


Article

Excellent Seizure and Friction Properties Achieved with a Combination of an a-C:H:Si DLC-Coated Journal and an Aluminum Alloy Plain Bearing

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Abstract: Friction occurring between the crank journal and main bearings accounts for a large share of the mechanical losses of automotive engines. The effects of higher in-cylinder pressures and narrower bearings have raised the specific load applied to bearings, making it essential to secure sufficient seizure resistance as well. For the purpose of meeting both requirements, we have endeavored to reduce friction and improve seizure resistance by applying a diamond-like carbon (DLC) coating to the crank journal. In the present study, a bearing tester was used that has received international standard certification from the International Organization for Standardization for reproducing the sliding behavior occurring between the crank journal and main bearings in actual engines. Test results indicated that a silicon-containing hydrogenated amorphous carbon (a-C:H:Si) DLC-coated journal showed a definite friction reduction and a marked improvement in seizure resistance. An acoustic emission (AE) analysis revealed that an adhesion-induced AE peak observed for a steel journal was not seen for the DLC-coated journal. Additionally, tin and aluminum elements in the bearing material that were transferred to and observed on the sliding surface of the steel journal were not seen on the DLC-coated journal. Accordingly, the low affinity of the DLC coating with these metal elements presumably led to the clear friction reduction and superior seizure resistance displayed by the DLC coating.

Keywords: diamond-like carbon; a-C:H:Si; engine; crank journal; aluminum alloy plain bearing; seizure; friction; acoustic emission; adhesion



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1. Introduction

In October 2020, the Japanese government announced a “Green Growth Strategy Through Achieving Carbon Neutrality by 2050” and a specific policy was formulated in June 2021 [1]. As of December 2020, 123 countries and one territory had expressed their support for carbon neutrality [2]. Toward that end, an urgent priority is to improve the thermal efficiency of internal combustion engines, especially for automotive gasoline engines. Looking at the energy losses incurred by engines, it is crucial to reduce the friction losses of the crankshaft-main bearing system that account for a major portion of the mechanical losses in engines. In recent years, bearing specific load have risen owing to the effects of higher in-cylinder pressures and the adoption of narrower-width bearings, making it essential to ensure seizure resistance as well. In this regard, this study focused on diamond-like carbon (DLC) coatings [3] that have been increasingly applied to sliding gasoline engine parts such as valve lifters and piston rings for the purpose of improving

seizure resistance and reducing friction under mixed lubrication and boundary lubrication regions. It has been reported in recent years that DLC coatings are effective in reducing friction under an elasto-hydrodynamic lubrication (EHL) region [4–8] and that applying a DLC coating to the steel tip of tools for cutting aluminum can inhibit the sticking of aluminum to the tool owing to the low affinity of DLC coatings with aluminum [9].

In view of these findings, it was reasoned that applying a DLC coating to the crankshaft main journal would both reduce friction and improve seizure resistance under various lubrication regions. To verify this effect, tests were conducted on actual engine parts in isolation to evaluate the friction and seizure properties of a combination of a silicon-containing hydrogenated amorphous carbon (a-C:H:Si) DLC-coated journal and a lead-free Al-Sn-Si alloy bearing for recent gasoline engines [10]. The evaluations were performed using a bearing test rig as specified in ISO 21866-1 for automotive journal bearings [11], which makes it possible to examine the properties under fluid, mixed, and boundary lubrication regions. The friction and seizure properties of DLC-coated journals in a specific load range up to a maximum specific load of 121 MPa have previously been reported along with the related influence of surface roughness and engine oil additives [12,13]. In the present study, friction and seizure properties were investigated under specific load as high as 181 MPa, along with analyzing the sliding part surfaces and conducting acoustic emission (AE) tests to analyze the phenomena involved.

2. Test Method

2.1. Bearing Tester

The overall configuration of the bearing tester used to measure the friction and seizure properties of the journal and bearing is shown in Figure 1. The test shaft incorporating the journal is rotated by a AC motor (i), and the shaft torque produced during the test is measured with a torque meter (ii) installed between the motor and the test shaft. The test section (iii) of the bearing tester consists of the test shaft and a pair of plain bearings that form a set with it (Figure 2). Both ends of the test shaft are supported by a total of four rolling bearings, denoted as a support bearing in the figure. The plain bearings are attached to highly rigid connecting rods (Figure 3) that serve to suppress the connecting rod deformation which occurs in actual engines. The highly rigid connecting rods apply the load to the journal in a step-like manner via the plain bearings by means of a hydraulic vibration generator (iv). It also has a tilting device (v) that adjusts the parallelism between the journal and the bearing [12,13]. The applied load is measured with a load cell (vi). The hydraulic vibration generator can apply various types of dynamic loads such as sine wave, rectangular wave and triangular wave loads. It can also apply static loads by performing control based on displacement. In an actual engine, the load applied to the journals is dynamic, but it was decided to apply static loads in this study in order to evaluate friction and seizure properties under more severe conditions than those of an actual engine. If a sharp rise in shaft torque exceeding a set value is detected during a test, the torque limiter (vii) installed between the torque meter and the test shaft acts immediately to decouple the motor and the test shaft in order to prevent damage to the tester. The occurrence of such a sharp torque rise was regarded as the moment of seizure. The upper load limit of the bearing tester was set at 99 kN. Plain bearings, journals, and lubricant conform to the standard specifications of commercially available gasoline engines (TOYOTA 2ZR-FXE, Tokyo, Japan).

2.2. Test Shaft

The specifications of the journal incorporated in the test shaft are listed in Table 1. Figure 4 is a photograph showing the appearance of the test shaft. The shaft was made of SCM 420H alloy steel (Konan Precision Grinding, Tokyo, Japan). The outer diameter of the journal was 48 mm, the same as that of the target engine. The shaft underwent a carburizing quenching process to give it a surface hardness of 78–83 HRA. Surface roughness was 0.06 $\mu\text{m Ra}$.

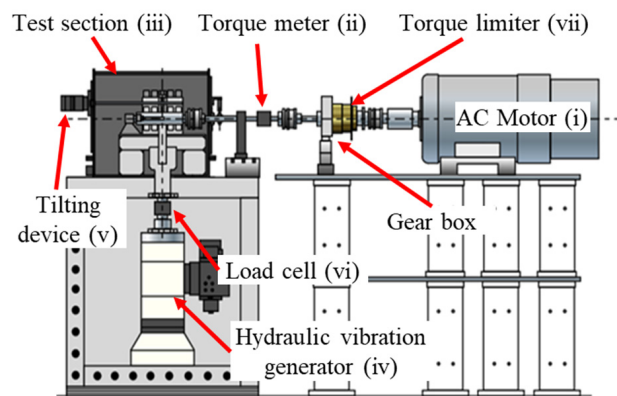


Figure 1. Configuration of bearing tester.

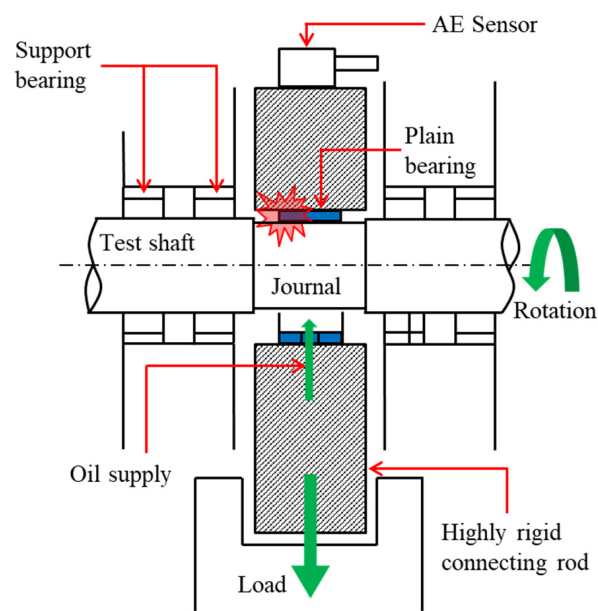


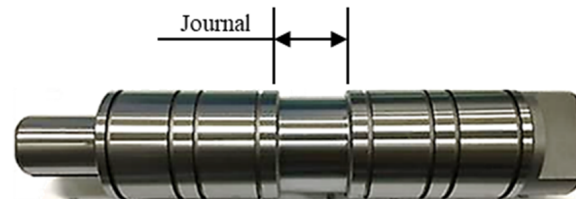
Figure 2. Detailed view of test section.



Figure 3. Highly rigid connecting rod.

Table 1. Main journal specifications.

Item	Specification
Material	Steel (SCM 420H)
Quenching process	Carburizing
Diameter (mm), φ	48
Roughness (μm), Ra	0.06
Hardness	HRA (surface)
	HRC (interior)
	78–83
	30–45

**Figure 4.** Test shaft.

2.3. Lubricating Oil

A general-purpose gasoline engine oil of the SAE 0W-20 (according to the standard of the automotive company) viscosity grade containing a molybdenum dithiocarbamate (MoDTC) additive as a friction modifier was used as the lubricating oil in the tests. MoDTC additives are used to reduce the friction of many sliding steel engine parts operating under a boundary lubrication region. The kinematic viscosity properties of the lubricating oil at various temperatures are shown in Table 2.

Table 2. Kinematic viscosity of lubricating oil at various temperatures.

Item	Specification
SAE viscosity grade	0W-20
Kinematic viscosity at 40 ($^{\circ}\text{C}$) (mm^2/s)	37.25
Kinematic viscosity at 100 ($^{\circ}\text{C}$) (mm^2/s)	8.313
Kinematic viscosity at 110 ($^{\circ}\text{C}$) (mm^2/s)	6.975

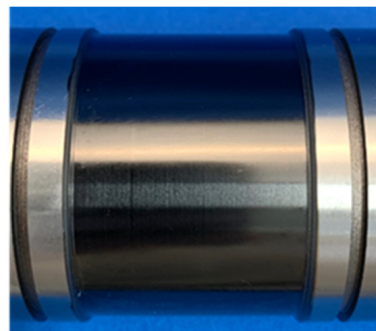
2.4. a-C:H:Si DLC Coating

The friction and seizure properties of journal bearings are largely governed by the properties of the bearing surface. Accordingly, in this study, attention was focused on a silicon-containing hydrogenated amorphous carbon (a-C:H:Si) DLC coating among the DLC coatings for which there are examples of application to automotive internal combustion engines. Following the formation of this coating, it has surface properties equal to those of the base metal. However, it has been reported that a-C:H DLC coatings suffer abnormal wear due to the MoDTC friction modifier contained in engine oils [14–16]. Therefore, the a-C:H:Si coating [17] was selected as one of the DLC coatings capable of suppressing such wear and applied to the journal portion of the test shaft. The a-C:H:Si coating was deposited on the journal of steel shaft by PECVD (plasma-enhanced chemical vapor deposition). Table 3 is the deposition process. Figure 5 is a photograph of the DLC-coated journal surface. Table 4 shows the properties of a-C:H:Si. Hydrogen content was measured by ERDA (Elastic Recoil Detection Analysis), and the coating thickness was measured at the cross section of DLC film by SEM (Scanning Electron Microscope) observation. Roughness was measured by stylus-based profilometer. The surface roughness of the coated journal in the axial direction is shown in Figure 6 in comparison with the steel journal surface. It is seen that applying the a-C:H:Si coating caused no substantial change in surface roughness.

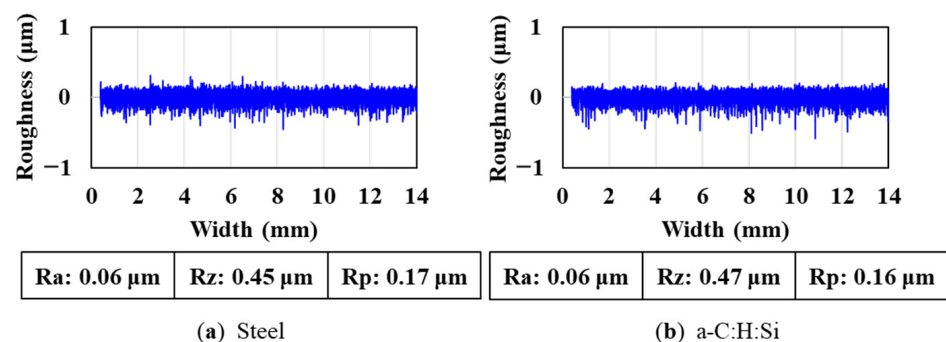
Table 3. PECVD deposition process of a-C:H:Si coating to journal.

Process	Step 1 Cleaning	Step 2 Interlayer	Step 3 DLC Coating
Gas	Ar	TMS ¹	TMS, C ₂ H ₂
Time (min)	30	20	180
Pressure (Pa)	0.28–0.31	0.10	0.28–0.31
Gas flow rate (mL/min.)	50	10	TMS: 2 C ₂ H ₂ : 70
RF (W) (13.56 (MHz))	100	50	100
BIAS voltage (V)	2500	2500	2500

¹ Tetramethylsilane.

**Figure 5.** DLC-coated journal.**Table 4.** a-C:H:Si coating specifications.

Item	Specification
Hydrogen content (at%)	20
Silicon Content (at%)	1.8
Film thickness (mm)	0.001
Roughness (μm), Ra	0.06
Hardness (GPa)	20

**Figure 6.** Surface roughness of: (a) steel journal and (b) a-C:H:Si-coated journal.

2.5. Bearings

The specifications of the bearings used are shown in Table 5. In a previous study [12,13], 17 mm wide bearings were used, but in the present study the bearing width was narrowed by 31% to 11.4 mm. That was done to make the difference in seizure properties clearer by increasing the contact pressure at the maximum load level of the bearing tester. The bearing surface was grooved to a groove depth of approximately 0.8 μm at a pitch of 200–250 μm, as indicated in Figure 7. The initial surface roughness was 0.15 μm Ra and 1.1 μm Rz.

Table 5. Main bearing specifications.

Item		Specification
Material		Al-Sn-Si alloy
Al (mass%)		Balance
Sn (mass%)		12.5
Si (mass%)		2.7
Cu (mass%)		1.0
Overlay (metal/polymer)		-
Width (mm)		11.4
Bearing clearance (mm)		0.050 (In diameter)
Surface treatment		Grooved
Roughness (μm)	Ra	0.15
	Rz	1.1

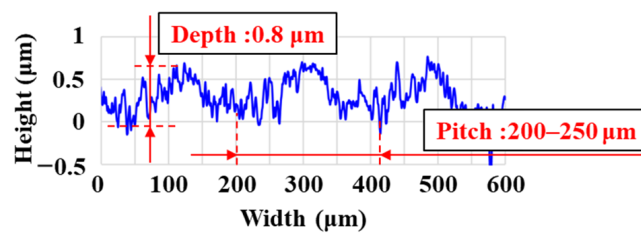


Figure 7. Measured results for bearing surface grooves.

2.6. Seizure Test

The seizure test conditions are given in Table 6, and the tester operating modes are shown in Figure 8. The rotational speed of the test shaft was set at 5200 rpm, the same as the maximum output speed of the target engine. The load was increased in increments of 3 kN from a pre-load level of 3 to 99 kN, which was the maximum load capacity of the bearing tester. A sharp rise in friction torque during the test was deemed to indicate the occurrence of seizure. The test was suspended at that point, and seizure resistance was evaluated on the basis of the bearing specific load calculated at the moment seizure occurred. The method of calculating the bearing specific load is shown in Figure 9. The bearing specific load was found by dividing the applied load by the projected area of the bearing surface. The applied load during the seizure test was increased in steps of 3.0 kN, which was equal to specific load of approximately 5.5 MPa.

Table 6. Seizure test conditions.

Item	Condition
Journal rotation speed (rpm)	5200
Load (kN)	3–99 (3 kN steps)
Lubricant supply pressure (MPa)	0.4
Lubricant inlet temperature ($^{\circ}\text{C}$)	110

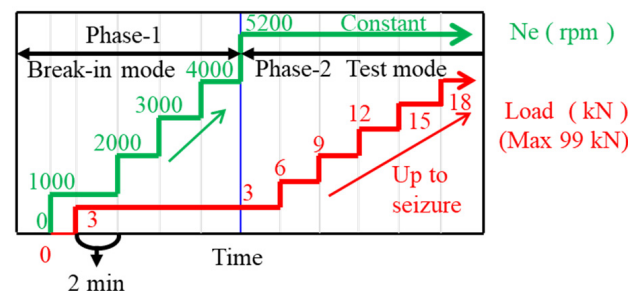


Figure 8. Operating modes in seizure test.

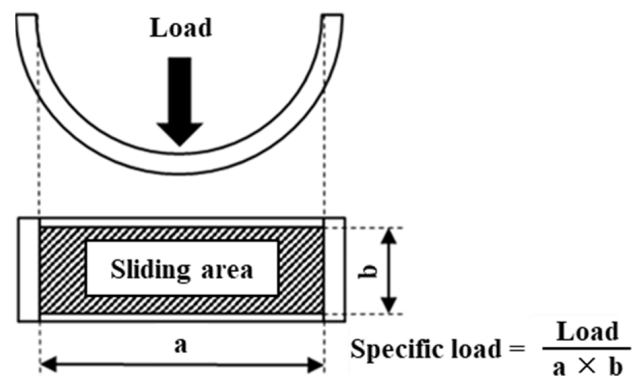


Figure 9. Method of calculating bearing specific load.

2.7. AE Measurement

Acoustic emission (AE) measurements were made during the seizure test to investigate the change in wear up to the occurrence of seizure and the effect of the wear state on reducing friction. The AE measurement conditions are given in Table 7. As shown in Figure 2, an AE sensor was installed on top of a connecting rod. The measured AE waves were recorded in a dedicated high-resolution data logger. The measured signals were filtered using a high-pass filter at 100 kHz to remove the influence of journal rotation.

Table 7. AE measurement conditions.

Item	Condition
High-pass filter (kHz)	100
Low-pass filter	Through
Sampling rate (MHz)	5

3. Results

3.1. Seizure Properties

Table 8 shows the specific load calculated at the completion of the seizure test, and Figure 10 shows the change in torque at various specific load (specific loads) for the steel journal and the a-C:H:Si-coated journal. In Figures 10 and 11, the average values of the torque and coefficient of friction were found at each applied load for two minutes and the plots are connected by a line. For the steel journal, seizure occurred at a specific load of 159 MPa (87 kN), whereas seizure did not occur for the a-C:H:Si-coated journal even at 181 MPa (99 kN), which was the maximum load limit of the tester. These results indicate that applying the a-C:H:Si coating to the journal improved seizure resistance by at least 12% over the steel journal. With the steel journal, the backside temperature of the bearing just prior to seizure was 191.3 °C and it rose as high as 204.5 °C accompanying the occurrence of seizure. In contrast, the bearing backside temperature with the a-C:H:Si-coated journal rose as high as 197.5 °C, but seizure did not occur.

Table 8. Specific load at conclusion of seizure test.

Journal	Specific Load at Seizure (MPa)
Steel	159
a-C:H:Si	181 (No seizure)

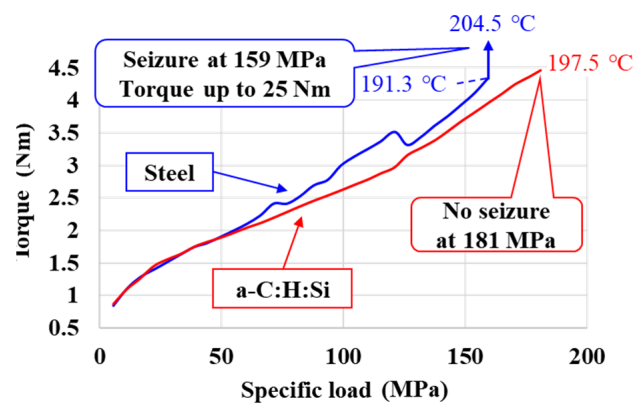


Figure 10. Change in torque at various specific load.

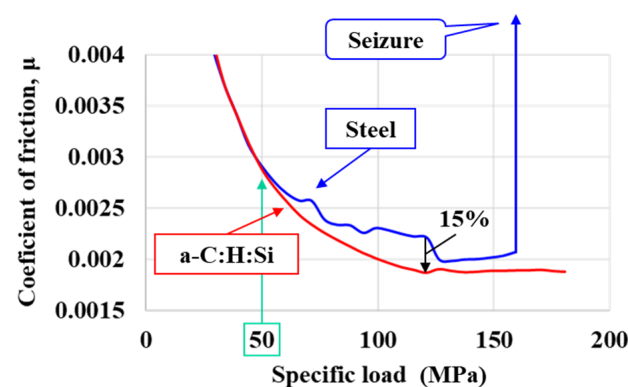


Figure 11. Change in coefficient of friction at various specific load.

3.2. Friction Properties

The changes in the coefficient of friction of the steel journal and the a-C:H:Si-coated journal at various specific load during the seizure test are plotted in Figure 11. It is seen that the a-C:H:Si coating was effective in reducing friction in the region above 50 MPa (27 kN), and a maximum friction reduction effect of 15% was obtained at 121 MPa (66 kN).

3.3. Torque Characteristics of Steel Journal and a-C:H:Si-Coated Journal

Figure 12 shows a time history of the change in torque for the steel journal. This figure presents the raw data measured for the journal during the test, which differ from the average torque values shown in Figure 10. In addition to the increase in torque at the time of seizure, it is seen that torque spikes, defined as a sharp rise to less than the value signifying seizure followed by a sudden decline, occurred at three points where the specific load was 44 MPa (24 kN), 77 MPa (42 kN), and 126 MPa (69 kN), respectively. The third torque spike at 126 MPa was especially prominent. The torque value immediately following the occurrence of a torque spike was equal to or lower than the value before the spike occurred. In addition, the torque value just before the occurrence of a torque spike tended to increase compared with the level prior to that point (This tendency was especially pronounced for the second torque spike at 77 MPa.). These torque rises and falls accompanying the torque spikes induced the changes in the coefficient of friction of the steel journal shown in Figure 11. In contrast, as shown in Figure 13 for the a-C:H:Si-coated journal, torque spikes did not occur, and no tendency was observed for the torque level to increase just prior to the occurrence of a torque spike like that seen for the steel journal. It is concluded from these results that the occurrence of torque spikes depended on differences in material properties.

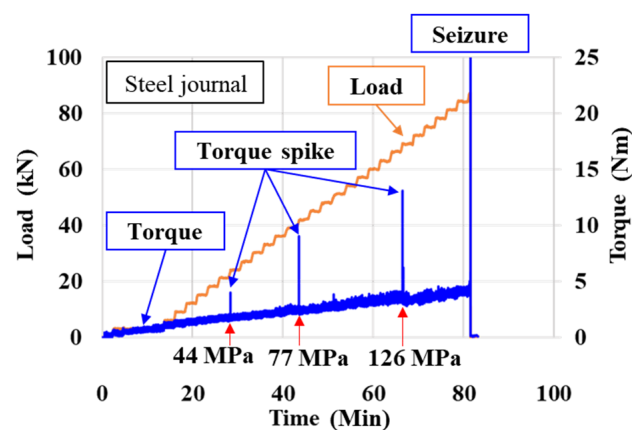


Figure 12. Torque characteristics of steel journal.

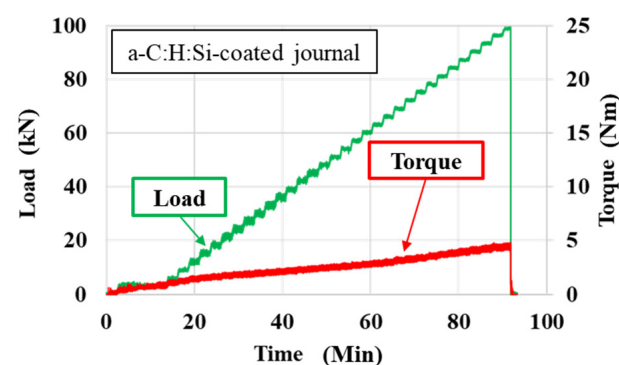


Figure 13. Torque characteristics of a-C:H:Si-coated journal.

4. Discussion

4.1. Verification of the Mechanisms Causing Torque Spikes and Seizure Based on AE Signal Analysis

The AE signal waveform obtained for the steel journal was subjected to a frequency analysis at the time the first torque spike occurred (44 MPa) as well as before and after its occurrence. The results are shown in Figure 14a. The frequency analysis results for the AE signal at the time of seizure and before and after it occurred are presented in Figure 14b. A total of three peaks were detected in the vicinity of 0.1, 0.6, and 1.4 MHz in the results at the time of the torque spike and seizure. Only two peaks were detected at 0.1 and 0.6 MHz in the other portion of the signal. These results were the same for all the torque spikes that occurred during the seizure test. A previous report that analyzed wear modes related to the features of AE signals attributed the peak near 1.4 MHz to the occurrence of adhesive wear and the peak near 0.6 MHz to the occurrence of abrasive wear [18]. Based on the foregoing results, it is inferred that the torque spikes and seizure observed in this study can both be ascribed to the occurrence of adhesive wear. Figure 15 presents the frequency analysis results for the AE signal of the a-C:H:Si-coated journal at a specific load of 181 MPa (99 kN). Only two peaks at 0.1 and 0.6 MHz were always detected throughout the entire test for the a-C:H:Si-coated journal. A peak corresponding to adhesive wear was not confirmed.

Based on these results, the seizure test was concluded after the occurrence of the first torque spike and the surface of the steel journal was analyzed. The purpose of this surface analysis was to prove that adhesive wear had occurred on the journal and the bearing at the time the first torque spike occurred. It will be noted that the first torque spike occurred at 49 MPa (27 kN). Figure 16a shows low- to high-magnification electron microscopy images by energy dispersive X-ray analysis (EDX) (AZtecEnergy, Oxford Instruments, Abingdon-on-Thames, UK) after the occurrence of seizure and (b) shows the results of a high magnification elemental analysis after seizure occurred. Figure 17 shows the surface analysis results for the journal after the occurrence of the first torque spike.

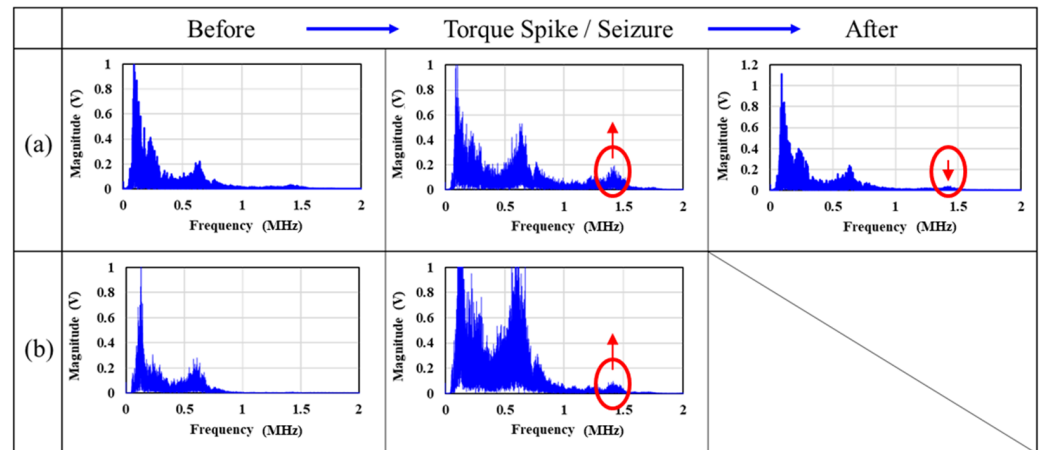


Figure 14. AE signal frequency characteristics for: (a) torque spikes and (b) until seizure occurred.

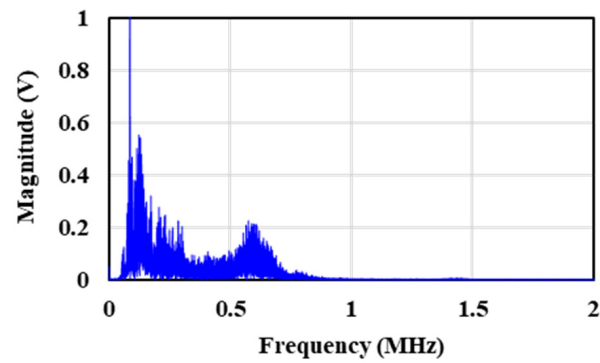


Figure 15. AE signal characteristics for a-C:H:Si-coated journal at load of 99 kN (181 MPa).

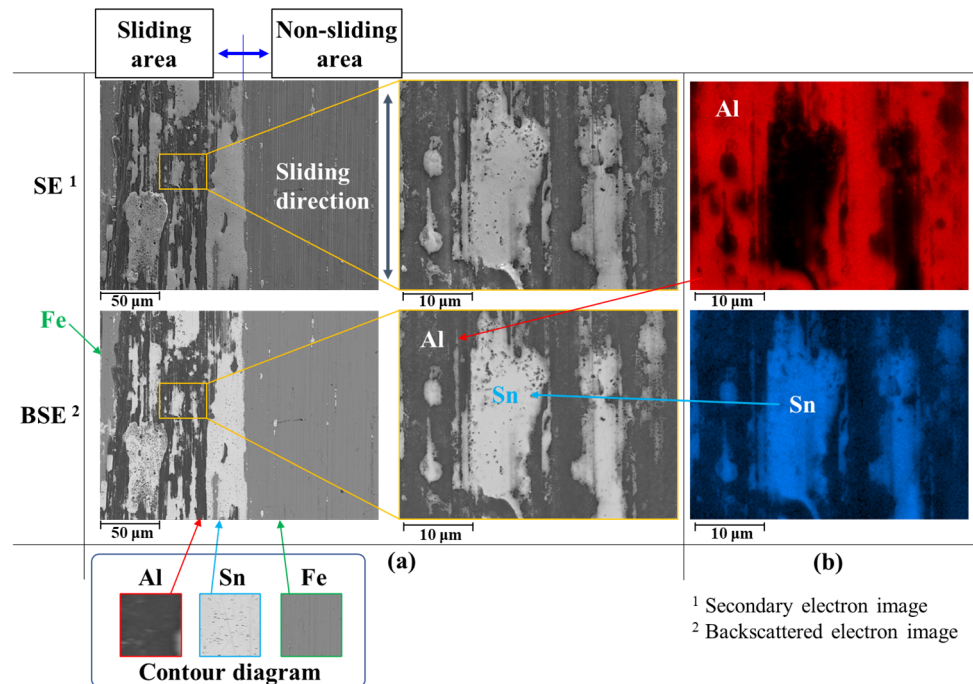


Figure 16. EDX analysis of steel journal surface after occurrence of seizure. (a) Low- to high-magnification electron microscopy images. (b) High-magnification elemental analysis results after seizure occurred.

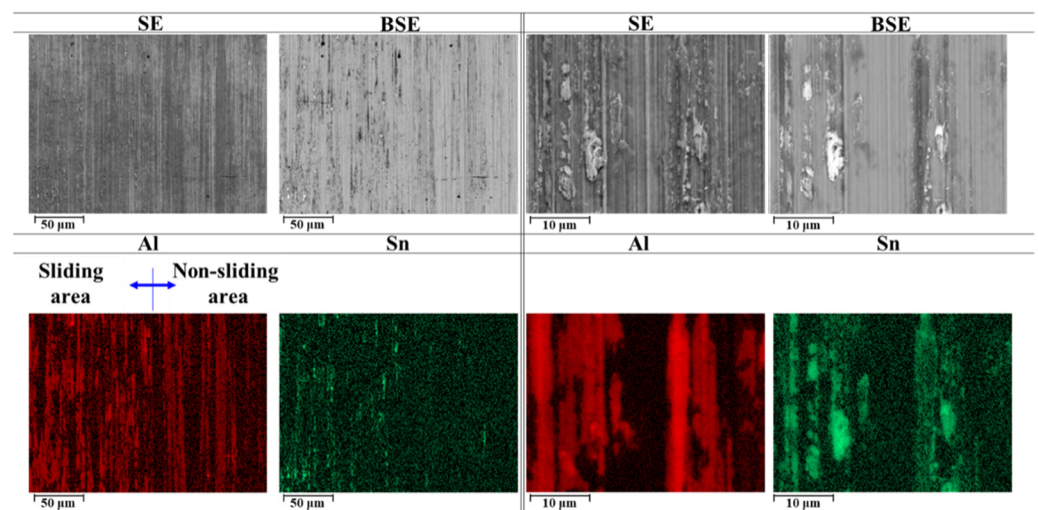


Figure 17. EDX analysis of steel journal surface after occurrence of first torque spike.

Figure 16b shows that aluminum and tin, which were constituent elements of the bearing, can be seen on the steel journal surface after seizure occurred. As can be observed in the low magnification image of the transfer region in Figure 16a, aluminum was transferred widely in the sliding direction and over the entirety of the sliding area. Meanwhile, tin was transferred in a lump on the uppermost surface of the transferred aluminum, presumably indicating that it was not transferred simultaneously with the latter metal. In addition, neither aluminum nor tin was transferred to a portion of the sliding area, leaving the Fe there clearly visible. The presence of tin in a lump suggests that it was probably semi-melted by the heat of friction while the journal was rotating and precipitated on the sliding surface. After seizure occurred and the journal stopping rotating, tin coagulated into a lump in the process of cooling and being transferred to the journal.

The amounts of aluminum and tin transferred after the first torque spike are shown in Figure 17. Although the amounts were less than those after seizure occurred, it can be seen that the metals were transferred in the same manner as after the occurrence of seizure. Accordingly, the presence of adhesive wear at the time torque spikes and seizure occurred as inferred from the analysis of the AE signal can presumably be understood as follows. Solid contact between asperities on the journal and bearing surfaces caused semi-melting of the low-melting-point tin and softening of the aluminum elements in the bearing material, resulting in their transfer to the steel journal.

The surface of the a-C:H:Si-coated journal following the seizure test was examined by EDX (AZtecEnergy, Oxford Instruments, Abingdon-on-Thames, UK) and the images presented in Figure 18 clearly show that there was no transfer of tin and aluminum to the coating. The presence of calcium and oxygen seen in the center portion of the images suggests that the temperature of the sliding interface was rather high. These elements were presumably transferred from the calcium-based detergent-dispersant added to the engine oil to suppress oxidation. Because there was no definite presence of tin and aluminum on the DLC coating surface like that observed in Figure 17, it is presumed that there was no transfer of semi-molten tin and aluminum elements to the a-C:H:Si DLC coating. Accordingly, the low affinity of the DLC coating with the tin and aluminum elements of the bearing alloy avoided chemical bonding between them, and that is probably the reason why seizure did not occur with the a-C:H:Si-coated journal.

4.2. Verification of the Friction Reduction Mechanism

As mentioned in Section 3.2, the friction reduction effect of DLC was obtained in the region above 50 MPa. Figure 19 shows the calculated film parameter Λ and the coefficient of friction as a function of the specific load during the seizure test. The value of Λ is calculated from the surface roughness of the two sliding surfaces and the minimum oil film

thickness between them. A value above 3 is regarded as a fluid lubrication region, 1 to 3 as a mixed lubrication region, and less than 1 as a boundary lubrication region. The film parameter Λ is calculated with the following equation.

$$\Lambda = \frac{h_{min}}{\sqrt{(R_{qB})^2 + (R_{qJ})^2}} \quad (1)$$

h_{min} : minimum oil film thickness

R_{qB} : root mean square roughness of the bearing

R_{qJ} : root mean square roughness of the journal

The calculated Λ values suggest that the two surfaces were sliding under a fluid lubrication region at a specific load of 121 MPa where the largest friction reduction effect was observed in Figure 11. In the peripheral region from 104 to 126 MPa in particular, it is seen in Figure 20 that the raw waveform of the AE signal, which indicates the wear between the a-C:H:Si-coated journal and the bearing, tended to decrease from ± 2 to ± 0.5 V, i.e., to about 1/4 of the level prior to that point. Presumably, there is some relationship between the decline in the AE signal output and friction reduction.

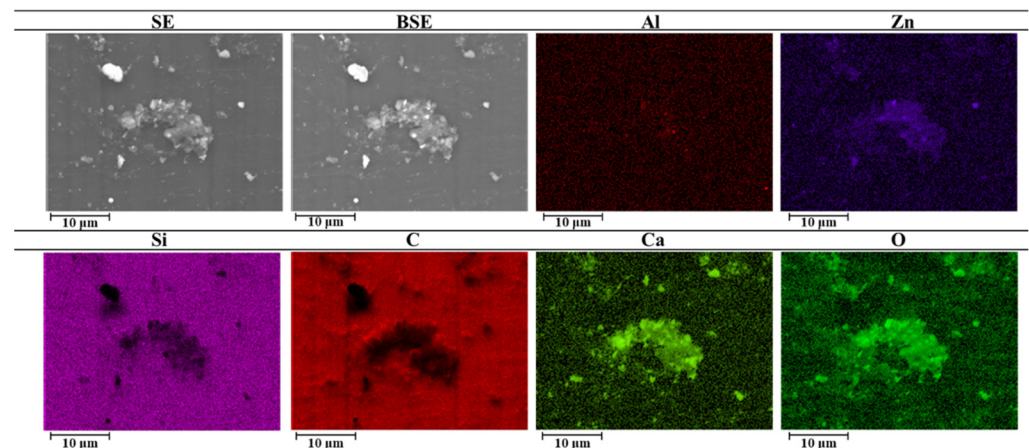


Figure 18. EDX analysis results for a-C:H:Si-coated journal.

The study of Bobzin et al. [4], which investigated the friction reduction effect in the fluid lubrication and elastic fluid lubrication regions of the DLC-coated journal part for the crank journal of an automobile engine is referred to our study. In this report, DLC (a-C:H) is deposited on the surface of a steel four-cylinder engine crankshaft and a steel plain bearing, which is not commonly used. Experiments were conducted in engine motoring tests on non-coated (Steel) and coated with DLC (a-C:H) from 500 to 6000 rpm, and the effect of increasing the friction reduction rate in the fluid lubrication range (high rpm) was obtained.

On the other hand, this study investigated the case where DLC (a-C:H:Si) was deposited on the journal only, using an Al alloy plain bearing used in a general-purpose gasoline engine. Experiments were conducted with increasing loads, and friction reduction effects were obtained in the EHL lubrication region under higher loads. Also, we have found that DLC coating significantly improves the seizure resistance of aluminum alloy and steel, which has never been reported before. There are still some unclear mechanism about friction reduction phenomena in the EHL region, and we will continue to work on elucidating these phenomena.

Figure 21 shows the surface roughness of the bearing measured before and after the seizure test with the a-C:H:Si-coated journal. The post-test results indicated that the bearing edges wore by around 10 μm , but the maximum profile peak height R_p was reduced compared with the value before the test. It will be noted that the surface roughness

of the journal changed only minutely by 0–3 nm. In contrast, when slid on the steel journal, the bearing surface was roughened by the occurrence of seizure and displayed large wear of around 30 μm. In addition, wear of around 6 μm was observed at the ends of the bearing at the time the first torque spike occurred. It is inferred from these results that one mechanism of the friction reduction obtained with the a-C:H:Si-coated journal can probably be attributed to a larger Λ value resulting from a reduction of the bearing surface roughness. This effect seems to be due to the lapping effect of the DLC coating [19]. A friction reduction mechanism has also been reported that is attributed to wall slip [19], caused by a decline in lubricant viscosity accompanying a localized temperature increase owing to the low thermal conductivity of the DLC coating [20,21] and by the effects of functional groups on the DLC coating surface. The friction reduction mechanism will continue to be studied in future work.

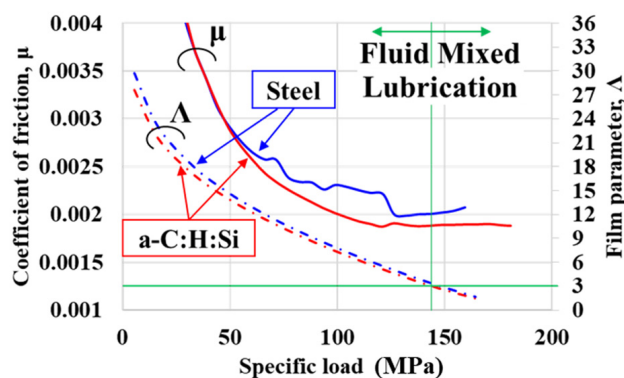


Figure 19. Relation between film parameter Λ and coefficient of friction μ .

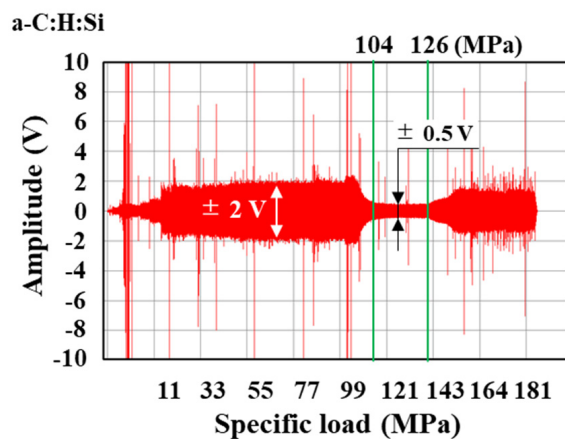


Figure 20. Raw AE signal waveform for a-C:H:Si-coated journal.

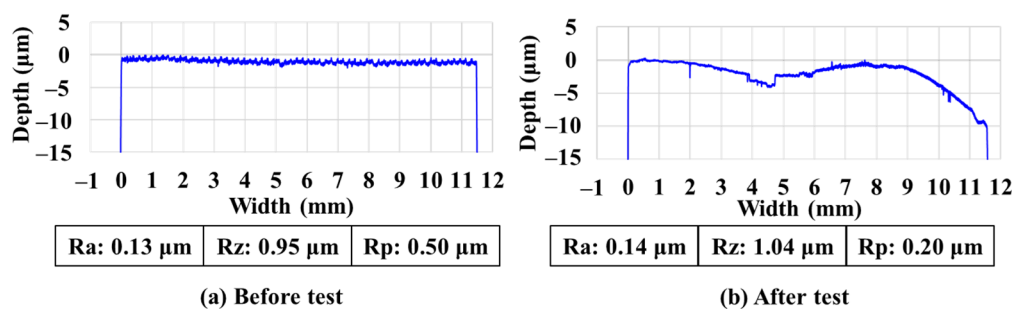


Figure 21. Bearing surface properties with a-C:H:Si-coated journal: (a) before test and (b) after test.

5. Conclusions

A bearing tester was used to investigate the seizure and friction properties of a combination of an a-C:H:Si-coated journal and an aluminum alloy plain bearing. The results revealed excellent seizure properties showing a 12% improvement over a steel journal at the seizure-limit specific load and a clear reduction of friction properties under a fluid lubrication region.

1. One factor causing the seizure observed for the steel journal is presumably ascribable to adhesion of softened aluminum on the journal surface, which occurred accompanying the semi-melting of the tin component of the aluminum alloy that formed the bearing.
2. An AE analysis revealed that the adhesion-induced AE peak seen for the steel journal was not observed for the DLC-coated journal; furthermore, the transfer of tin and aluminum components of the bearing material observed on the sliding surface of the steel journal was not seen for the DLC-coated journal. Accordingly, the low chemical affinity of the a-C:H:Si DLC coating with aluminum and tin presumably suppressed the transfer of these components to the journal sliding area, resulting in a marked improvement of seizure resistance.
3. One mechanism accounting for the friction reduction observed under a fluid lubrication region is presumed to be a higher Λ value that resulted from a reduction of the R_p value due to the lapping effect of the DLC coating.

This paper has presented a comparison and discussion of the friction and seizure properties of an a-C:H:Si-coated journal and a steel journal. In future work, it is planned to investigate other DLC coatings, including a-C:H and ta-C films.

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