Improvement of sliding bearings durability in ultra pure water by diamond film

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Abstract

Silicon carbide (SiC) is known for its superior abrasion resistance, and is widely used in pumps as a material for water-lubricated sliding bearings.

Ultra pure water (UPW), with a specific resistance of greater than 10 MΩ/cm, is often used for purposes such as washing water in semiconductor manufacturing processes and recirculation water in nuclear power generation plants.

However, in cases where SiC sliding bearings are lubricated with ultra pure water, abnormal wear is occasionally found. Such a problem is not seen with normal water lubrication.

The abnormal wear when lubricated with UPW is caused by oxidation of the SiC surface and generation of silicon dioxide.

Abstract

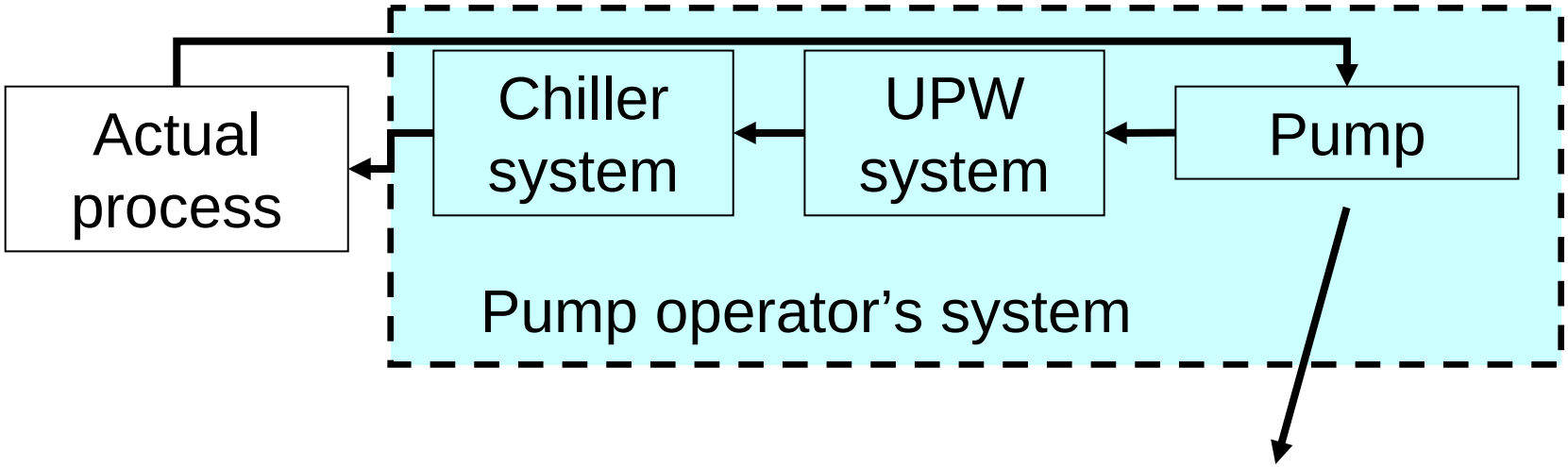
Diamond is the hardest material in the world, and are expected to provide effective abrasion resistance.

Polycrystalline diamond film is harder than SiC and can be formed by chemical vapor deposition (CVD). There are various potential applications for this material, including sliding bearings.

This report describes a case study in which the durability of sliding bearings in ultra pure water was improved by forming a polycrystalline CVD diamond coating on the SiC sliding surface.

Overview

Ultra pure water (UPW) circulation system with a high-speed canned-motor pump containing a SiC bearing

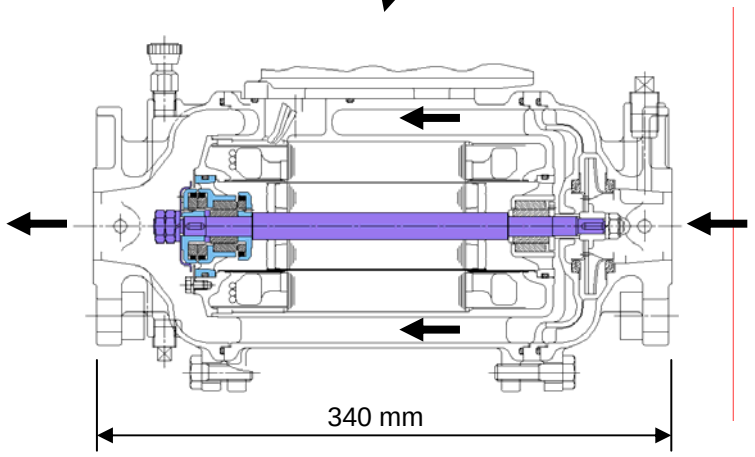


- Reasons for this selection -

Canned-pump ☐ No leakage

High-speed ☐ Compact

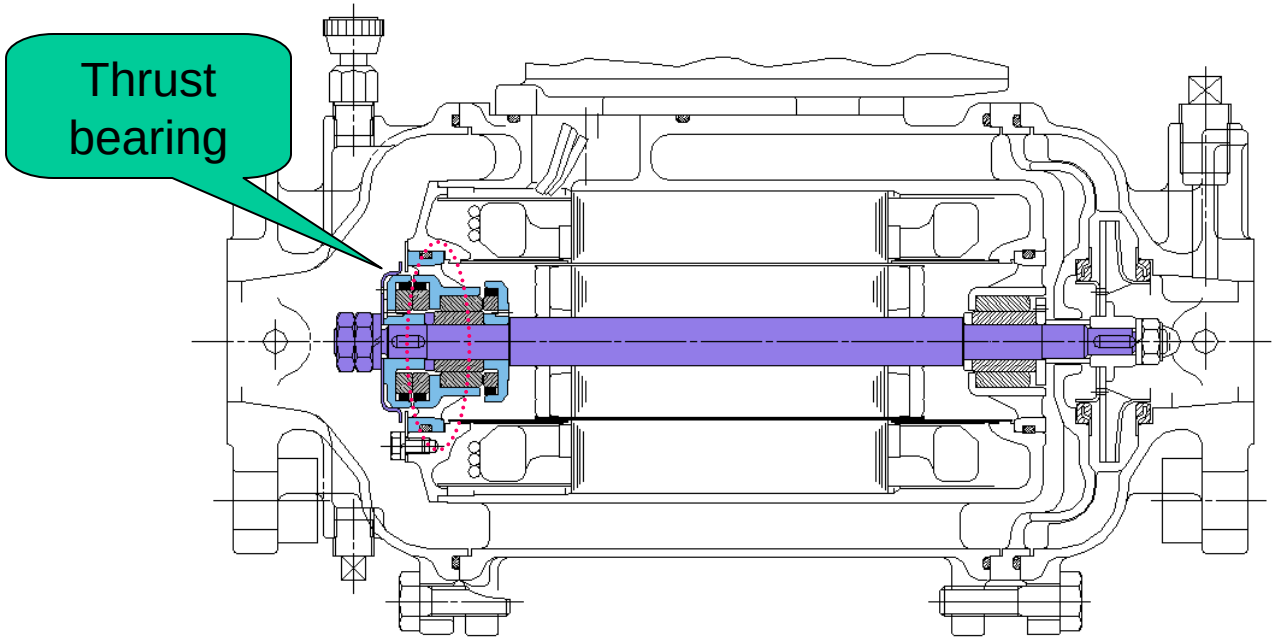
SiC bearing ☐ Long life



75L/min×58m×9190 rpm

Overview

Pump structure



Bearing specifications

Speed□9190 (rpm)

Load□30 (kgf)

P = 5.69 (kgf/cm^2)

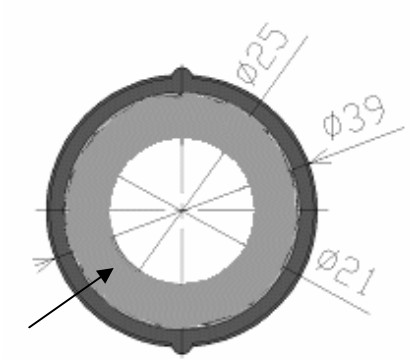
V = 16.35 (m/s)

PV = 93 (kgf/cm^2□m/s)

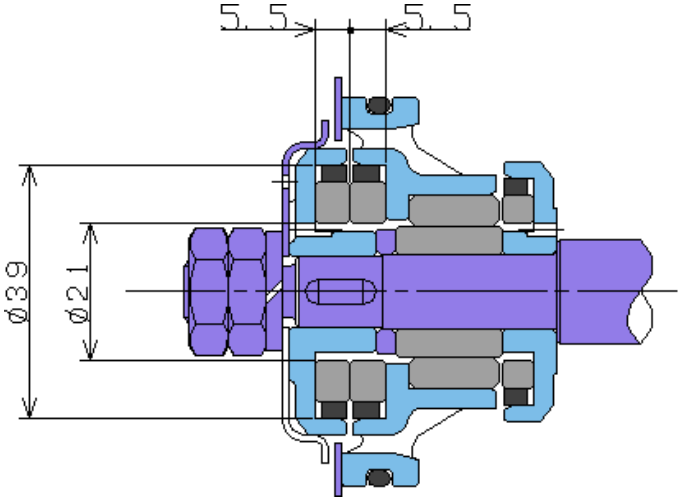
Water temp□Approx. 30°C

Circulated liquid: Pure to ultra pure water

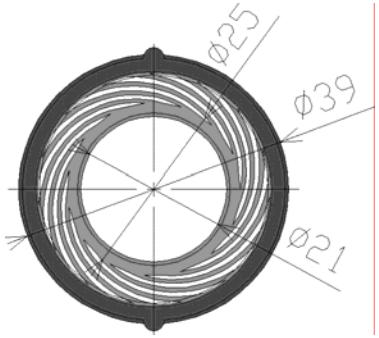
(Max. 18.2 MΩ/cm)



Rotating side (no groove)



Detailed view of thrust bearing

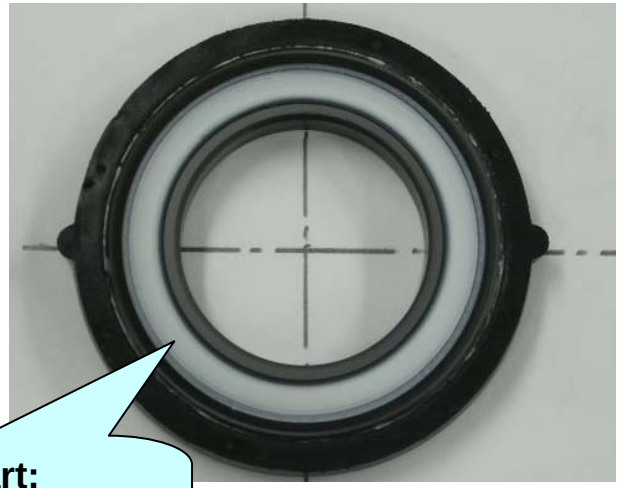


Stationary side (with groove)

Overview

Phenomenon occurring in SiC thrust bearings that are used in UPW.

- SiC is changed into SiO_2, grooves are blocked, and friction-loss increases.
- Bearing lifetime is 2,000 - 4,000 h.



White part:
SiC that was changed into SiO_2

Rotating side

White part
Grooves blocked with SiO_2

Stationary side

Required MTBF is minimum 16,000 h, and expected bearing lifetime is greater than 40,000 h.

Therefore, drastic improvement of the bearing lifetime was necessary without changing pump size.

Process of the Case Study

STEP 1 Selection of Bearing Material

The corrosion level of SiC depends on the pressure and the flow conditions of the UPW. The UPW jet method was adopted as material evaluation and the superiority of the diamond coating against UPW was verified.

STEP 2 Optimizing Groove Shape Design

A bearing shape which is suitable for the diamond coating was determined after several attempts.

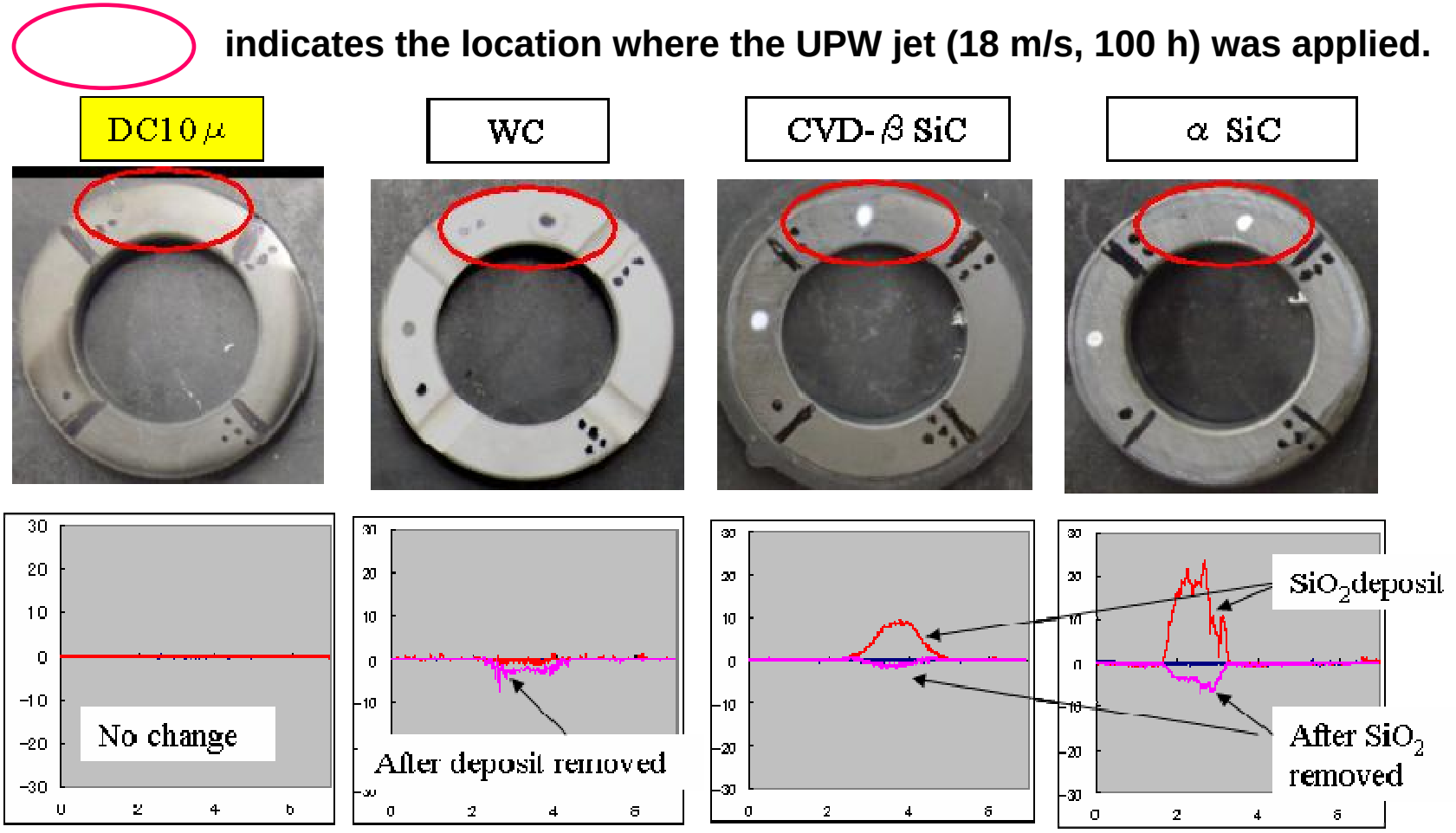
STEP 3 Estimation of Bearing Lifetime

An evaluation was conducted using a verification test in UPW (amount of wear vs. running time), and the expected bearing lifetime was calculated.

STEP 1-1 Selection of Bearing Material

Evaluation of sliding material resistance against UPW (water jet test)

Result: Only the diamond coat (DC) yielded a good result.



STEP 1-2 Selection of Bearing Material

Effect of layer thickness (first trial)

Trial production bearings with a layer thickness of 5 μm and 10 μm were evaluated in an actual pump operation test using UPW.

Layer thickness:5 μm	Layer thickness:10 μm

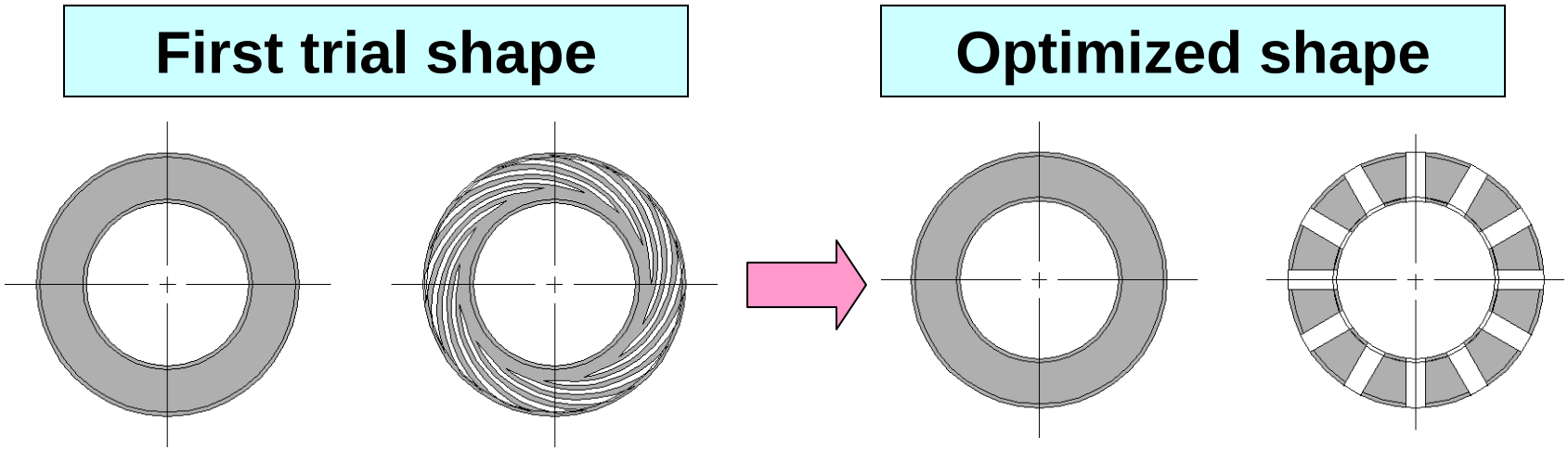
Separation of the DC layer was found after 1 month of operation.	No change was found even after 4 months of operation.

STEP 2-1 Optimizing Groove Shape Design

The soundness of the coating is ensured by not only the thickness but also by the shape and surface conditions of the grooves.

Oxidation caused by laser machining of grooves and sharp edges are thought to impede the coating contact.

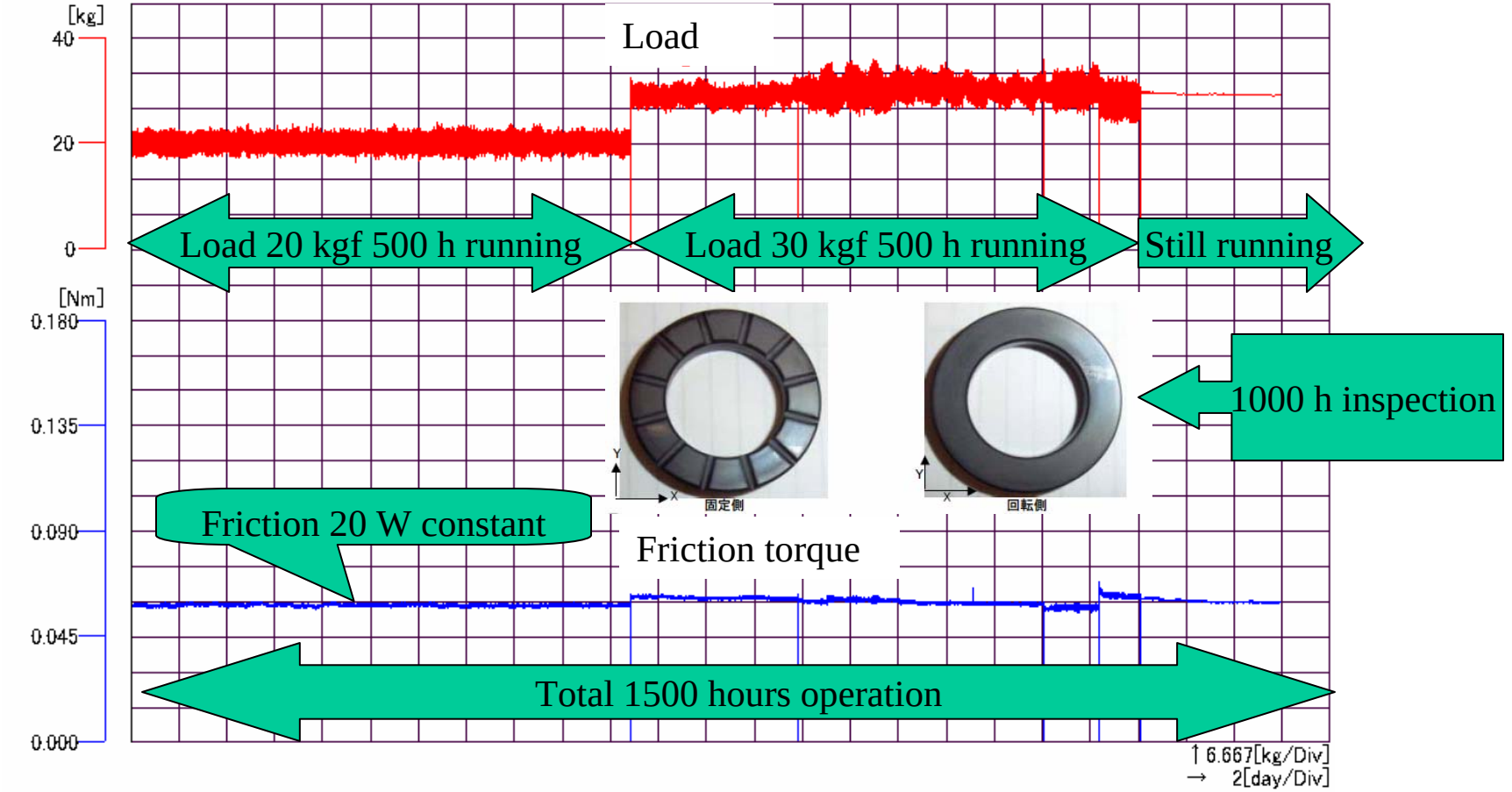
Finally we decided on radial grooves which can be shaped by press molding, and a minimum layer thickness of 12 μm.



STEP 2-2 Optimizing Groove Shape Design

The friction torque of new-shape bearings (type with 12 radial grooves) with UPW was monitored for 1500 hours.

The friction torque was stable and no separation of the DC layer was found after the test.



STEP 3-1 Estimation of Bearing Lifetime

Pump running tests with 4 systems were used to estimate the bearing lifetime.

The estimation method is as follows.

Bearing lifetime = Layer thickness / (Reduction in thickness / Hours of operation)

Here,

Layer thickness = 12 μm

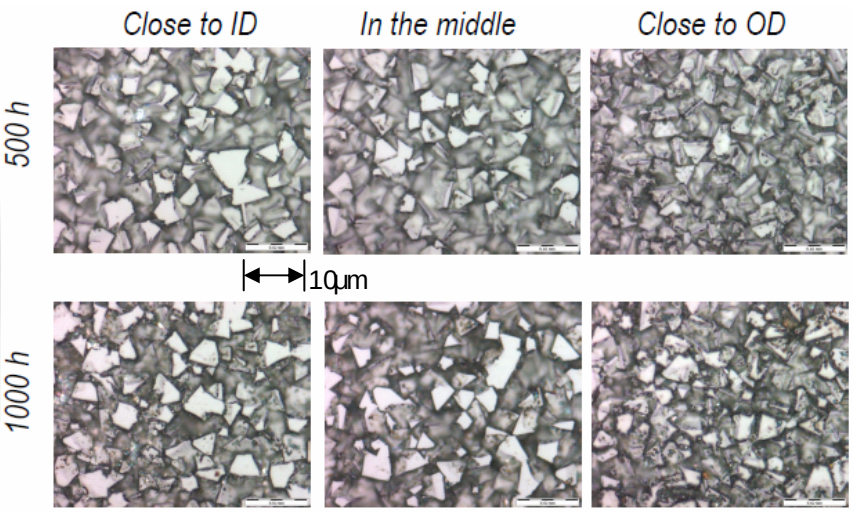
Operating time = Max. 2520 h

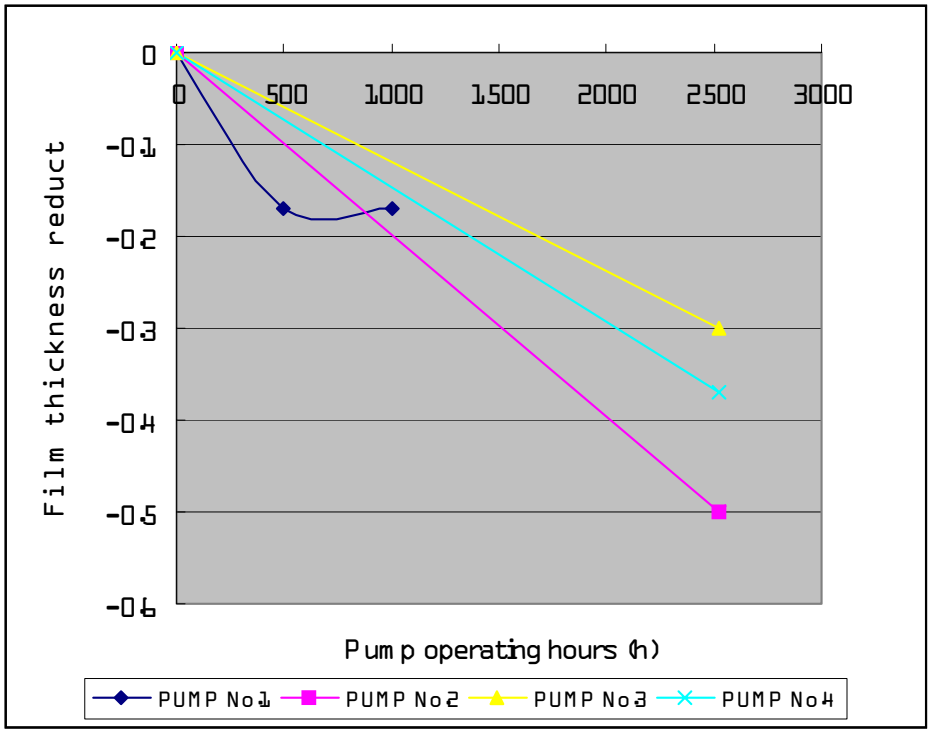
Pump running test

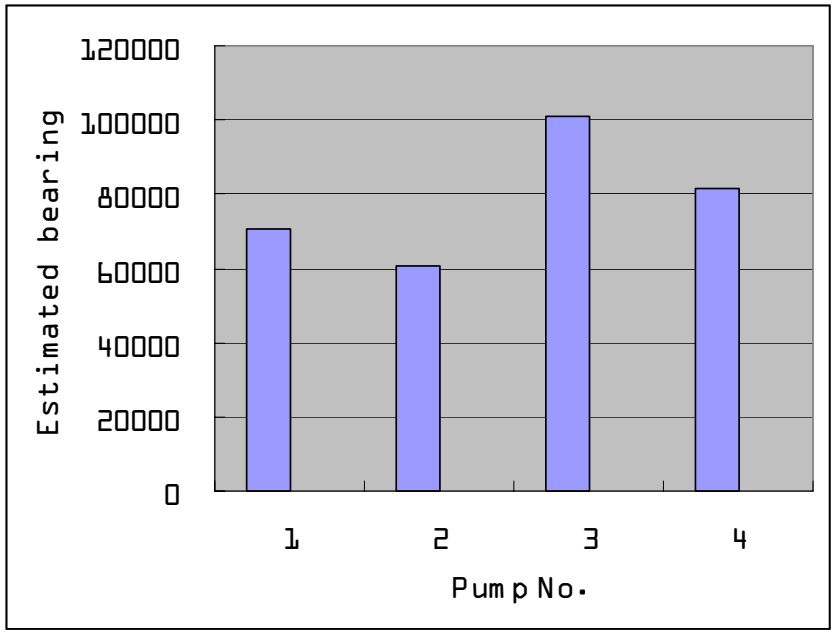
STEP 3-2 Estimation of Bearing Lifetime

Rotating side

Stationary side







Conclusion

The lifetime of sliding bearings used in ultra pure water has been improved by forming a polycrystalline CVD diamond film on a SiC surface.

We hope that this finding will offer a solution to the problems which pump operators are facing. This technology can also be applied to mechanical seals.

Thank you for your kind attention.