Applicability of micro shot peening as surface modification for rolling sliding interface

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Abstract

The present study describes the applicability of micro shot peening as surface modification for reduction of friction loss of thrust needle roller bearing. A micro shot peening system capable of controlling the flow rate and the impact speed individually was developed. The impact media was fine steel beads (50 μm in size) coated with polytetrafluoroethylene (PTFE) powder. The bearing ring and the washer surfaces of the thrust needle roller bearing were shot peened using the developed apparatus. After the peening, transfer of the PTFE from the impact media to the target was confirmed by measuring the contact angle of the oil droplet on the surface. The results indicate that the contact angle was large and the PTFE coated selectively into the dents. Friction properties were evaluated with rolling/sliding and sliding experiments. It was found that the friction loss of the PTFE coated surface decreased in the rolling/sliding and the sliding conditions. The profile measurement and observation of the surface showed that PTFE coating resulted in the restriction of the transfer during the sliding contact. Therefore, it is concluded that the micro shot peening with the PTFE coated beads is an effective means to decrease the friction loss of thrust needle roller bearing.

Keywords : Micro shot peening, PTFE coating, rolling sliding contact, friction loss, steel beads.

Introduction

It is well recognized that shot peening is an essential surface treatment to improve fatigue properties for mechanical components subject to cyclic loading such as gears and coil springs [1, 2]. Recent advancements in the peening technology including media production actualizes the use of fine particle less than 100 μm as the impact media. As a result, applied compressive residual stress near the target region significantly increases without increasing the surface roughness of the peened surface. Peening treatment with the fine particles is defined as micro shot peening, and apparently classified differently from the current peening treatments [3]. Since surface texture consisted of micro-sized dimples resulting from the particle impact, the micro shot peening is also an attractive means as a surface treatment to decrease and to stabilize the friction resistance at the interface. The applicability of the micro shot peening to the interface was evaluated [4, 5]. It was found that the micro dimples acting as an oil reservoir and entrapment of wear debris decreased the friction resistance in boundary lubricated condition [4]. In addition, the adhesion and migration of the impact media formed the transfer film. It was reported that solid lubricant film formed by the peening decreased the friction resistance [5, 6]. The compressive residual stress accompanied with hardening is naturally induced. Therefore, it is expected that the micro shot peening becomes a candidate technique as a surface modification methodology for the sliding interface. The present study describes the applicability of the micro shot peening as surface modification for thrust needle roller bearing. The surface texture consisted of micro dimples and PTFE coating was simultaneously applied to the target surface. Friction properties were evaluated not only in rolling/sliding but also in sliding contact conditions. Mechanism of the decrease of the friction resistance of the surface peened with the PTFE coated beads is discussed.

Micro shot peening treatment

The micro shot peening treatment was carried out with the developed apparatus [6]. A schematic of the media ejection mechanism installed to the apparatus are shown in Fig. 1. The system consists of a double walled nozzle and a media storage tank enclosing rubber balls. Low pressure air, introduced intermittently into the tank, resulted in not only blowing up the media but also shaking the rubber balls. As a result, the cohesive media was pulverised, and it was possible to blow the fine media (less than 10 μm in size) separately. The blown up media introduced in the inner tube was mixed with high pressure air from the outer tube at the tip of the nozzle. As a result, the flow rate and the impact velocity of the media could be controlled individually by adjusting the air pressure. The impact media was fine steel beads (50 μm in size, 800 of Vickers hardness) coated with polytetrafluoroethylene (PTFE) powder (10 μm in size). The scanning electron microscope images of the uncoated and the coated steel beads are shown in Fig. 2. It was found that the steel beads were entirely covered with the PTFE powder.

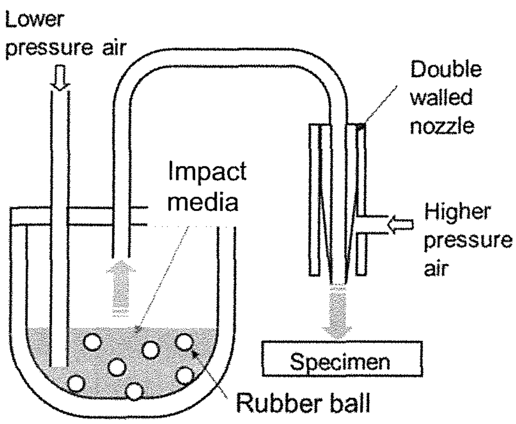


Fig. 1 Schematic of media ejection system

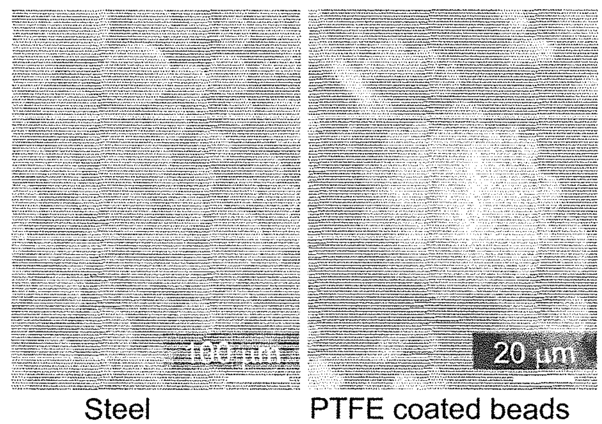


Fig. 2 SEM images of steel and PTFE coated beads

Specimen

The specimen was a conventional needle roller thrust bearing assembly (type TP2542, 42 mm outer diameter), consisted of a bearing ring, needle roller unit and washer. The material of the bearing ring, the washer and the needle was hardened chromium alloy steel (800 Hv). An overview of the specimen is shown in Fig. 3. The needle was aligned in the radial direction of the cage. The shot peening was applied to the bearing and the washer surfaces. The surfaces were polished less than 10 nm in average surface roughness, Ra with diamond slurry prior to peening.

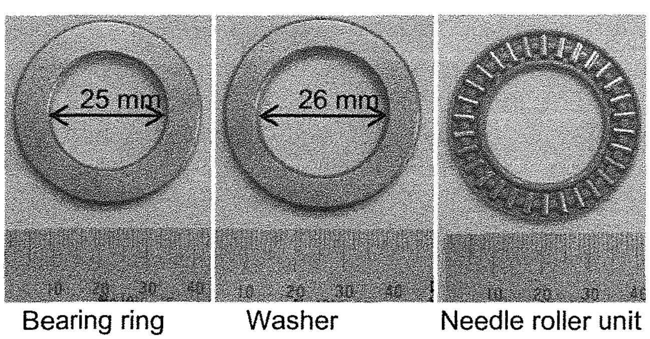


Fig. 3 Overview of specimen

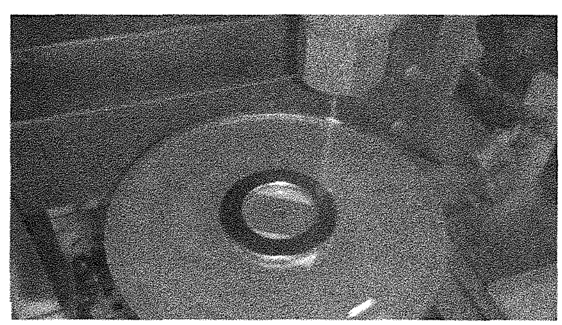


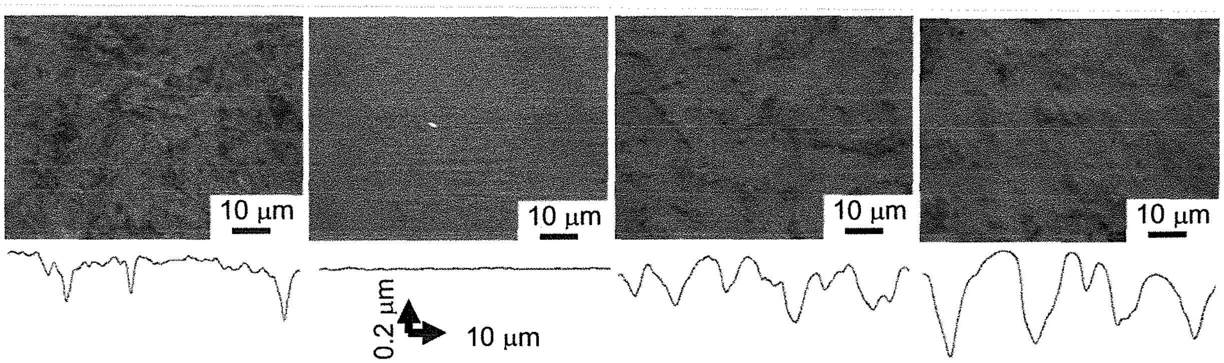
Fig. 4 Overview of peening treatment

An overview of the peening treatment is shown in Fig. 4. The bearing ring and the washer were fixed to the turntable driven at constant rotational speed of 120 rpm. The steel beads with/without PTFE powder, shown in Fig. 2 was peened at the conditions listed in Table 1.

Table 1 Peening conditions

Gas pressure of outer/inner nozzle (MPa)	Treatment time (sec)	Nozzle distance (mm)
0.6/0.5	300	100

The morphology of the PTFE coating was evaluated with a diffusion of oil droplet because the PTFE exhibited oil repellency property. On the surface peened with the PTFE coated beads, the contact angle was large, and the oil diffusion pass avoided the dimples. Therefore, the selective coating of PTFE into the dimples was determined. After peening, roller burnishing with a cemented carbide roller (36 mm in diameter and 4mm of tip radius) was carried out on the surface to truncate asperities. In addition to the peened surfaces, a polished and burnished surface without the peening and an unpolished nominal surface were also prepared. Optical micro images and surface profile of the peened surface are shown in Fig. 5. Micro dimples were formed on the peened surfaces. As mentioned above, the PTFE was plated into the dimples on the surface peened with the PTFE coated beads. The surface roughness of the nominal, the polished, the dimpled and the PTFE coated surfaces was 80 nm, less than 10 nm, 90 nm and 120 nm respectively, and the difference of the surface roughness between the nominal and the peened surfaces was small.



Nominal surface Burnished surface Dimpled surface PTFE coated surface

Fig. 5 Optical micro image and surface profile of bearing ring and washer surface

Rolling/sliding friction experiment

A schematic of the apparatus is shown in Fig. 6. The bearing ring and the washer were fixed to the drive shaft and the supporting rod was installed with a torque measurement device. The contact load was applied with a piston driven by pressurized gas. The washer was dipped into poly alpha olefin (PAO, 22cSt@40°C), used as a lubricant. The thrust needle roller unit was inserted between the bearing ring and the washer, the contact load was applied and the bearing ring was driven by a DC motor in the testing conditions listed in Table 2. The number of the rotations was 108,000 for 3 hours. The friction loss was evaluated by measuring the friction torque with the measurement device every 1sec during the experiment.

Table 2 Testing conditions of rolling sliding contact

Contact load	Rotational speed	Testing time	Environment
1060 N	600 rpm	3 hours	20-25°C/40-60C%

Results

The friction torque as a function of the testing time are shown in Fig. 7. The friction torque of the nominal, the burnished and the dimpled surfaces ranged from 0.029 Nm to 0.025 Nm, and was almost stable during the experiment. The value of the PTFE coated surface ranged from 0.023 Nm to 0.017 Nm and was smaller than that of other treated surfaces.

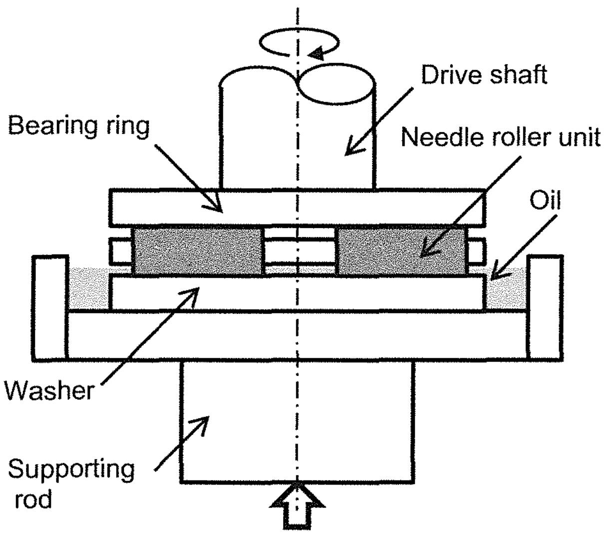


Fig. 6 Schematic of Rolling sliding apparatus

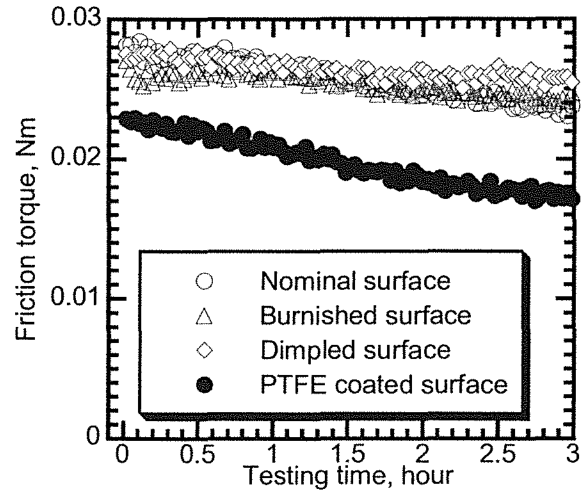


Fig. 7 Friction torque vs. testing time

Optical micro image of the bearing ring and the washer surface after the experiment are shown in Fig. 8. The color and the position of grooves between the bearing ring and the washer raceways in the rotatory direction (vertical direction of the image) seemed to be similar. The surface damage of the raceway was smaller at the inner part and was larger near the contact boundary. In particular, the raceway of the burnished surface discolored black.

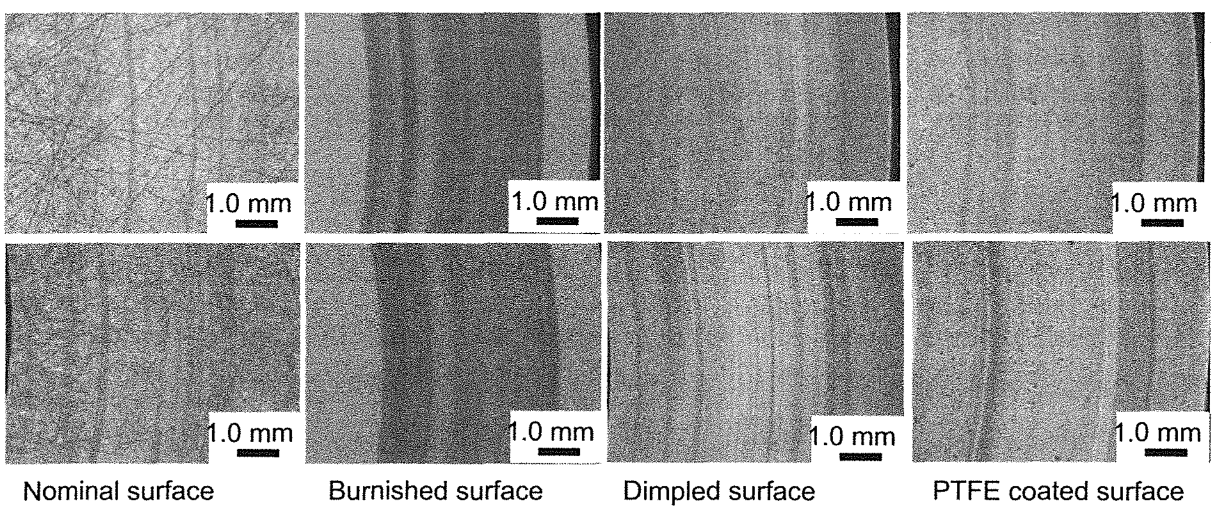


Fig. 8 Optical image of raceway of bearing ring (upper) and washer (bottom)

Discussion

It is well recognized that thrust needle roller bearing is accompanied with skewness and that the component of the sliding friction influences the friction loss since the peripheral velocity of the bearing ring is different depending on the contact radius. The optical micro image of the raceway after the test (Fig 8) showed that the surface damage was larger at the outside of the raceway, where the relative slip between the needle and the bearing ring was large. Therefore, the component of the sliding contact affects significantly at the outside of the raceway. In order to evaluate the effects of the PTFE coating on the sliding contact, sliding friction experiment was carried out with a ring on disc type apparatus. A mated ring having 40/30 mm of outer/inner diameter instead of the washer and the needle roller unit was used. The ring surface was polished less than 10 nm in Ra. The testing conditions are listed in Table 3.

Table 3 Testing conditions of sliding contact

Contact load	Rotational speed	Testing time	Environment
100 N	600 rpm	3 hours	20-25°C/40-60C%

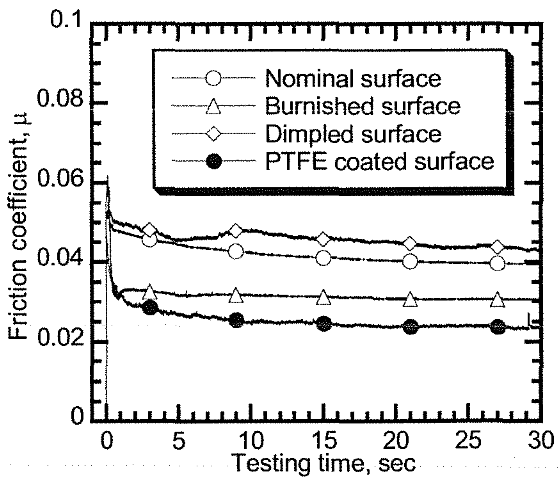


Fig. 9 Friction coefficient vs. testing time

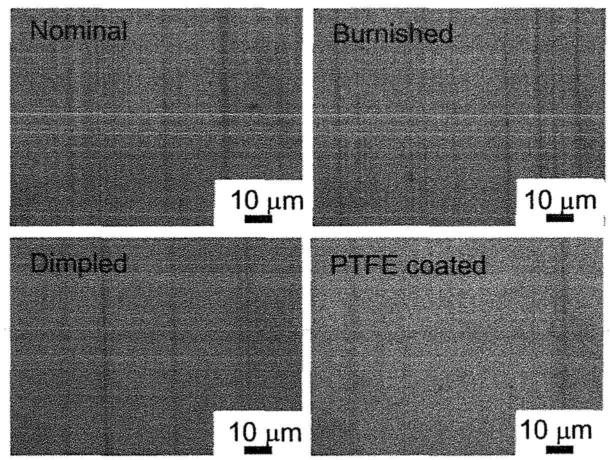
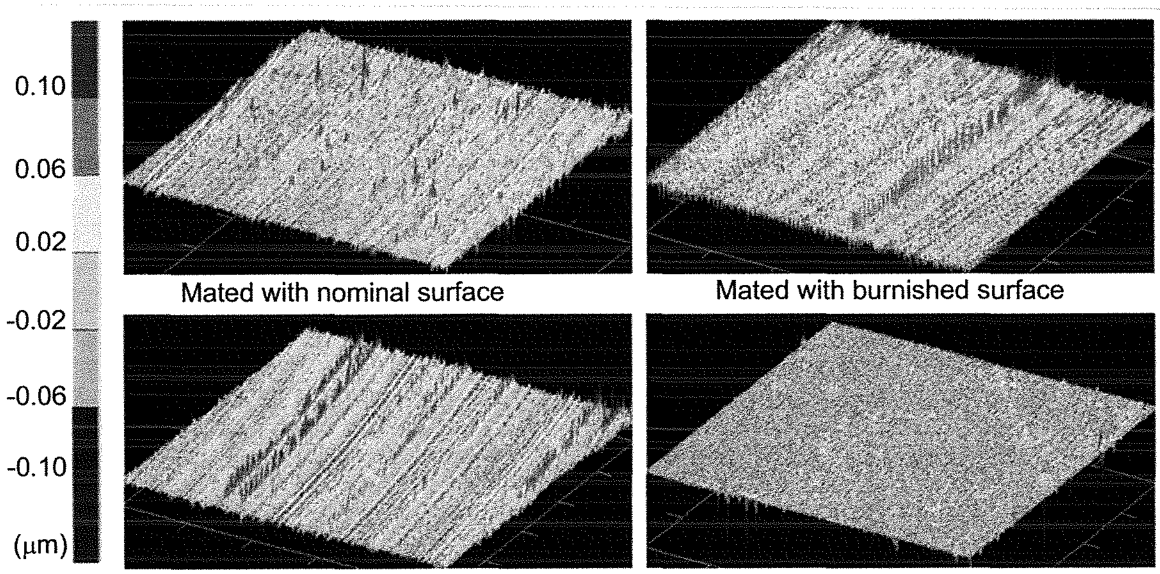


Fig. 10 Optical micro image of ring surface



Mated with nominal surface

Mated with burnished surface

Mated with dimpled surface

Mated with PTFE coated surface

Fig. 11 3-D Surface profile of ring surface mated with dimpled and PTFE coated surface

The friction coefficient as a function of the testing time is shown in Fig. 9. The friction coefficients were higher at the beginning of the experiment then decreased gradually with the increase in the testing time. After 20 minutes of the testing, the friction coefficients became stable except for that of the dimpled surface. The order of the friction coefficient at the steady state from highest to lowest was the dimpled, the nominal, the burnished and the PTFE coated surfaces, and the effect of the PTFE coating on the reduction of the sliding friction with the peening was confirmed. An optical micro image and 3-D surface profile of the ring surface after the experiment are shown in Figs. 10 and 11. Scratches parallel to the sliding direction were found on the optical micro image. From the 3-D surface profile, aligned dots parallel to the sliding direction on the surface were formed. It is assumed that the dots were a result of the transfer from the mated surface. The dot height on the surface mated with the PTFE coated specimen was small. This suggests that the PTFE coating restricted the adhesion in the sliding contact. Therefore, the friction loss in the rolling/sliding contact decreases, and it is concluded that the micro shot peening with the PTFE coated beads is an effective means for surface modification of thrust needle roller bearing.

Summary

The applicability of the developed micro shot peening treatment with the polytetrafluoroethylene (PTFE) coated steel beads as the surface modification to improve tribological performance of a thrust needle roller bearing was evaluated. The results indicate that PTFE coating was formed on the bearing ring and the washer surfaces, and decreased the friction loss. The restriction of the adhesion resulting from the PTFE coating was also found in the sliding contact experiment. Therefore, it is concluded that the micro shot peening with the PTFE coated beads is an effective means for surface modification of thrust needle roller bearing.

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