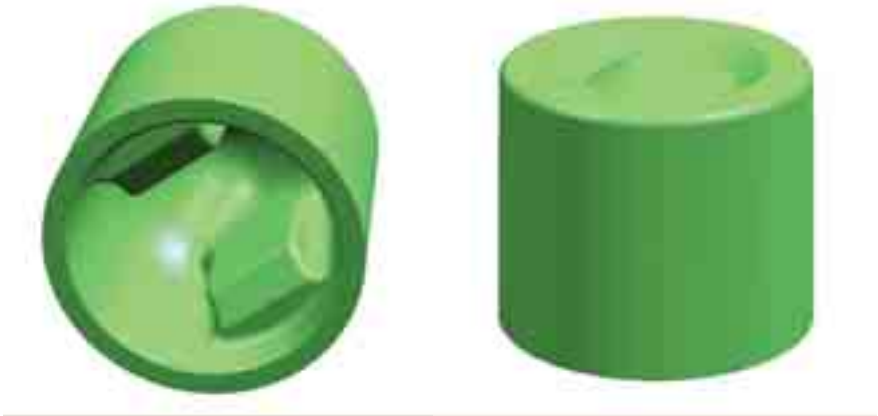

Fig. 2. 3D computer model mould of the 1304-05-1 novel piston

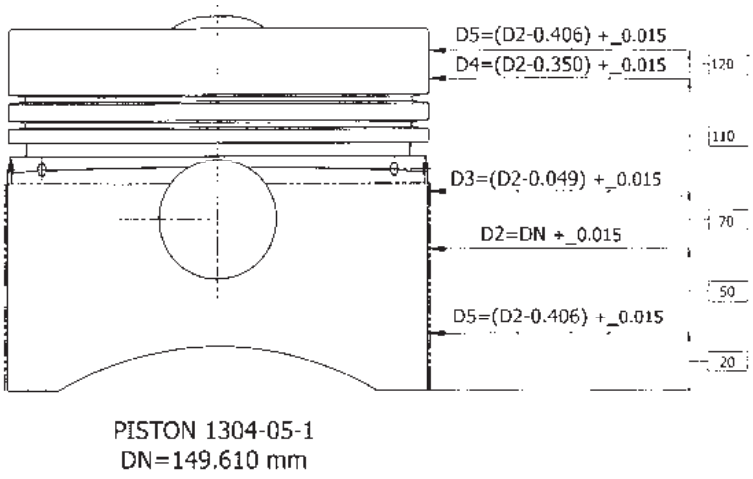

Fig. 3. Design of the 1304-05-1 novel piston

Using differences of the coefficient of thermal expansion α of both materials and its hysteresis, it was possible decrease clearance „on cold" for following sizes:
on the diameter DN of 0.095 mms this is approx. 20%,
on the diameter D3 of 0.104 mms this is approx. 19%,
on the diameter D4 of 0.175 mms this is approx. 19%,
on the diameter D5 of 0.187 mms this is approx. 19%.

On the basis worked out technical documentation trial pack 1304-05-1 novel composite pistons was performed. The engine with mounted novel pistons was a subject of engine researches, which was performed on engine test bench. The photograph of new pistons is introduced on Fig. 4.

Fig.4. The view of the 1304-05-1 new prototype pistons before engine researches

4. Programme and methodology of research

The engine dynamometer researches of the engine were performed on the test bench of the "PZL-WOLA" in two stages:
I the stage – the test of the engine with standard pistons 3304-05-24.01BX.
II the stage – the test of the engine with composite pistons 1304-05-1.

For the purpose of reduction to the minimum of the influence of factors not connected with investigated pistons on parameters of the work, the researches were carried out on the same piece of the engine S12-U. To every stage of research except the set of the pistons, new parts directly connected with them this is piston rings and cylinder liners mounted. Assuming that this were parts coming from running fully repeatable line production, then one can accept that on the value of the lube oil consumption the influence has only the change of the piston.

The researches were performed at fuelled a basic fuel the urban super diesel oil and at use of multiseasonal engine lube oil CF-4 SAE 20W/50 (the mass density of lube oil: g=0.9 kg/dm^3).

Everytime before the beginning of research of the lube oil consumption the engine was prepared according to plan of the standard industrial tests involving:
- breaking-in engine in 150 mines,
- the regular test in 90 mines,
- the approval test in time 30.

The researches of the lube oil consumption were performed in lasting of 300 minutes of the test at the variable load and different rotational speeds. Rotational speeds of the engine, the range of loads and the working period on each load is introduced in Tab. 1.

Measurement of the lube oil-level in reservoir was performed at the beginning and at the end the test, at rotational speeds of the engine 1800 rpm, on the external characteristics, at the stabilized temperature of lube oil on the inlet to the engine 75°C. During the all time of the measurement of the lube oil, consumption following temperatures of water and lube oil were within the range:
- temperature of water at the outlet from the engine within the range 70-90^{o}C,
- the temperature of lube oil at the outlet from the engine within the range 70-95^{o}C,

The measuring precision of the lube oil-level carried out 0.5 dm^3.

Measurement of the lube oil consumption according to worked out programme were repeated three times, in three following days of research of the engine, during every stage of research.

5. Test results

5.1. Test results of lube oil consumption for engine with the 3304-05-24.01BX standard pistons

Test results of lube oil consumption for engine with the 3304-05-24.01BX standard piston are presented in Tab. 2.

Tab. 1. Rotational engine speeds, the range of loads and the working period on individual loads

Rotational engine speeds [rpm]	Loads [Nm]	Working time [min]
1800	According to max. torque characteristics	To the moment of parameters' stabilization and achievements of lube oil weighs
1400	1200 - 1300	20
800	0 - 300	5
1400	1800 - 1900	20
800	0 - 300	5
1400	2400 - 2500	20
800	0 - 300	5
1600	1200 - 1300	20
800	0 - 300	5
1600	1800 - 1900	20
800	0 - 300	5
1600	2400 - 2500	20
800	0 - 300	5
1800	1200 - 1300	20
800	0 - 300	5
1800	1800 - 1900	20
800	0 - 300	5
1800	2400 - 2500	20
800	0 - 300	5
2000	1200 - 1300	20
800	0 - 300	5
2000	1800 - 1900	20
800	0 - 300	5
2000	2400 - 2500	20
800	0 - 300	5
1800	According to max. torque characteristics	To the moment of parameters' stabilization and achievements of lube oil weighs

Tab. 2. Test results of lube oil consumption for engine with the 3304-05-24.01BX standard piston

Test number	Reading	Volume of lube oil in reservoir V[dm³]	Working period engine	Lube oil consumtion	
				$(V_1 - V_2) / (t_2 - t_1)$ [dm³/h]	$[(V_1 - V_2) / (t_2 - t_1)]$ g [kg/h]
1	First	57	t_1 - 53 min	2.29	2.1
	Second	45	t_2 - 6 h 8min		
2	First	58	t_1 - 47 min	2.21	1.99
	Second	46	t_2 - 6h 12min		
3	First	56	t_1 - 56min	2.24	2.02
	Second	44.5	t_2 - 5h 49min		

The average lube oil consumption from three tests is (2.1+1.99+2.02)/3 = 2.04 kg/h

5.2. Test results of lube oil consumption for engine with the 1304-05-1 novel composite pistons

Test results of lube oil consumption for engine with the 1304-05-1 novel composite pistons are presented in Tab. 3.

Tab. 3. Test results of lube oil consumption for engine with the 1304-05-1 novel composite pistons

Test number	Reading	Volume of lube oil in reservoir V[dm³l]	Working period engine	Lube oil consumption	
				$(V_1 - V_2) / (t_2 - t_1)$ [dm³/h]	$[(V_1 - V_2) / (t_2 - t_1)]$ g [kg/h]
1	First	77	t_1 - 23 min	1.79	1.61
	Second	67.5	t_2 - 5h 41min		
2	First	75	t_1 - 14 min	2.05	1.84
	Second	64.5	t_2 - 5h 22min		
3	First	76	t_1 - 3 min	1.97	1.77
	Second	66	t_2 - 5h 8min		

The average lube oil consumption from three tests is (1.61+1.84+1.77)/2 = 1.74 kg/h.

6. Conclusions

Novel material on the pistons is characterized with the small hysteresis of the coefficient of thermal expansion α, with unique strength properties and the high resistance on seisings.

Changes of the coefficient of thermal expansion α, in reference to standard piston-materials applied on the pistons can be very high during warming and cooling, as well as during following cycles warming and piston cooling of the combustion engine.

The average lube oil consumption measured at work the engine with composite pistons 1304-05-1 was smaller than in case of standard pistons 3304-05-24.01BX of 0.3 kg/h, what makes reduction about approx. 15%.

References

[1] Jankowska-Sieminska, B., Jankowski, A., Slawinski, Z., *Composite Alloy for IC Engine Pistons,* Journal of KONES Powertrain and Transport, Vol. 17, No. 2, pp. 159-166, Warsaw2010.

[2] Jankowska-Sieminska, B., Jankowski, A., Slezak, M., *Analysis and research of piston working conditions of combustion engine in high thermal load conditions,* Journal of KONES 2007, Vol. 14, No.3, pp. 233-234, Warsaw 2007.

[3] Jankowski, A., Pietrowski, S., Sieminska, B., Szymczak, T., *High-quality silumin on pistons of combustion engines*, Journal of KONES Internal Combustion Engines, Vol. 16, No. 4, pp. 563-573, Warsaw 2009.

[4] Jankowski, A., Sandel, A., *Exhaust Emission Reduction Problems of Internal Combustion Engines Fueled With Biofuels*, Journal of KONES Internal Combustion Engines 2003, Vol. 10,.No. 3-4, Warsaw 2003.

[5] Jankowski, A., Sandel, A., *Influence of Fuel Quality on Mixture Preparation and Exhaust Emissions from Diesel Engines with Common Rail System,* Journal of KONES Internal Combustion Engines 2003, Vol. 10, No. 3-4, Warsaw 2003.

[6] Jankowski, A., Sandel, A., Sęczyk, J., Siemińska-Jankowska, B., *Some Problems of Improvement of Fuel Efficiency and Emissions in Internal Combustion Engines,* Journal of KONES Internal Combustion Engines 2002, Vol. 9, 3-4, pp. 333-356 Warsaw 2002.

[7] Jankowski, A., Sieminska, B., Slawinski, Z., *The Resistance on Thermal Shocks of Combustion Engine Pistons,* FISITA Transactions, London 2007.

[8] Jankowski, A., *Some Aspects of Heterogeneous Processes of the Combustion Including Two Phases*, Journal of KONES Internal Combustion Engines, Vol. 12, No. 1-2, pp. 121-134, Warsaw 2005.

[9] Jankowski, A., *Study of the influence of different factors on combustion processes (Part two),* Journal of KONES Internal Combustion Engines, Vol. 16, No. 3, s. 135-140, Warsaw 2009.

[10] Jankowski, A., *Heat Transfer in Combustion Chamber of Piston Engines*, Journal of KONES Powertrain and Transport, Vol. 17, No. 1, pp. 187–198, Warsaw 2010.

[11] Jankowski, A., Jankowska, B, Slawinski, Z., *The Resistance on Thermal Shocks of Combustion Engine Pistons*, FISITA Transactions, London 2007.

[12] Jankowski, A., *Laser Research of Fuel Atomization and Combustion Processes in the Aspect of Exhaust Gases Emission,* Journal of KONES Powertrain and Transport, Vol. 15, No. 1, pp. 119–126, Warsaw 2008.

[13] Jankowski, A., Pietrowski, S., Sieminska, B., Szymczak, T., *High-Quality Silumin on Pistons of Combustion Engines,* Journal of KONES Powertrain and Transport, Vol. 16, No. 4, pp. 563–573, Warsaw 2009.

[14] Kuroishi, M., Kawaguchi, A., Inagaki, M., Torii, H., *Computational Method of Piston Structure and Lubrication Using Flexible Multibody Dynamics Technique,* FISITA2006 Proc. F2006P359, Yokohama Japan 2006.

[15] Sieminska, B., Jankowski, A., *Composite Alloy with Very Low Dimensional Hysteresis During Heating and Cooling for Combustion Engine Piston*, 17th International Conference on Composites or Nano Engineering, USA 2009.

[16] Sieminska, B., Jankowski, A., Pietrowski, S., Ślęzak, M., *The Pistons from Novel Composite Alloys for Future Combustion Engines of Low Emission Exhausts Gases and Low Noise Levels*, FISITA 2008 Congress Proceedings, F2008-06-180, Germany 2008.