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Experimental Research Oil-Film Temperature of the Connecting-Rod Big End Bearing

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***Abstract*— *This paper present the experimental study the lubricated film temperature of the connecting-rod big end bearing. A specific experimental device and the connecting-rod model of photo elastic material are used to determine the load diagram and measure the oil film pressure and the oil film temperature. The temperature is measured at six different positions on the cross-section in the middle of the bearing according to the perimeter by the type K temperature sensors. We analyze the influence of the rotation speed on the oil film temperature versus the crank angle. The results have shown that, the lubricated film temperature increase with the rotation speed and the numbers of operating cycle of the engine.*

***Keywords*— *Connecting-rod, bearing, temperature. type K sensor.*

I. INTRODUCTION

Research about oil film in the connecting rod big end bearing is a question of great interest in extensive research over the world. In 1991, F.A Martin and M. Stanojevic researched about oil flow in connecting – rod bearing. In 1993, D.N Fenner and his partners at Dept of mechanical engineering, king's college, university of London did a research about the effect of compliance on peak oil film pressure in connecting-rod bearing. This research showed at maximum load there is a marked reduction on the oil film thickness toward the bearing edges and flattening of the pressure variation in the axial direction. In 2003, B. Fantino and B. Bou Said researched about inertia, shear- thinning and thermal effects on connecting - rod bearing behaviors. Fantino and his partners show the essential consequence of the thermal effect is the increase of the axial flow and the friction torque while the minimum film thickness and the shaft trajectories stay still the same compared to the isothermal situation. In 2007, F.M. Meng and his partners at State Key Laboratory of Tribology, Tsinghua University, Beijing researched Thermo-elasto-hydrodynamic lubrication analysis of piston skirt considering oil film inertia effect. In 2014, Aurelian Fatu and his partners researched Shaft roughness effect on elasto-hydrodynamic lubrication of rotary lip seals: Experimentation and numerical simulation. In Viet Nam 2001, Ng Xuan Toan and his partners set up an automatic calculation program in hydrodynamic lubrication for bearing as well as research on the change of geometric errors of bearing. The problem was solved on the basic of the equation of oil film thickness, Reynolds equation under the Somerfield boundary condition. The research result was pressure curve of bearing when no geometric errors and errors. In 2006, Tran Thi Thanh Hai researched hydrodynamic lubrication for connecting rod bearing with elastic deformation effect of the surface silver.

In 2014, H. Shahmohamadi research big end bearing Losses with thermal cavitation flow under cylinder deactivation. The paper presents a mixed thermo-hydrodynamic analysis of elliptic bore bearings using combined solution of Navier–Stokes, continuity and energy equations for multi-phase flow conditions.

In 2015, H. Chamani research thermo-elasto-hydrodynamic (TEHD) analysis of oil film lubrication in big end bearing of a diesel engine. Results of a thermo-elasto-hydrodynamic (TEHD) analysis of a connecting rod big end (BE) bearing of a heavy duty diesel engine are presented. Here, the oil film viscosity is considered a function of oil's local temperature and pressure.

In 2017, Norbert Lorenz research thermal analysis of hydrodynamic lubricated journal bearings in internal combustion engines. This paper shows a newly developed model for the temperature distribution in the lubricant and the bearing structures. It includes thermal interface conditions between these domains, which incorporates the asperity energy source and predicts the temperature in supply areas. Along with theoretical research, in this article our group has performed experimental research about the temperature of the lubrication oil film in the connecting rod big end bearing with temperature of oil film in terms of different load conditions and velocities of spin.

II. EXPERIENCE EQUIPMENT

A. The Sorting Bowl Design

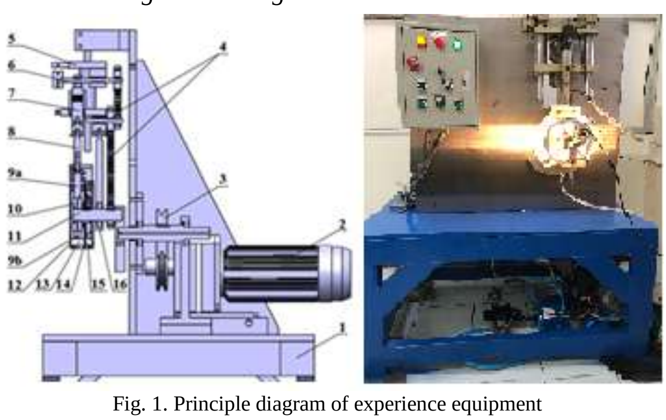

Fig. 1. Principle diagram of experience equipment

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The experimental device respects the kinematics of 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 photo elastic material (9). It is placed patrolled with master connecting-rod. The studied connecting-rod big end formed by a body (9a), a cap (9b) and the journal (11) form a smoothed 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. A master steel connecting-rod (16) is linked to the journal and it is food in linked to master piston (5). This system can slide on two solid paroled 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 resulting, motion has the classic movement of connecting-rod crank system in the internal combustion engine. The piston (8) plays resole of piston in an interal can bustion 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 compress 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 big end is 97 mm, the radius clearance is C = 0.5 mm and the thickness is 20 mm. The oil lubrication for the connecting-rod is supplying by a hydraulic pump and a rotating distriloution and a distribution channel which cross all along the length of the crankshaft. To determine the force of traction compression on the connecting-rod, the technique of extensonety is used. We use two sensors formed of 8 gauges of extensometry, a sensor for the long gitudinal (X direction) and the other for the flexion moment. The connecting-rod is created from PLM4 epoxy plastic and PLMH4 additive.

TABLE 1: Technical Information oil

Technical Information	Atox 320	Besil F100
Density at 20ºC, (g/ml)	0.875	0.97
Viscosity (cSt)	288/352 at 40ºC	250/400 at 25ºC
Pour point, (ºC)	-12	-50
Flash point, (ºC)	256	300
Viscosity index	118	101

III. METHOD OF MESUREMENT

A. Temperature Sensor

Temperature sensor to measurement the temperature of the oil film lubrication of connecting-rod big end bearing, we use the thermocouple type K.

The structure of thermocouple consists of two different metal wires that are chemically bonded at one end (hot end) to the other end (cold end). The thermocouple sensor is based on the difference in temperature between the two terminals of the two wires (hot and cold head) different in chemical nature so that there appears electromotive force in the circuit. By measuring the electricity of the electrolyte, we can obtain the corresponding temperature. Thermocoupple sensor type K include one wire 0.5 mm, temparature rage -200 ^{o}C to 1250 ^{o}C

Fig. 2. Structure of thermocouple

B. Sensor Location

To measure the temperature of the oil film in the connecting-rod big end bearing, the research had used six temperature sensors thermocouple type K which are placed at six positions at angle 0^0, 45^0, 135^0, 180^0, 225^0, 315^0 of boring.

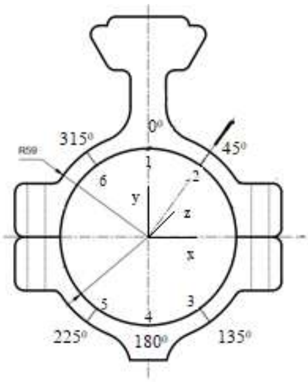

Fig. 3. Sensor location.

C. The Method of Receiving Signals from the Sensor

The thermal coup type K transmits the signal and reads the DAQ signal connected to the computer via the Ethernet cable and displays the test result interface on the Lab VIEW software.

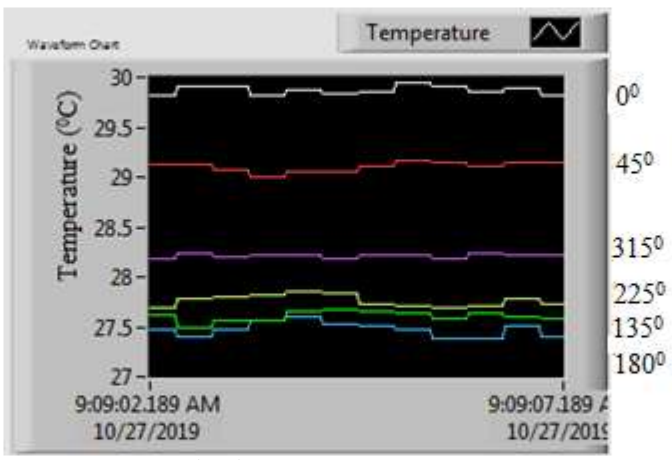

Fig. 4. Temperature of oil film throughout the time according to the Lab view software.

The temperature measurement system is using DAQ hardware to collect analog data from temperature sensors. Thanks to National Instruments Measurement signals are

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processed and programmed using NI-DAQmx software and display results in Lab VIEW software. National Instruments.

IV. RESULT OF RESEARCH AND SURVEY

This research experimental oil film temperature of the connecting-rod big end bearing at rotational speed 100 rpm,150 rpm, 200 rpm and the load on the drive changes with the vacuum extracting cycles of the simulated internal combustion engine.

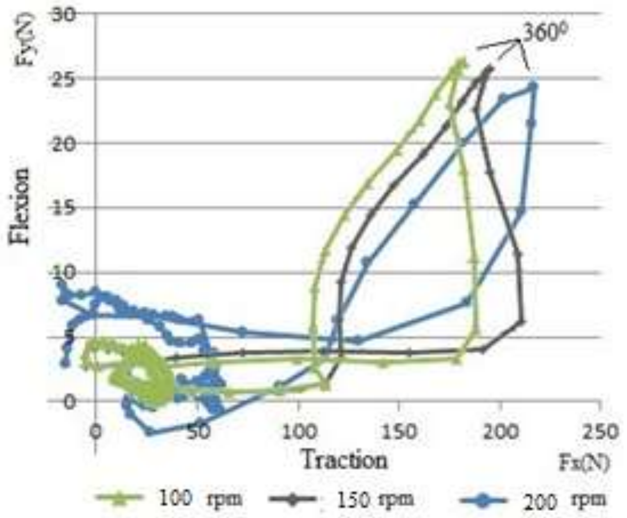

Fig. 5. Load diagrams

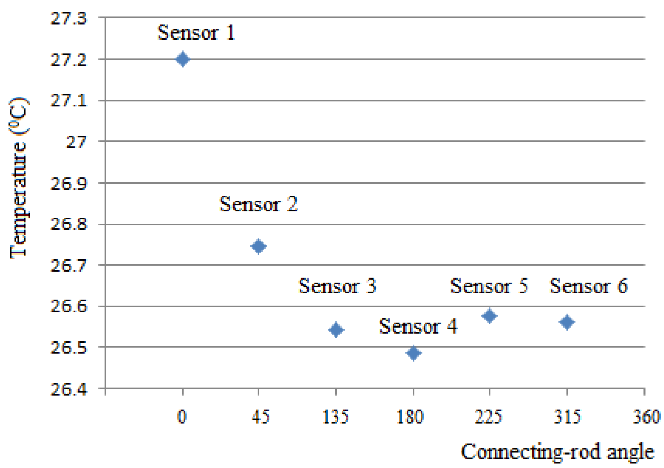

Fig. 6. Temperature of oil film at cycle 1000th

The experience using silicon oil BESIL F-100 of Brugarolas μ= 0.135 Pa.s

The figure 6 indicates the temperature range of sensor 1 and sensor 2 is the highest. The temperature of sensor 1 is 27.1987 ^{0}C and sensor 2 is 26.7465 ^{0}C because the location of sensor 1 at angle 0^0 of boring is where this stroke of the piston begins at top dead center, so the temperature value at angle 0^0 of the connecting-rod is always the highest.

The temperature range of sensor 3 (26.5434 ^{0}C) and sensor 4 (26.4854 ^{0}C) is the lowest. The temperature value of sensor 4 is the lowest because the position of sensor 4 is the 180^0 angle of boring where the oil film thickness is the highest and the pressure is the lowest; therefore, the temperature value of sensor 4 is the lowest.

The temperature range of sensor 5 (26.5768 ^{0}C) and sensor 6 (26.5603 ^{0}C) is lower than sensor 1 & 2 and higher than sensor 3 & 4. Because the crank rotates clockwise, sensor 5 and sensor 6 are in the oil film's pressure area, so the temperature value is higher than sensor 3 and sensor 4 (these 2 sensors are in the area that does not have any pressure).

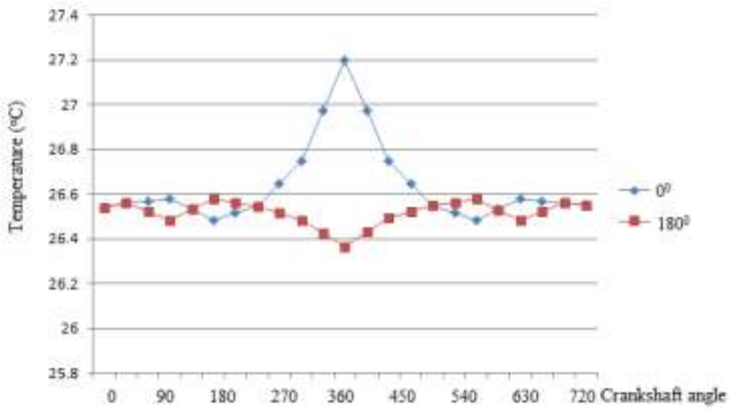

Fig. 7. Temperature of oil film according to the crankshaft angle at cycle 1000th.

Figure 7 presents the temperature at 0^0 of boring according to the crankshaft angle with 100 rpm speed of the connecting-rod big end bearing. When the piston is at the top dead center, at the angle 360^0 of the crankshaft, the highest temperature is 27.1987 ^{0}C. At the angle 180^0 and 540^0 of the crankshaft, the oil film's temperature is the lowest because the oil film thickness is the maximum.

On the opposite side of the 0^0 angle of boring is the $180^{0.}$ angle. When the piston is at the top dead center, at the angle 540^0 of the crankshaft, the lowest temperature is 26.3654 ^{0}C.

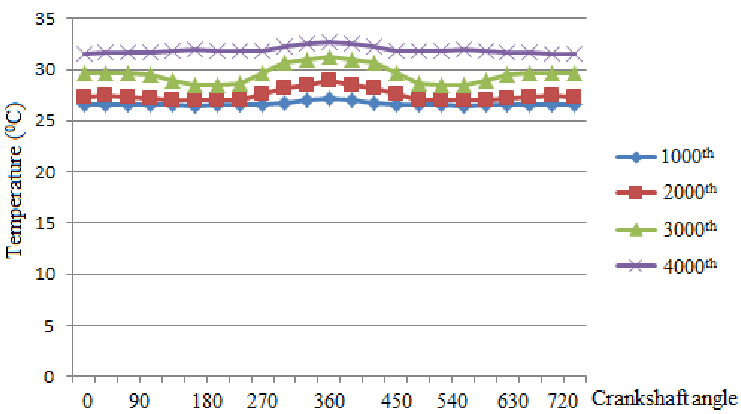

Fig. 8. Temperature of oil film according to the crankshaft angle at different cycle.

Figure 8 compares the temperature of oil film according to the crankshaft angle at different cycles. From the cycle 1000th to cycle 3000th when the temperature of the oil film is not stable, the temperature among the angles of the crankshaft is much different. After the cycle 3000th, when the temperature

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in the connecting-rod big end bearing is stable, the temperature among the angles of the crankshaft is not much different. From the cycle 1000th to 3000th, the temperature increases a lot. From the cycle 3000th to 4000th, when the connecting-rod big end bearing operates stably, the temperature does not increase much.

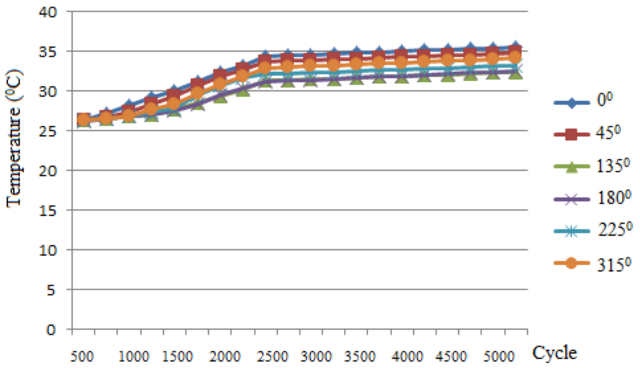

Fig. 9. Temperature of oil film according to the cycle at 100rmp speed

Figure 9 indicates the temperature of oil film at 100rpm speed. The value of senor 1 is the highest and sensor 4 is lowest. At 100 rpm speed and implementing during 100 minutes (5000 cycles), the connecting-rod bearing reaches the stable temperature status after 2500 cycles and increase 6 ^{0}C. After that, the connecting-rod bearing reaches the stable status and the temperature increases slightly throughout the operation time.

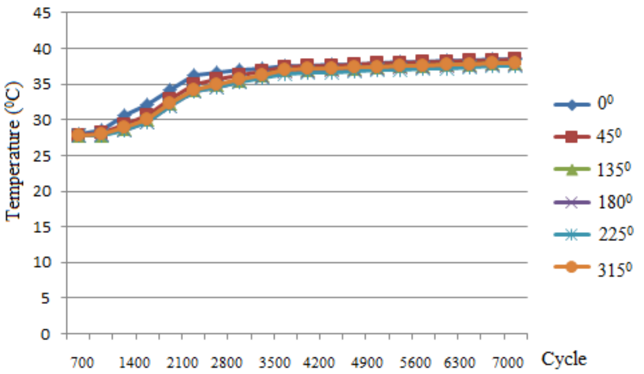

Fig. 10. Temperature of oil film according to the cycle at 150rmp speed

Figure 10 presents the temperature of oil film at 150 rpm speed. The value of senor 1 is the highest and sensor 4 is lowest. At 150 rpm speed and implementing during 100 minutes (7000 cycles), the connecting-rod big end bearing reaches the stable temperature status after 3000 cycles and increase 8 ^{0}C. After that, the connecting-rod bearing reaches the stable status and the temperature increases slightly throughout the operation time.

Figure 11 shows the temperature of oil film at 200 rpm speed. The value of senor 1 is the highest and sensor 4 is lowest. At 200 rpm speed and implementing during 100 minutes (10.000 cycles), the connecting-rod big end bearing reaches the stable temperature status after 3500 cycles and increase 10 ^{0}C. After that, the connecting-rod big end bearing reaches the stable status and the temperature increases slightly throughout the operation time.

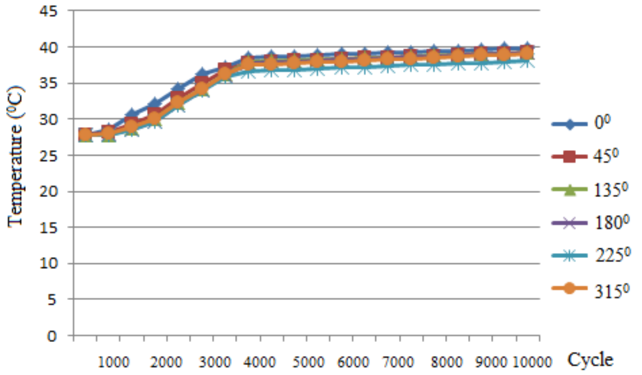

Fig. 11. Temperature of oil film according to the cycle at 200rmp speed

The experience using silicon oil BESLUX ATOX 320 of Brugarolas with μ= 0.28 Pa.s. at the speed of 100 rpm,150 rpm, 200 rpm is the same with the experience using silicon oil F-100.

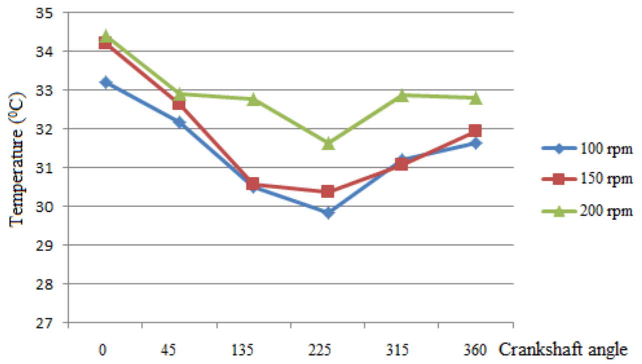

Fig. 12. Temperature of oil film at 0^o with different speed.

Figure 12 presents the temperature of 6 sensors during the operation cycle of the connecting-rod big end bearing. When the speed increases, the temperatures increases too.

From the experiment, figure 13 shows that the connecting-rod bearing operates stably after the cycle 2500 to 3500 with silicon oil F-100 of μ= 0.135 Pa.s. The connecting-rod bearing operates stably after the cycle 1500 to 2500 with Atox oil 320 of μ= 0.28 Pa.s

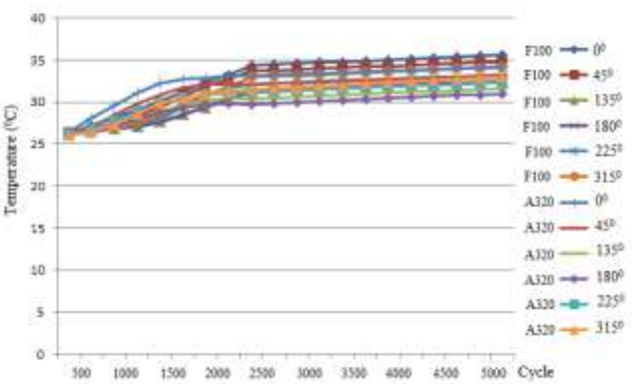

Fig. 13. Comparison of the temperature of the oil film with oil F-100 and oil Atox 320 according to the cycle at 100rmp speed

Oil Atox 320 has a higher kinematic viscosity than oil F-100; therefore, when the connecting-rod big end bearing operates, the temperature increases faster and the time it operates stably is shorter. At the same speed of 100 rpm, the connecting rod big end bearing using oil F-100 will operate stably after 2500 cycles (50 minutes), while using oil Atox 320, it will operate stably after 1500 cycles (30 minutes). At the same speed, oil with a higher kinematic viscosity has a higher temperature different but not too much (at 100 rpm, oil F-100 $\Delta T = 6\ ^0$C, oil Atox 320 $\Delta T = 7\ ^0$C)

The temperature increases dramatically from the starting period until it reaches the stable condition, and then the temperature increases slightly throughout the operation time. The higher the speed of the connecting-rod big end bearing is, the higher and faster the temperature is. The temperature difference among the sensors are not too much. There is a clear temperature division. At the position of sensor 1 and sensor 2, the temperature is the highest and then the lower temperature area is sensor 5 and sensor 6. The temperature area of sensor 3 and sensor 4 is the lowest. The results of the experiment is completely suitable to the hydrodynamic lubrication theory for the connecting rod big end bearing. When the rotation speed increases, the temperature increases and within the area where the loading capacity is the highest and the oil film thickness is the thinnest, the temperature value is the highest.

V. CONCLUSION

This research presents an experimental instrument for investigating and analyzing the lubricating properties of the connecting rod big end bearing. At the same rotational speed, the load on the drive changes with the vacuum extracting cycles of the simulated internal combustion engine, the temperature value of the oil film increases as the cycle changes. At the oil-laden load (high oil film temperature) corresponds to the minimum oil film thickness at the time of the power. The temperature at the survey sites also increased slightly according to the time of operation, but increased slightly. The measurement results are consistent with the hydrodynamic theory.

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