Experimental Study on the Lubricated Oil Film Pressure of the Connecting-Rod Big End Bearing in the Experimental Device

Nghiên cứu thực nghiệm áp suất màng dầu bôi trơn ổ đầu to thanh truyền trong thiết bị thực nghiệm

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Abstract

This paper presents the experimental study of the lubricating oil film pressure of the connecting-rod big end bearing in the special device for the lubricating condition of the connecting-rod big end bearing. A connecting-rod model of photoelastic material is subjected to simulated load as in an engine. The oil film pressure is measured at different positions in the circumferential direction and the mid-section in length by a pressure sensor located on the shaft. The measured results show that the oil film pressure corresponds to the load acting on the connecting-rod. At the position 0º of the bearing, the oil film pressure reaches a maximum value around the 360° of crank angle, the zone of the explosion, and the oil pressure is at minimum at 720º (0º) angle of the crankshaft, corresponding to the minimum load zone to the connecting-rod. In the opposite position, at the 180° of the housing bearing, the oil film pressure is at minimum when an explosion occurs and is at maximum in the neighborhoods of 0º of the crank angle. At the other position of the connecting-rod, the oil film pressure is also corresponding to the load acting on the connecting-rod. The maximum value of oil film pressure decreases when the rotational speed of the crankshaft increases, the minimum pressure of the oil film slightly varies.

Keywords: oil film pressure; connecting-rod; lubrication.

Tóm tắt

Bài báo giới thiệu nghiên cứu thực nghiệm áp suất màng dầu bôi trơn ổ đầu to thanh truyền trong thiết bị thực nghiệm đặc chủng khảo sát bôi trơn ổ đầu to thanh truyền. Một thanh truyền nghiên cứu bằng vật liệu quang đàn hồi chịu lực tác dụng mô phỏng như trong động cơ. Áp suất màng dầu được đo tại các vị trí khác nhau theo phương chu vi và tại tiết diện giữa ổ theo phương chiều dài bởi biến áp suất đặt trên trục. Các kết quả đo cho thấy, áp suất màng dầu tương ứng với tải tác dụng lên thanh truyền, Tại vị trí 0º của ổ, áp suất màng dầu đạt giá trị lớn nhất xung quanh góc 360º của trục khuỷu, tức vùng xảy ra sự nổ, và áp suất màng dầu đạt giá trị nhỏ nhất tại 720º (0º) của trục khuỷu, lúc này thanh truyền ở điểm chết trên, tương ứng với vùng tải nhỏ nhất tác dụng xuống thanh truyền. Ở vị trí đối xứng, tức tại góc 180º của ổ, áp suất màng dầu đạt giá trị nhỏ nhất khi xảy ra sự nổ và có giá trị lớn nhất tại xung quanh 0o của trục khuỷu. Ở các vị trí khác của thanh truyền, áp suất màng dầu cũng có giá trị tương ứng với tải tác dụng lên thanh truyền. Khi tốc độ quay của trục khuỷu tăng, áp suất lớn nhất của màng dầu giảm, còn áp suất nhỏ nhất của màng dầu thay đổi rất ít.

Từ khóa: Áp suất màng dầu, thanh truyền, bôi trơn.

1. Introduction

A connecting-rod is one the most critical transmission components of the engine, in that the connecting-rod big-end bearing suffers not only from the tough working conditions (e.g. extremely inconstant load, fast velocity, high temperature, hard lubrication) but also from different effects as well as from environment with a lot of steel grits. In order to measure the axel center's orbit of the crankshaft bearing in a diesel engine with a single-cylinder, Cook used a pulse generator in his research in 1965. The results of this work showed that the elastic deformation of the bearing had a major variation caused by the extreme load. In 1985, 1987, and 1988, Bates and his colleagues designed a device using V6-variable petrol resource. It could measure the behaviours of the connecting rod big-end bearing. Pierre- Eugene and his partners studied the elastic deformation of the connecting rod big-end bearing under the fixed acting load. The connecting- rod was made of epoxy plastic. Thanks to the optic method, especially, laser ray, the authors succeeded in the

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measurement. The connecting- rod was attached to a steel axis rotating with the speed from 50 to 200 rpm, the active load changed from 60N to 300N. Optasanu, in 2000, carried out the experimental device to study the connecting rod big-end bearing with a simulated structure corresponding to the engine. The device complied with the principle of crank-edge and used the connecting-rod made of clear material such as PSM1 or PSM4. After that, Hoang and Tran used it with the epoxy PLM4 plastic and PLMH4 admixture for connecting-rod in order to study the lubrication of the connecting-rod big end bearing including thermal effect and radial clearance between two big-end terminals, screw turning force coupling two halves of connecting-rod. One year ago, Tan Nguyen Dinh researched the simulation of hydrodynamic lubrication for the connecting- rod big- end bearing in Camry 5S FE engine. Tan's calculation was compared to the result via a commercial soft-ware for lubricating Accel engine and made some recommendations for auto maintenance in replacing plain bearings and other components of the connecting- rod big- end bearing. In 2008, Hai Tran Thi Thanh- an author studied a solution for designing a simulated load that affected the connecting-rod big-end bearing in the experimental device. Then, it was published in the theme of a research B2016-BKA-20, 2019 of Hai Tran, and her partners. In the journal, the author presented the experimental study in the measured oil film pressure of the connecting rod big-end bearing with an active load on load simulated crankshaft of the internal combustion engine.

2. Experimental measurement.

2.1. Experimental device

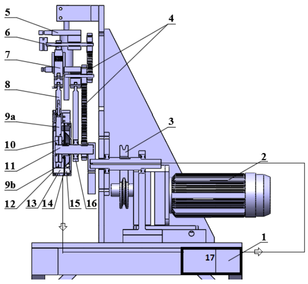

Fig. 1. The principle of experimental device of the lubricated connecting rod big- end bearing

The experimental device respects the kinematics of the connecting-rod crank system and the connecting - rod model. The connecting-rod model is formed by a rigid small end (8) and a big end in photoelastic material (9)

It is placed parallel with the master connecting-rod. The studied connecting-rod big end formed by a body (9a), a cap (9b), and the journal (11) form a smoothen bearing. An electric motor (2) rotates the crankshaft (11) by the reduction gear. The rotation speed of the crankshaft is ranged between 0 and 250 rpm. Master steel connecting- rod (16) is linked to the journal and it is a foot in linking to the master piston (5). This system can slide on two solid parallel pillars of the main body (1).

During the operation, the master connecting-rod alternatively pushes the piston to the top and pulls it to the under-neath. This results in the classic movement of the connecting-rod crank system in the internal combustion engine. The piston (8) plays resole of piston in an internal combustion engine. To simulate the explosion as in a real engine, which occurs a turn on two in a 4-stroke engine, the axis of the camshaft (6) turns twice more slowly than the crankshaft (11). The action of the camshaft on the push rod compresses the spring which in turn exerts a fort on the small end that thus simulates the explosion in an engine. The study in connecting–rod is immersed in an oil chamber.

The diameter of the big end is 97 mm, the radius clearance is C = 0.3 mm and the thickness of the connecting-rod is 20mm. The oil lubrication for the connecting-rod is supplying by a hydraulic pump and a rotating distribution channel that cross all along the length of the crankshaft. To determine the force of traction compression on the connecting-rod, the technique of extensometer is used. We use two sensors formed of 8 gauges of extensometer, a sensor for the long perimeter (X direction), and the other for the flexion moment.

Fig. 2. Experimental device

2.2. Experimental measurement

To measure oil film pressure of the big end connecting rod using a sensor called XCQ-062 35BARA of KULITE brand. A sensor is attached on rotary crankshaft at mid- section in length and measured at 24 points (equal- spaced 15) of oil film in circumference like (Fig. 3).

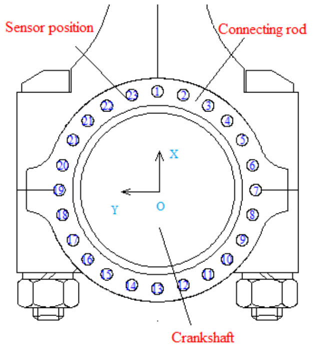

Fig. 3. Measuring position sensor diagram

Measurement system uses wireless link technology with RF waves. Signal reception equipment includes a signal generator is fixed on the rotary axel and connected directly to a sensor. A signal receiver is not laid on the axel. It gets a signal from a detector and sends signal to the Arduino chain. The Arduino chain transmits singles that it gets to the computer and programs to show on the Lab view software

3. Experimental results.

The pressure of the connecting-rod big end bearing is investigated with silicon bessil F-100 grease having dynamic viscosity 0.33 pas. Figure 4 is the active load diagram changes according to the crank angle at the speed of 100 rpm, 120 rpm, 180 rpm.

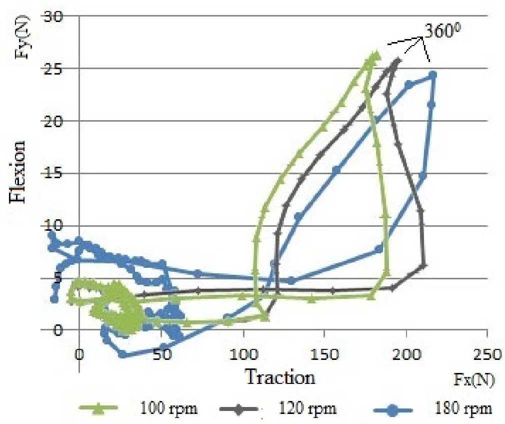

Fig. 4. Load diagrams

Fig.5 presents the oil film pressure at the different crank angles for 0o of boring at rotation speed 100 rpm. The oil film pressure is maximum (0,735 MPa) around the 360° of crank angle, zone of explosion, and the oil pressure is minimum (0.152 MPa) at angle 720° (0°) of the crankshaft, then the connecting-rod in the top dead center zone, corresponding to the minimum load zone to the connecting-rod.

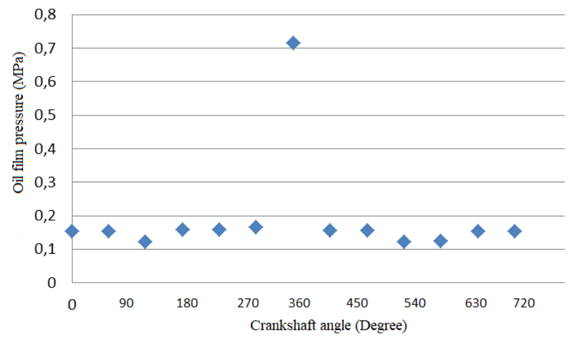

Fig. 5. Oil film pressure at the different angles of the crank shaft for 0^0 of the boring, 100 rpm.

On the contrary, at the position 180° of the boring, the rotation speed 100 rpm, the oil film pressure's minimum value of 0.129 MPa, zone of explosion, 0.422 MPa is the maximum at 0° of the crankshaft (Fig. 6). The pressure value increases at the zone from 90° to 180° and from 540° to 630° of the crankshaft because of the connecting-rod's inertia force.

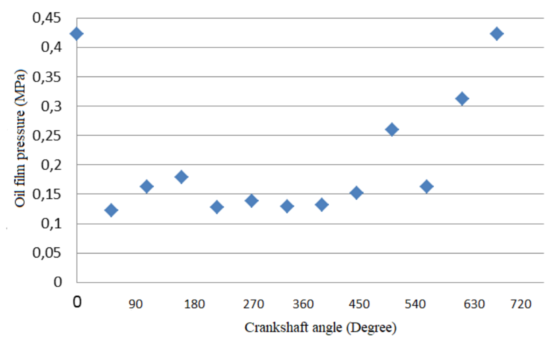

Fig. 6. Oil film pressure at the different angles of crank shaft for the 180° of the boring, 100 rpm

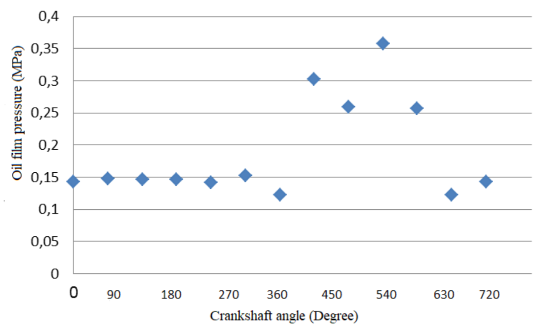

Fig. 7. Oil films pressure at different angles of the crank shaft for 90^0 the boring, 100 rpm.

Fig.7 shows that the oil film pressure at 90° of crank angle. In the range from 4200 to 6000, oil film pressure reaches the maximum value of 0.352 MPa. in angle, 900 to 3600, its value is the minimum because of the crank angle in the maximum oil film zone. It is consistent with the active loading diagram.

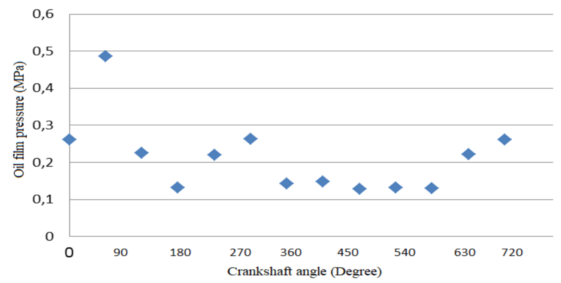

Fig. 8. Oil film pressure at the different crank angles for 270^0 of boring, 100 rpm.

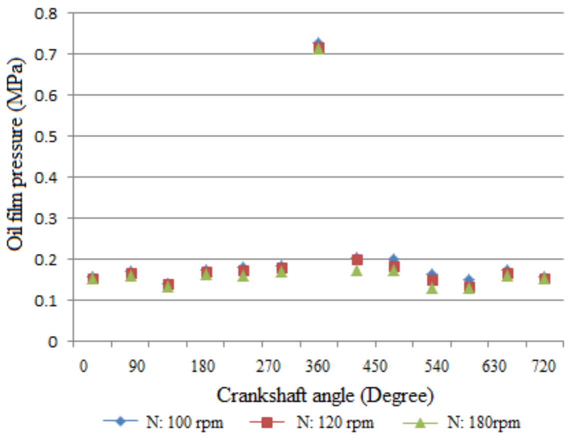

Fig. 9. Oil film pressure at different rotational frequencies

At the symmetrical position, when the journal rotates 3/8 and 3/4 cycles, at 2700 of the housing bearing, the oil film pressure reaches the maximum value of 0.486 MPa in the range of 70º to 120º of the crankshaft (Fig. 8). When the connecting-rod moves close to the top dead center zone, zone of explosion at 360° of crank angle, the minimum oil film pressure is 0.132 MPa. This is consistent with the active load and load diagram during engine cycles. When increasing the rotary speed of the crankshaft, the maximum and minimum of the oil film pressure change a little bit. This is right because, at this time, the minimum oil film thickness increases with the rotational frequencies.

Fig.9 indicates a comparison of the film pressure at 0^0 of the housing bearing at three rotation speeds, with the rotation speed 100 rpm, 120 rpm, and 180rpm. It shows that the maximum oil film's pressure decreases as the rotation speed increases, the minimum pressure zone of the oil film slightly varies. This is consistent with the theory of hydrodynamic lubrication because as the speed increases, the deviation of the shaft and bearing decrease, the minimum oil film thickness will increase, the maximum oil film thickness will decrease.

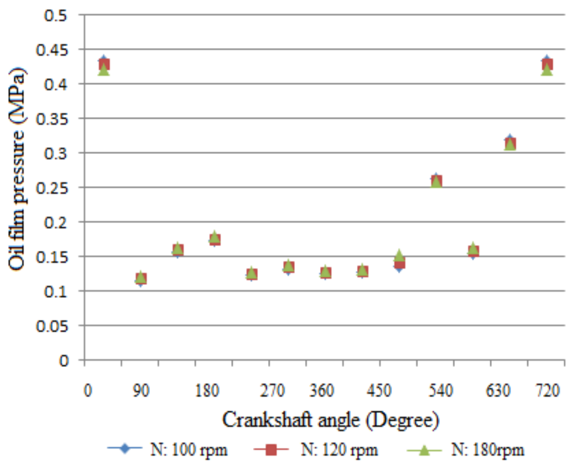

Fig. 10. Oil film pressure according to rotation angle of the crankshaft at 180º of boring with different rotation speeds

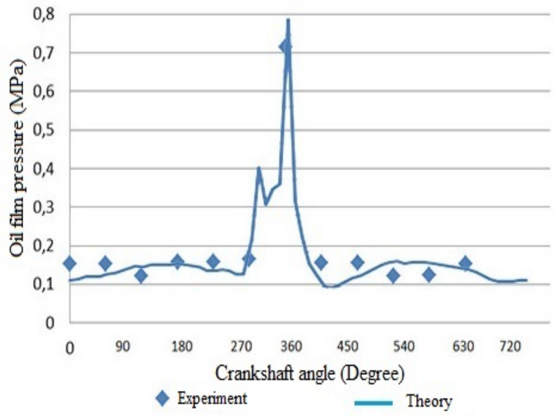

Fig. 11. Comparison between the calculated film pressure and the experimental film pressure at 0º of the boring, 100 rpm

Similarly, Fig.10 shows the oil film pressure at the 180^0 position of the boring with different rotation speeds. It shows that, the maximum oil film pressure also decreases from 0,146 MPa to 0.141 MPa and when increasing rotation speed of the crankshaft from 100 rpm to 120 rpm and 180 rpm is 0.112 MPa.

Fig.11 presents a comparison between the experimental oil film pressure and the numerically calculated pressure at 0º of the housing bearing with 100 rpm of the rotation speed. It shows a good agreement on the film pressure, however, in the explosion zone, specifically in the range 270º to 360º of the crankshaft, the calculated pressure is higher than the experimental pressure, 0.776 MPa and 0.735 MPa.

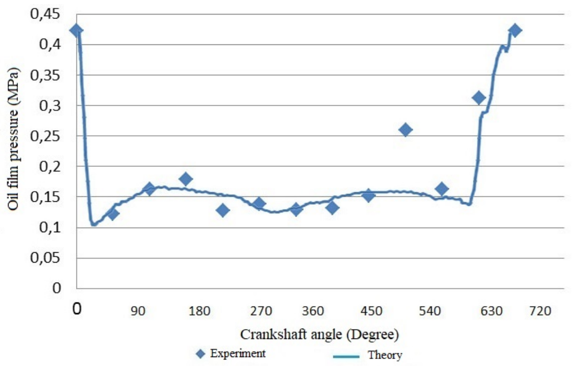

Fig. 12. Comparison between the calculated film pressure and the experimental film pressure at 180° of the boring, 100 rpm

Fig.12 indicates a comparison of oil film pressure in experiments and numerically calculated at 180^0 of the boring with the rotation speed of 100 rpm [10]. It shows that, a good agreement on the film pressure. However, at 520° of the crankshaft, the pressure is much higher than the numerical calculation. Maybe the experimental results are affected by the constant error at the measuring point because of the abnormal neighborhood, the value of the load is compressed and curved (Fig.5) and the characteristic line of experimental pressure follows up the theoretical line so that the measuring points with abnormal value are the points that can be affected by random errors.

4. Conclusion

This paper presents the experimental study of the lubricating oil film pressure of the connecting-rod big end bearing in the special device for the lubricating condition of the connecting-rod big end bearing with the model connecting-rod.

At the position 0° of bearing, the oil film pressure is maximum around the 360° of crank angle, the zone of explosion, and the oil pressure is minimum at angle 720° (0°) of the crankshaft, then the connecting-rod in the top dead center zone, corresponding to the minimum load zone to the connecting-rod. When increasing the rotation speed of the connecting-rod big end bearing, the maximum pressure value at the 360^0 of the crankshaft decrease, and the pressure value at other positions increases a bit.

The measured film pressure is the same as the calculated pressure, however, in the explosion zone, specifically in the range 270° to 360° of the crankshaft, the calculated pressure is higher than the experimental pressure.

References

[1] Cook W.L., 1965-1966, Dynamic Displacement in a Diesel Engine Main Bearing, Proceedings, Lubrication and Wear Second Convention, Instn. Mech. Engrs., Vol. 23.

[2] Rosenberg R.C., 1973, A Method for Determining the Influence of Multigrade Oils on Journal Bearing Performance, SEA TRANS. Paper 730483, Vol 82.

[3] Goodwin G., Holmes R., 1975, Determination of the Oil Film Thickness in a Crankshaft Main Bearing, The Journal of Automotive Engineering, Instn, Mech, Engrs, 1975.

[4] Bates T.W., Evans P.G., 1985, Effect of Oil Rheology on Journal Bearing Performance: Part 1 Instrumentation of the Big-End Bearing of a Fired Engine, Proc. of the JSLE International Tribology Conference, 8-10 July, Tokyo, Japan, 1985.

[5] Bates T.W., Benwell S., Evans P.G., 1987, Effect of Oil Rheology on Journal Bearing Performance: Part 2 Oil Film Thickness in the Big-End Bearing of an Operating Engine, Proc. 4th SAE Int. Pacific Conference on Automotive Engineering, Melbourne, Australia, Paper No. 871272.

[6] Bates T.W., Benwell S., 1988, Effect of Oil Rheology on Journal Bearing Performance: Part 2- Newtonian Oils in the Connecting-Rod Bearing of an Operating Engine, SAE Paper No. 880679.

[7] Pierre-Eugeune J., Contribution à l'Etude de la Déformation Elastique d'un Coussinet de Tete de Bielle en Fonctionnement Hydrodynamique Permanent, Thèse de Doctorat de l'Université de Poitiers.

[8] Optasanu V., 2002, Modélisation Expérimentale et Numérique de la Lubrification des Paliers Complants sous Chargement Dynamique. Thèse de Doctorat de l'Universite de Poitiers.

[9] Hoang L.V., 2002, Modélisation Expérimentale de la Lubrification Thermoélastohydrodynamique des Paliers de Tete de Bielle. Comparaison enter les Résulats Théoriques et Expérimentaux". Thèse de Dotorat de l'Universite de Poitiers.

[10] Nguyễn Đình Tân, 2018, Nghiên cứu mô phỏng số bôi trơn thủy động ổ đầu to thanh truyền của động đốt trong, Luận án tiến sỹ, Trường Đại Học Bách Khoa Hà Nội.

[11] Trần Thị Thanh Hải, 2018, Giải pháp tạo tải mô phỏng tác dụng lên thanh truyền trong thiết bị thực nghiệm bôi trơn ổ đầu to thanh truyền, Tạp chí Khoa học và Công nghệ các trường Đại học, số 129 năm 2018