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Study on Bearing Lubricity with 2-stroke Engine Oil

Hideaki Kawabe　Mitsuaki Ishimaru

● Yamaha Motor Co., Ltd./ Nippon Oil Corporation

Abstract

Polybutene is generally formulated into 2-stroke engine oil in order to prevent smoke and carbon accumulation in the exhaust systems of motorcycles. The higher content of polybutene in the oil is said to be essential to maintain the initial performance of 2-stroke engines. However, it is not so well known that this polybutene deteriorates the lubricity of engine bearings. Therefore, we developed a method for evaluating the lubricity of the bearings to verify the influence of 2-stroke engine oils. Tests were conducted to measure the temperature of the big end of the connecting rod directly while running the engine. The bearing lubricity was evaluated by comparing the temperature of the big end of the connecting rod with the different candidate oils compared to a standard oil. A better 2-stroke engine oil formulation can be found by adding this bearing lubricity test to the JASO (or ISO) standard tests.

1 INTRODUCTION

It is important to maintain the initial performance of a 2-stroke engine for a longer time in order to address environmental concerns. For this purpose, JASO standard tests are generally used to evaluate oil performance, and they have played an appreciable role in eliminating the low performance oils in the market[1]. Various 2-stroke oils have also been developed by the authors using JASO tests. Recently, some oils having extremely high performance indices in JASO standard tests appeared on the market. The authors found that a new evaluation item, that is, the bearing lubricity is necessary as one of the oil performances to be evaluated when these oils were investigated.

In this paper, the characteristics of oils which maintain initial engine performance evaluated by the JASO standard tests are described, and also the results of evaluating the bearing lubricity achieved by those oils is described. Finally, the information necessary for designing engine oil for 2-stroke engines in the future based on these examination results is described.

2 CHARACTERISTICS OF OILS THAT MAINTAIN INITIAL ENGINE PERFORMANCE

The initial performance of an engine decreases chiefly due to exhaust system blocking caused by the accumulation of deposits[2]. Therefore, five kinds of oils which consisted of a typical composition in the market were evaluated by using the JASO M343-92 test procedure[3].

As for base oil, polybutene was the most outstanding in terms of exhaust system anti-blocking performance as shown in **Figure 1**. Moreover, the performance decreased greatly in mixture with other base oils, such as mineral oil. The current low exhaust smoke type oils are generally formulated from a mixture of mineral oil and polybutene.

Figure 2 shows the effect of the polybutene content on the exhaust system blocking index. Here, three FB oils and seven FC oils were arbitrarily chosen from the market. As **Figure 2** shows, the index improves remarkably when the polybutene content exceeds 80%. Thus, it can be said that polybutene is an indispensable base oil for maintaining the initial performance of a 2-stroke engine.

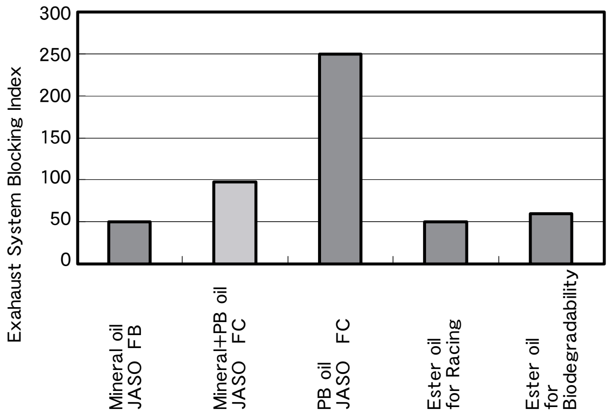

Figure .1 Influence of Oil Composition on Performance in Exhaust System Blocking (PB means Polybutene)

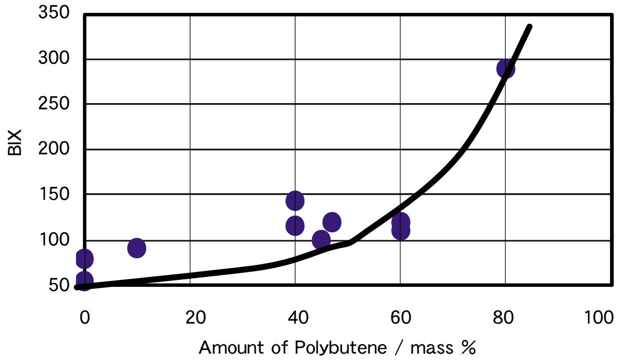

Figure.2 Influence of Polybutene Component on Exhaust Carbon Blocking Index (BIX)

3 DISADVANTAGES OF POLYBUTENE

It has been reported that polybutene based oil causes a slight drop in engine power output compared to mineral based oil, a fact that is related to the stickiness of the polybutene[4]. This means that the oil adhering to the engine parts could not be replaced easily by new oil. This characteristic can be recognized by observing that the color of the small end or the big end of the connecting rod changes to a blue color due to heat. Accordingly, the difference between the temperature on the surface of the crank pin at the big end of the connecting rod while running the engine with a mineral based oil and a polybutene based oil was measured. The examination was carried out using an engine shown in **Table 1**.

Table.1 Specification of The Test Engine

Cooling Method	Water Cooling
Bore × Stroke	56.4mm × 50mm
Displacement	124.1cm^3
Engine Output	25kw/9,000r/min
Lubrication system	Separate oiling system

The engine was a 125cm^3 displacement liquid-cooled engine with a separate oil supply system. The engine was run at high speed and full load without disassembling the engine in order to evaluate many kinds of oils in a short period of time. As shown in **Figure 3**, the polybutene based oil had crank pin temperatures 5℃ to 30℃ higher than the mineral based oil. And the difference in the temperatures increased as the engine revolution increased. Furthermore, when the polybutene based oil was run at 9,000 rpm, the crank pin temperature suddenly increased. The engine was stopped and disassembled. We confirmed that the color of the big end of the connecting rod had changed to a deep blue. Therefore, we thought it is necessary to propose an index for bearing lubricity based on the temperature of the big end of the connecting rod.

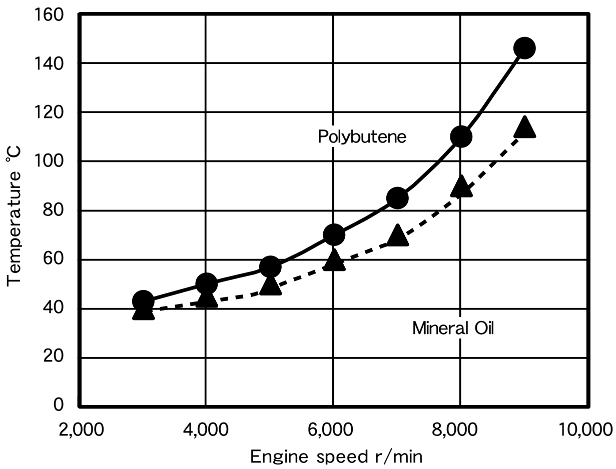

Figure .3　Influence of Oil Composition on Crank Pin Temperature

4 BEARING LUBRICITY TEST

In order to evaluate the oil lubricity on the bearing part, the engine was remodeled as shown in **Figure 4**.

A thermocouple was buried in the circumference face on the side of the big-end pin inertial force. The engine was run at 9,000 rpm and full load. The results of the engine tests were reported as performance indices, taking JATRE-1, the standard reference oil, as 100.

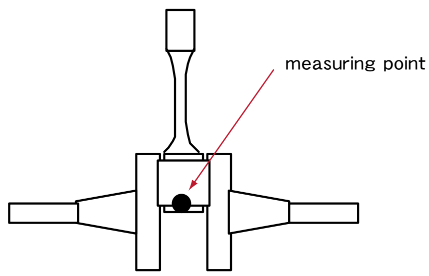

Figure .4　Installation of temperature sensor

$$BLIX = TJ1 / TS \times 100$$

BLIX:Bearing Lubricity Index

TJ1:Crank pin temperature with JATRE-1

TS:Crank pin temperature with the sample oil

5 INFLUENCE OF POLYBUTENE ON BEARING LUBRICITY

- The effect of polybutene based oils on bearing lubricity using the above-mentioned test method.

(1) Influence of polybutene content

As shown in **Figure 5**, an increase in polybutene content deteriorated the lubricity of the bearings. However, the difference in the index between two oils tested was 10, even though the polybutene content was the same. It was assumed that the molecular weight of polybutene contained in these oils influenced their indices.

(2) Influence of polybutene molecular weight

The bearing lubricity decreased obviously as the average molecular weight of the polybutene increased, as shown in **Figure 6**. Even if a small quantity of polybutene which has a molecular weight of 1000 or more is contained, the stickiness of the polybutene on the bearing might be very high. Therefore, from the standpoint of bearing lubricity, it is preferable to avoid oil formulations containing polybutene with a high molecular weight.

(3) Influence of commercial oils

Figure 7 shows the results of the bearing lubricity tests using commercial oils shown in **Figure 1**. The FC oils based on oil containing polybutene were inferior in terms of bearing lubricity compared with the FB oil based on mineral oil, the racing type oil and the biodegradable oil based on esters. In the current state, mineral oil should be included in the formulation of low smoke type 2-stroke oils even at the expense of poorer performance regarding exhaust system blocking.

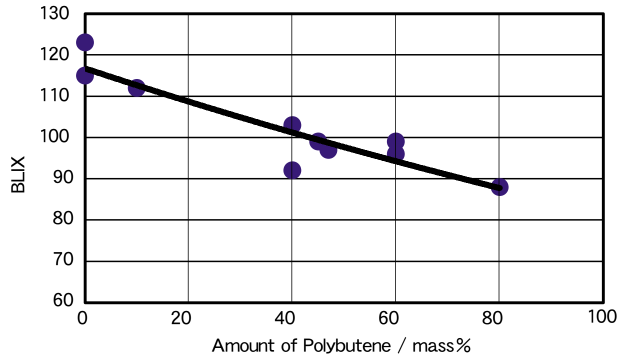

Figure .5 Influence of Polybutene Component on Bearing Lubricity Index (BLIX)

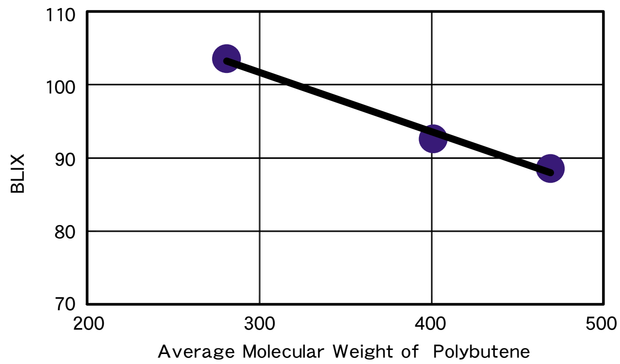

Figure .6 Influence of Polybutene Molecular Weight on Bearing Lubricity Index

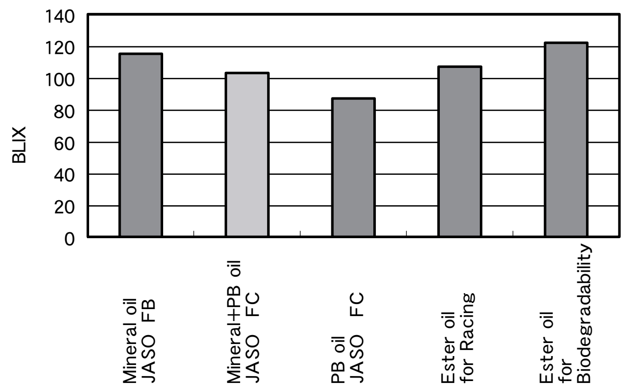

Figure .7 Influence of Oil Composition on Bearing Lubricity

6 RELATIONSHIP BETWEEN BEARING LUBRICITY TESTS AND JASO TESTS

Results of the bearing lubricity tests seemed to correlate with those of the JASO M340-92 (initial torque)[5] and the JASO M343-92 (exhaust system blocking). Though the bearing test developed by the authors had a good repeatability and reproducibility, we had a hard time remodeling the engine to measure the temperature at the big end of the connecting rod. And the durability of the measurement part was a little poor. Then, it was investigated whether bearing lubricity could be estimated from the results of JASO examination tests[3,5,6]. The results appear in **Figures 8**, **9** and **10**.

A comparatively high correlation was shown between the bearing lubricity index and indices of JASO tests. In order to get a bearing lubricity index of 100 or more, each performance index of the candidate oil must achieve the following levels.

(1)Exhaust system blocking index: 120 or less
(2)Initial torque index: 100 or more
(3)Exhaust smoke index: 100 or less

The candidate oils which do not achieve the three indices mentioned above are presumed to be comparatively low in bearing lubricity performance. Oppositely, oils that satisfy all three indices are presumed to be high in bearing lubricity performance. It is important for the future to develop 2-stroke engine oil with consideration for these three indices and the balance with other performance factors when a bearing lubricity test cannot be executed.

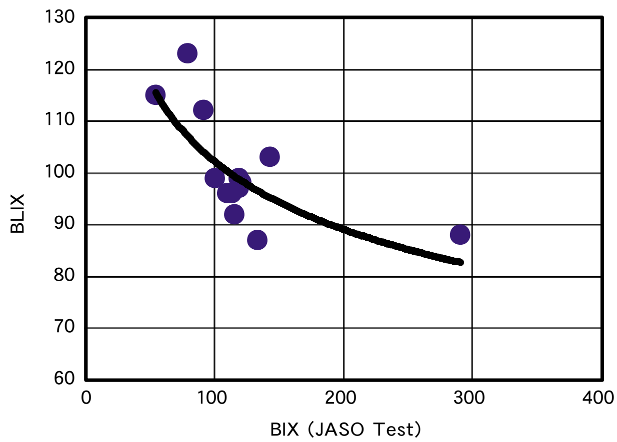

Figure .8 Relationship between Bearing Lubricity Index and Exhaust Carbon Blocking Index (BIX)

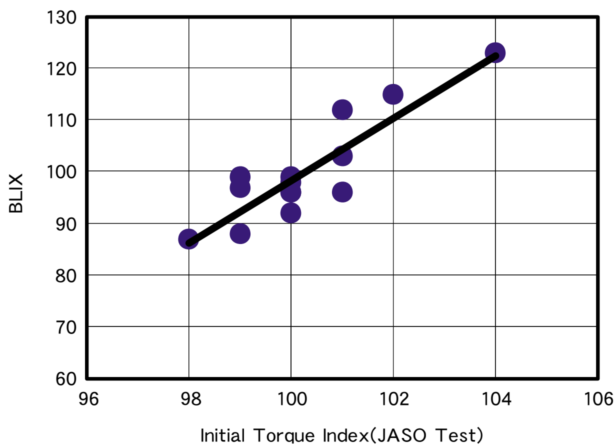

Figure .9 Relationship between Bearing Lubricity Index and Initial Torque Index

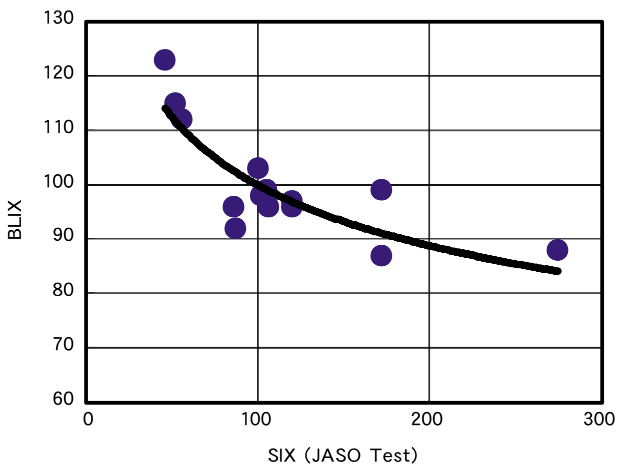

Figure .10 Relationship between Bearing Lubricity Index and Exhaust Smoke Index (SIX)

7 SUMMARY AND CONCLUSIONS

A test method was developed for evaluating lubricity of oil with regard to the bearings at the big end of the connecting rod. By testing various kinds of oils made with polybutene, mineral oil or ester based oils, the following results were obtained.

(1) A low-smoke type 2-stroke engine oil containing polybutene was essential to maintain the initial efficiency of engines.

(2) Mineral oil and ester are effective in improving bearing lubricity. It may be preferable to reduce the content of polybutene, provided that the required performance level for exhaust system blocking and exhaust smoke are satisfied.

(3) From the standpoint of bearing lubricity, it was not desirable to include polybutene with a high molecular weight, particularly 1000 or more.

(4) Bearing lubricity might be estimated by analyzing the three indices of "initial torque," "exhaust system blocking" and "exhaust smoke."

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■ AUTHORS


Hideaki Kawabe


Mitsuaki Ishimaru