1. Introduction

Oil-lubricated plummer blocks are used extensively in plant-related facilities using industrial machinery. For example, plummer blocks are used in air blowers for ventilation or drying installed in steel and petrochemical plants and thermal power stations or in crushers in mining facilities as shown in Fig. 1. Plummer blocks used in these facilities must meet the requirements of higher speed and shortened maintenance work to improve operational efficiency. They must meet the environmental requirement of preventing oil leakage while in use outdoors. In response to these requirements, we have modified existing oil-lubricated plummer blocks (SNOE series) and developed the SNOE II series products which are superior in terms of functionality and reliability while being designed to use common parts.

2. Oil-lubricated Plummer Block SNOE II

2.1. Construction

Fig. 2 shows the construction of the newly developed product. This product consists of a two-part housing using a series 222 or 223 self-aligning roller bearing (cylindrical hole). To lubricate the system efficiently, this product is mounted with the splash ring hanging from the slinger on the axis side; the ring

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feeds lubricant from the oil pan to the bearing during operation.

The product adopts the optimum labyrinth construction, using a felt seal compatible with high speed rotation. The housing must be supported securely to allow the bearing inside to rotate stably under severe environmental and load conditions. Installing the product on a common machine, two plummer blocks made up of the fixed side and the free side bearing are used. In particular, in response to the large axial displacement of a large-sized facility in operation, the housing of the plummer block used on the free side is designed to accommodate a large displacement of the bearing.

2.2 Functions

2.2.1 Lubrication

The self-aligning roller bearing inside the housing is lubricated with the oil stored in the lower part of the housing. In addition to ordinary oil-bath lubrication, lubricant is fed into the bearing by the splash ring, placed off-center with the axis, in the groove provided on the labyrinth spacer as shown in Fig. 3. In other words, the splash ring rotating with the shaft draws up lubricant from the ring immersed in the oil pan in the lower part of the housing, splashing the lubricant to the upper part of the bearing.

2.2.2 Sealing performance

This product is provided with a non-contact labyrinth seal on both sides of the bearing. By optimizing the design of the labyrinth ring (labyrinth spacer) on the rotating side and the labyrinth ring (cover with labyrinth) on the fixed side, the lubricant splashed onto the bearing is collected reliably to the oil pan inside the housing without leaking out of the plummer block.

The felt seal grooved cover shown in Fig. 2, added to the labyrinth seal, enables one to add felt depending on the surrounding environmental conditions such as the shaft rotational speed, temperature, humidity, and presence of dust. Furthermore, with this cover provided with a hole to feed grease to the felt seal groove, the grease seal scheme (grease-filled) may be adopted.

2.3 Features of plummer block SNOE II

2.3.1 Housing material

As shown in Table 1, gray cast iron (EN-GJL-250 (DIN GG25; JIS FC250)) characterized by large attenuation was used as SNOE housing material in the past.

In response to the recent increase in load and speed, however, nodular graphite cast iron (EN-GJS-600-3 (DIN GGG60; JIS FCD600) that excels in shock resistance and vibration characteristics is adopted.

2.3.2 Optimum design of the housing body

In order to minimize the effect on the strength of plummer blocks and on the bearing and bearing fitting face, the rigidity was increased without changing the outside dimensions and the tying method for the two-part housing, as shown in Fig. 4. In addition, the housing was designed, while considering the heat dissipation of the bearing while rotating, to improve lubrication and the bearing life.

The features of optimized housing design are shown below.
(Features)
• Adoption of the two-pillar construction system in the bearing support in the lower part of the housing
• Reinforcement between clamping bolts over the part from the lower part to the upper part of the housing
• Reinforcement of areas surrounding mounting bolts
• Change in the distance between the clamping bolts (both ends)
• Improvement of heat dissipation from the clamping face

(1) Pillar construction
In changing over from the conventional product to the one with two pillars, the construction was designed to maintain the volume of the oil pan. The finite element analysis method (FEM) shown in Fig. 5 was used to determine the pillar installation angle at which the deformation of the bearing fitting face is minimized.

As shown in Fig. 6, it was confirmed that the deformation of the bearing fitting face is smaller at the pillar angle of 25 degrees. The analysis of deformation in the upper and the lower part of the housing under this condition was conducted as shown in Figs. 7 and 8.

(2) Construction of the area around the clamping of the two-part housing
The two-part housing of the newly developed product is provided with a reinforcement rib between the fastening bolts shown in Fig. 9 for improved rigidity. The upper and the lower housing are held by the tapered securing pins to provide accurate positioning in maintenance and inspection.
(3) Position of clamping bolts
The clamping bolts fastening the upper and the lower housing are placed closer to each other on each side, as shown in Fig. 10, to prevent them from separating from each other and to suppress the shift of the bearing fitting surfaces (sections).

(4) Housing fastening face
As shown in Fig. 11, the ground contact face of the housing is stabilized against load by not providing the boring in the lower part of the bearing fitting part, with the heat from the bearing being radiated sufficiently.

The area surrounding the spot at which fastening bolts are connected is kept solid to allow the tension due to bolt clamping to be absorbed; this contributes to suppressing the effect on the deformation of the housing as a whole.

(5) Other examples of fastening
Installing sensors capturing vibration, temperature, and other physical quantities on this housing makes it possible to control the rotational state of plummer blocks. For this reason, holes for placing a sensor are provided in different parts of the housing. The oil level of the lubricant can be checked constantly with an oil gauge.

When a high temperature is expected during operation, installing a cooling pipe in the oil pan space as shown in Fig. 12 allows heat to be removed from the oil and transferred to the heat exchanger installed outdoors.

On the other hand, when the bearing is used in a cold region, preheating the lubricant is necessary before starting machines; for this purpose, consideration has been given to installing a heater and a thermostat as shown in Fig. 13.
2.3.3 Seal construction

The labyrinth seal is used as a common seal construction of plummer blocks. With the existing SNOE series product, the free side and the fixed side labyrinth alike are designed so that each cover (both through and non-through (for use at the shaft end)) may meet individual customer specifications. To address this situation, a unified design specification was used for labyrinths while accounting for different processing methods to reduce the number of parts and simplify specifications.

In SNOE series products, as shown in Fig. 14, the slinger and felt seal grooved cover for the fixed side and those for the free side, to be used in combination with the labyrinth winged cover for the fixed side bearing and the one for the free side bearing, are constructed in the same design.

This measure eliminated the necessity of substantial design changes to address special applications (reinforcement of sealing performance such as grease seal and resistance to desert environments).

![Flow of the lubricant](image)

**Fig. 14** Labyrinth sealing design of SNOE II (fixed side)

**Fig. 15** Labyrinth sealing design of fixed side

(1) Labyrinth seal function of the fixed side bearing

Fig. 15 shows the construction of the labyrinth. Lubricant is splashed, inside the housing, from the oil pan (3) by the splash ring to lubricate the upper part of the bearing. At the same time, lubricant attaches to the inclined surface of the labyrinth winged cover (1) or the outside diameter face (4) of the slinger (2) and is collected into the oil pan (3).

When splashed lubricant does not fall onto the lower part of the housing but flows into the labyrinth inside (the area around the inside diameter of the labyrinth winged cover (5)), lubricant attaches to the felt grooved cover (6) and is then collected via the route from the opening (7) of the lower part of the labyrinth winged cover to the oil pan (3).

When lubricant further penetrates into the labyrinth (8), it is returned from the labyrinth (8) due to the conical form of the slinger outside diameter part of the felt seal grooved cover (6), being collected via the path from the opening (7) of the lower part of the labyrinth winged cover to the oil pan (3).

Besides the action of the labyrinth seal function, providing a felt seal in the felt groove enables lubricant outflow to be prevented more efficiently.

![Flow of the lubricant](image)

(2) Labyrinth seal function of the free side bearing

As shown in Fig. 16, the construction of the labyrinth on the free side is basically identical to that on the fixed side. However, when the axial displacement (distance) of the bearing is the greatest with reference to the labyrinth winged cover, the labyrinth passage is secured, though the slinger position becomes shallow. On the other hand, the slinger position is determined so as to avoid the interference of the slinger with the labyrinth cover should the slinger position become the least remote; this assures the function of the labyrinth seal adequately.

![Flow of the lubricant](image)

**Fig. 15** Labyrinth sealing design of floating side

**Fig. 16** Labyrinth sealing design of floating side
2.4 Evaluation
Since the sealing performance is referred to as an important function of an oil-lubricated plummer block in an operating facility, the oil leakage evaluation test was conducted.

(1) Test conditions
Table 2 shows typical test conditions for evaluating the sealing performance of a labyrinth seal. This evaluation was not applied to the felt seal and grease, but the gap between the shaft and the felt seal grooved cover (the exit from the labyrinth) was monitored continuously as shown in Fig. 17.

Table 2 Test condition of lubricant leak (example)

<table>
<thead>
<tr>
<th>Basic scheme of a plummer block</th>
<th>SNOE II 218</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of bearing used (self-aligning roller bearing)</td>
<td>22218 (Ø90 × Ø160 × 40)</td>
</tr>
<tr>
<td>Test atmosphere temperature</td>
<td>20°C (RT)</td>
</tr>
<tr>
<td>Lubricant viscosity</td>
<td>40 mm²/s</td>
</tr>
<tr>
<td>Bearing rotational speed</td>
<td>3,000 min⁻¹ (max)</td>
</tr>
<tr>
<td>Shaft inclination (misalignment)</td>
<td>0° 0.25°</td>
</tr>
<tr>
<td>Test duration</td>
<td>Four hours for each test item</td>
</tr>
<tr>
<td>Criteria</td>
<td>Visual inspection; measurement of the oil level (oil gauge)</td>
</tr>
</tbody>
</table>

Fig. 17 Test plummer block (monitoring oil leak)

(2) Test results
As shown in Fig. 18 no oil leakage was observed in all of the tests, and abnormalities in the bearing and interference in the labyrinth were not observed, with these satisfactory results proving high sealing performance.

Fig. 18 Gap area after lubricant leak test (no leakage)

3. Conclusion
This paper introduces NTN-SNR oil-lubricated plummer blocks.
In addition to addressing an increase in efficiency arising from the improvement of performance of industrial plant facilities and from the reduction in maintenance work, the authors will give constant consideration to the environment under severe working conditions such as the outdoor environment and push ahead with a further improvement in performance.