Visualization of piston engine cylinder oil-jet lubricating process

S V Putintsev¹, S S Pilatskaya¹, Alexey S Ratnikov² and Alexander S Ratnikov²

¹ Bauman Moscow State Technical University, 2nd Baumanskaya str., 5/1,105005, Moscow, Russia
² Vladimir State University n a Alexander and Nikolay Stoletovs, str. Gorky, 87, 600000, Vladimir, Russia

E-mail: putintsev50@yandex.ru

Abstract. Topicality, purpose, objects, means, methods and some results concerning experimental research of oil-jet supply cylinder of a high-speed low-sized piston engine due to spraying oil from connecting rod special holes are presented. The straight visualization of this process by means of a breadboard plant with optical transparent cylinder and piston made it possible to determine and recommend for further motor tests a pilot connecting rod which ensured the best conditions of the cylinder oil supply in comparison with off-the-shelf items.

1. Introduction
To increase reliability of cylinder and piston group (CPG) operation via an improvement in the conditions of coupling “cylinder-piston” in a whole series of high-speed internal combustion engines (ICE), in particular the automobile engines of Japanese and Italian production, the systems of the oil-jet supply, intended for supplying the jet of oil into the internal space of cylinder from the special hole in the connecting rod [1-9] are used. The problem is the lack of knowledge of the actual nature and regularities of the jet oil supply process and, therefore, in the absence of evidence-based principles of design and application of such structures as elements of the combined lubrication system of modern high-speed ICE.

2. Purpose and objectives of research
The purpose of the work was comparative estimation of the low-sized diesel cylinder oil-jet supply effectiveness with the use of two (serial and pilot) versions of connecting rod, which have different design of oil-jet lubricating system. To achieve the above purpose it was planned to solve the following:

- visualization and monitoring the process of oil-jet supply from the connecting rod onto internal surfaces of piston and cylinder;
- evaluation of the oil amount on the cylinder inner surface using a serial and pilot connecting rod, under otherwise equal conditions.
3. Objects, equipment and test methods

3.1. Serial connecting rod for diesel engine 1Ch 8.5/8.0 having the oil-supply hole lying in the plane of crankshaft at an angle to the central axis of connecting rod and located in the zone of passage of connecting rod body into its big end - Object No 1 (figure 1a).

![Figure 1a](image1a.png)

**Figure 1.** Serial (a) and pilot (b) connecting rods - objects of test with the breadboard plant: 1, 2 - points of oil supplying hole outlet; 3 - oil-distributing groove on the upper connecting rod big end bearing liner.

3.2. Pilot connecting rod for the above diesel engine different from serial connecting rod by the presence of central channel in the body of connecting rod and by the presence of two oil-supply holes connected with this channel, situated on the different height and the sides in the plane of connecting rod swing, as well as by existence of oil-distributing groove on the connecting rod big end upper bearing liner (Object No 2 – figure 1b).

The equipment was a breadboard plant made on the base of aforesaid 1Ch 8.5/8.0 diesel engine, special feature of which is independence on the crankshaft oil pump drive as well as use of transparent cylinder and piston (figure 2) - [10]. The optical transparency of these components was achieved by application of plexiglass and ABS-resin for making cylinder and piston respectively. This made it possible to carry out visual monitoring as well as photo and video recording of the oil-jet supply process from the connecting rod holes to the cylinder.
The objects testing method on the breadboard plant assumed the use of quasistatic and dynamic operation modes (without and with the rotation of crankshaft respectively) with the independent on the crankshaft oil pump drive.

4. Results of the experiment
4.1. Quasistatic mode
As follows from table 1, oil-jet outflow through the hole of serial connecting rod occurs within Compression and Exhaust strokes and continues in each case during 20 angle degrees of crankshaft rotation (CSR). This duration of jet formation strictly corresponds to the extent of circular arc enclosed between the opposite edges of the oil-feed hole on the crankpin external surface. A basic quantity of oil falls on the lower half-surface of piston boss forming oil mist in the piston skirt cavity and the underlying cylinder capacity.

Table 1. Test objects oil-jet forming behavior.

| Object | Phases of oil-jet forming, deg. CSR | Stroke                              |
|--------|------------------------------------|------------------------------------|
|        | Start | Ending |                          | (the proportion of the phase duration from a stroke time, %) |
| No 1   | 289   | 309    | Compression (11)          |
|        | 649   | 669    | Exhaust(11)                |
| No 2   | 170   | 370    | Compression (100)          |
|        | 530   | 10     | Exhaust (100)              |
In the case of the pilot connecting rod (Object No 2) oil-jet formation occurs predominantly during identical the serial connecting rod strokes (Compression and Exhaust) but, because of the presence of oil-distributing groove on the connecting rod big end upper bearing liner it has a 10 times longer duration. Furthermore, as the results of jets visualization showed, both jets fall on the piston skirt internal surface: the right one falls at the level of the piston skirt upper edge from the so-called anti-thrust side of the cylinder wall; the left one falls at the level of the piston skirt lower edge from the thrust side of the cylinder wall.

4.2. Dynamic mode

The comparative tests of objects in the dynamic operation mode of the breadboard plant were carried out under the identical conditions: oil pressure 0.3 MPa and crankshaft rotation speed 500 r.p.m. The time of each test was 1 min.

The results of the visual monitoring of the cylinder oil-jet supply with different connecting rods, represented in figure 3 and figure 4, showed the following.

When the serial connecting rod which has one hole located in the plane of crankshaft (Object No 1) is used, the thrust side of cylinder wall obtains much less oil than the anti-thrust side (figure 3).

![Figure 3](image3.png)

**Figure 3.** View of the thrust (T) and anti-thrust (AT) sides of cylinder wall when using serial connecting rod (Object No 1).

Using the pilot experimental product with two oil-jet supply holes in the plane of the connecting rod swing, which has the oil-distributing groove of the half scope (180 deg.) on the connecting rod liners (Object No 2), significantly changed the picture of oil supply to the increase in the total volume of supplied oil as well as its more rational distribution on the thrust and anti-thrust sides of the cylinder wall (figure 4).
Figure 4. View of the thrust (T) and anti-thrust (AT) sides of cylinder wall when using the pilot connecting rod (Object No 2).

Conclusion
The design of oil-jet supply by the pilot connecting rod (Object No 2) showed itself more effective in comparison with the serial connecting rod design (Object No 1). The basis for such conclusion is prolonged, corresponding to the complete piston throw at the Compression and Exhaust stroke, jet-oil supply to the internal cavity of piston skirt and cylinder as well the more complete oil supply of a cylinder and rational distribution of oil along the thrust and anti-thrust sides of the cylinder wall. Taking into account these results the pilot connecting rod indicated was recommend for the further motor tests.

References
[1] Ishida M, Kinoshita T, Kato T and Tosaka T 2001 Bearing metal positioning structure in a split connecting rod Patent US 6312159B1
[2] Lloyd Glass D 2011 A lubrication system for a connecting rod Patent US 7975806B2
[3] Ihsan K and Necmettin K 2014 A comparison of fatigue life between two automotive connecting rods International Journal of Vehicle Design (IJVD) 43 1234
[4] Shenoy P and Fatemi A 2005 Connecting Rod Optimization for Weight and Cost Reduction SAE Technical Paper 2005-01-1382
[5] Zanghi E 2014 Analysis of Oil Flow Mechanisms in Internal Combustion Engines via High Speed Laser Induced Fluorescence (LIF) Spectroscopy (Massachusetts Institute of Technology)
[6] Mian A, Parker D and Williams B 2000 Measured Crankshaft Bearing Oil Flow and Temperatures with a Full and Partial Groove Main Bearing SAE Technical Paper 2000-01-1341
[7] Ferreyra S, Uehara S, Dos Santos Ferreira M and Mian O 2011 Engine Lubrication System for Oil Flow Reduction SAE Technical Paper 2011-36-0205
[8] Sang-Myung C 2010 The Design Review for Lubrication System of an Internal Combustion Engine Tribology and Lubricants 26 issue 3 175-183
[9] Khrulev A E 2000 Remont dvigateley zarubezhnykh avtomobiley [Repairing of foreign cars engines] Moscow Za rulem Publ 440
[10] Putintsev S V and Biktashev A F 2017 A breadboard setup for direct visualization and evaluation of oil supply of CPG's parts of low-sized high-speed air-cooled diesel engine Problemy i perspektivy studencheskoy nauki 1(1) 18-20