Formation of surface film and hydrogen permeation under rolling/sliding contact

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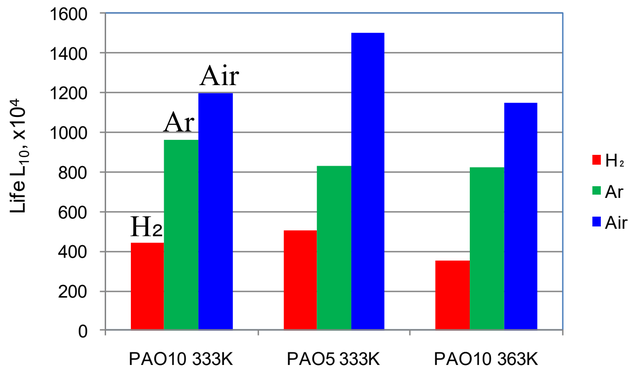
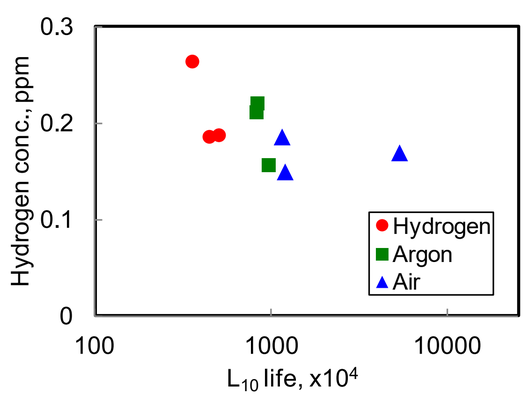
Effects of hydrogen embrittlement



Fatigue life of SUJ2 steel bearing in different lubrication conditions (Contact pressure: 4.8 GPa)

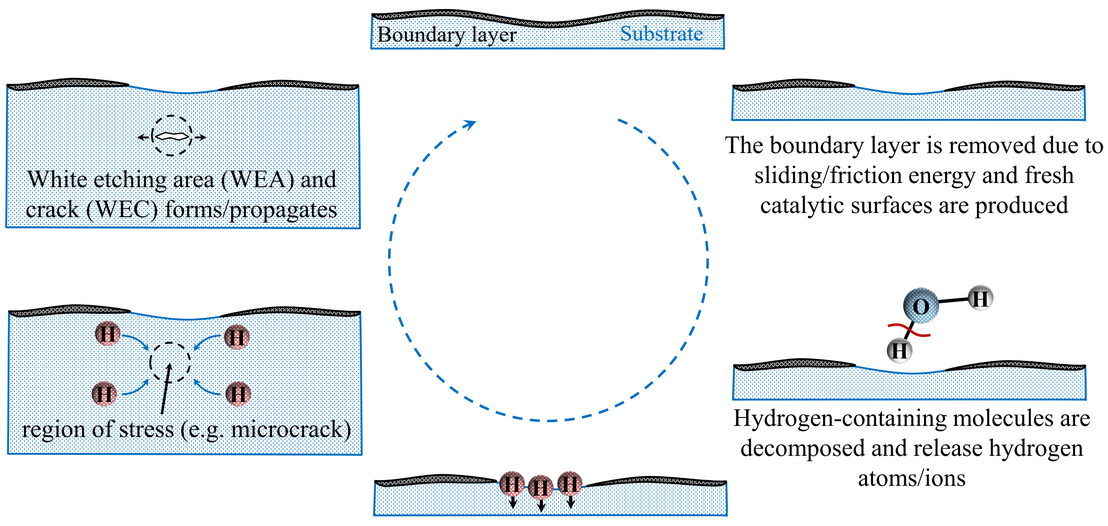


L10 fatigue life vs hydrogen penetration

Life is reduced in hydrogen.
Bearing of the low-life there are many hydrogen permeation.

The cause of the reduction in life is hydrogen permeation.

Mechanism of hydrogen embrittlement



Aims of the study

- Hydrogen permeation into steels under rolling contact in hydrogen with oil lubrication -

- **to see the effect of lubricant base oil on the hydrogen permeation**
- **To see the changes due to atmosphere and the lubricating oil of hydrogen permeation mechanism**

Rolling test
↓
Hydrogen concentration by TDS
Water content in the lubricating oil
AES　FT-IR　Raman

Experimental conditions

<Specimens>

SUJ2 flat disc, SUJ2 6.35mm ball

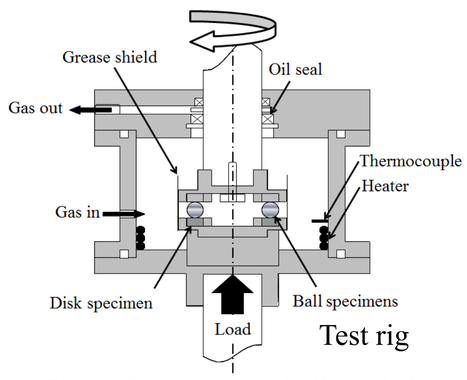
Cut it to a thickness of 1 mm with a fine cutter and perform TDS analysis.

<Lubricant oil>

	density g/cm³	viscosity mm²/s at 313K	viscosity mm²/s at 373K	film parameter
PPG	0.991	32.3	7.6	2.26
POE	0.993	24.5	5.1	2.26
PAO	0.826	28.8	5.6	1.99

<Experimental condition>

Hertzian pressure	4.8GPa
Number of rotation	1500rpm
Entrainment speed	3.4m/s
Track diameter	43mm
Ball diameter	6.35mm
Temperature	120℃
Test time	1h,2h,5h,10h
Gas	Air

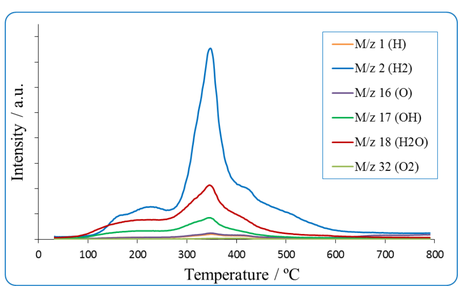


Test rig

Thrust bearing type ball on disk rolling test apparatus with environmental gas and temperature control chamber

<TDS Analysis>

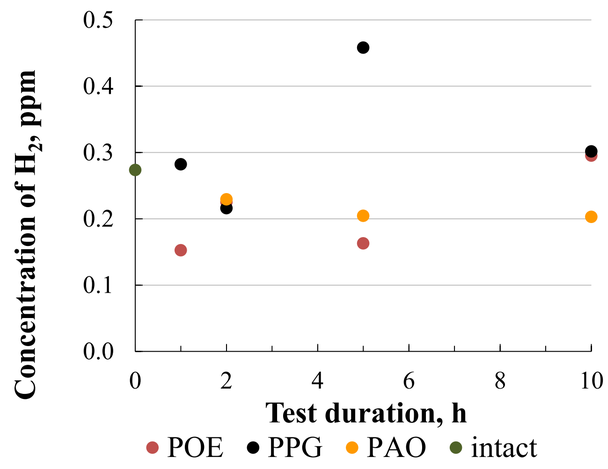
Thermal desorption spectroscopy (TDS) can measure the amount of gases absorbed in a sample. A mass spectrometer analyses the desorbed gases as the sample is heated with a constant rate



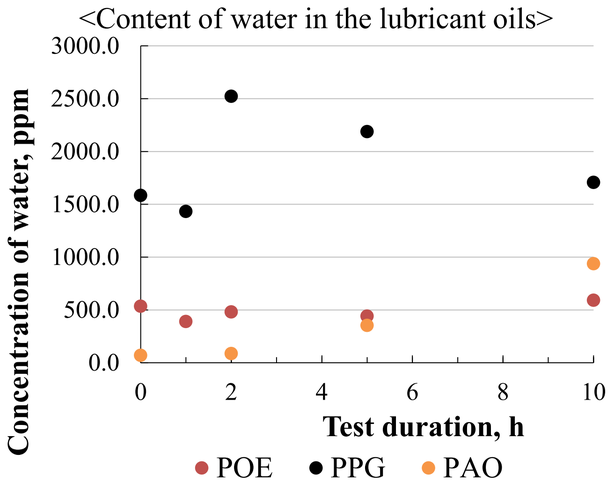
Gases desorbed during TDS analysis

Hydrogen permeation in steel

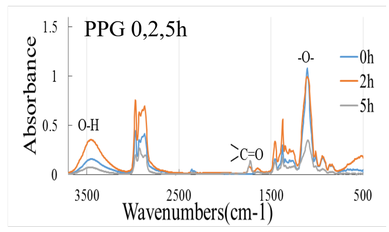
<Content of hydrogen in the disc specimens>

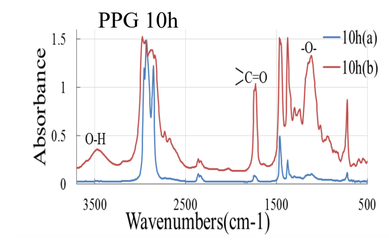


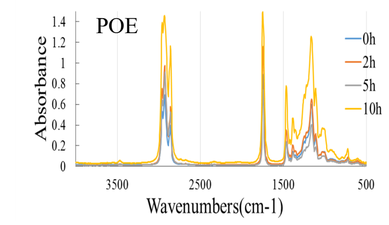
<Content of water in the lubricant oils>

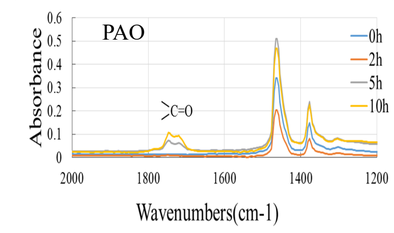


<Water content in the lubricant oils>

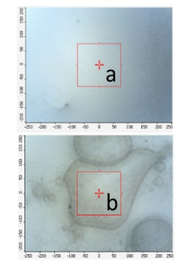








PPG10h

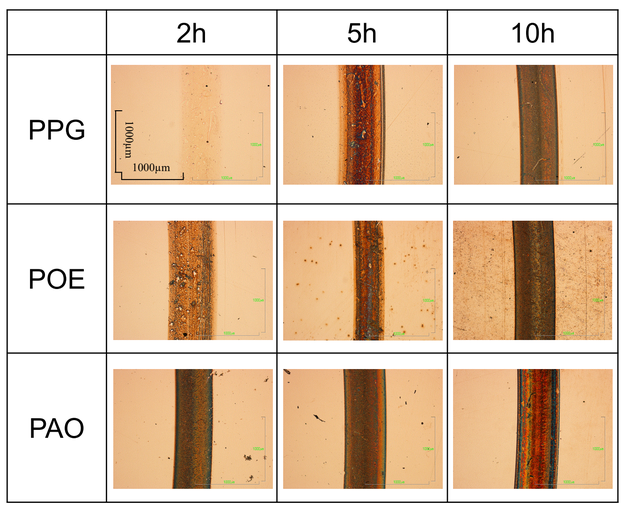


PPG
0h～ :
An ester bond was formed.

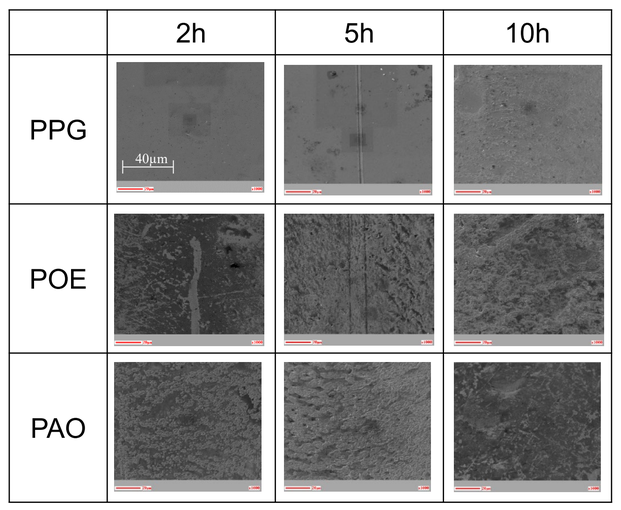
5h～10h :
Oil component separated
(Upper figure a,b)

PAO5,10h :
An ester bond was formed.
（Oxidative deterioration）

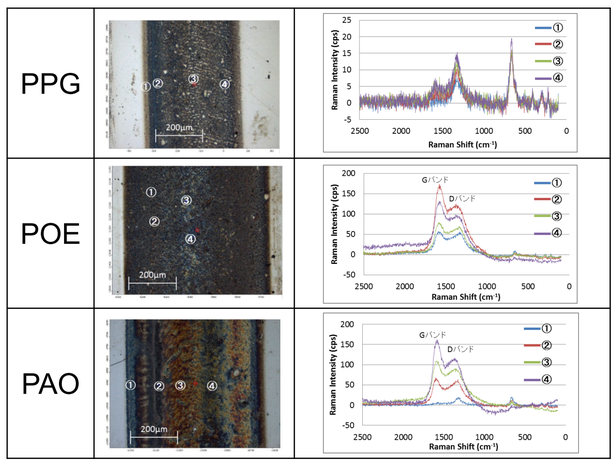
<Surface films (optical microscope)>



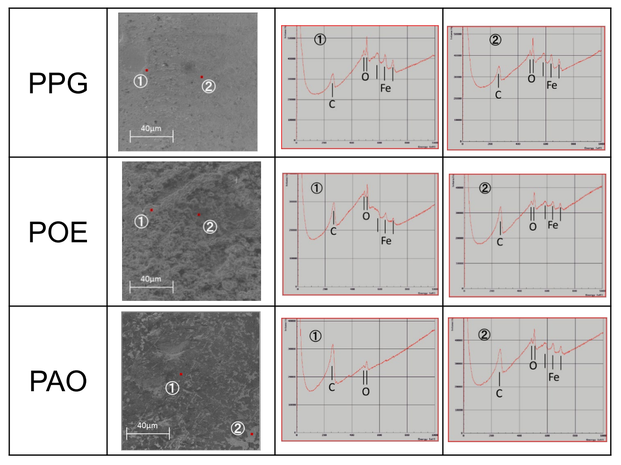
<Surface films (SEM)>



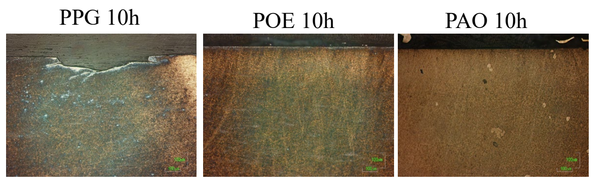
<Surface films analysis (Raman)>



<Surface films analysis (AES)>



<Track cross section>



PPG is slow in formation of oxide film.
In PAO, an oxide film is formed and a carbon film is formed.
Flaking occurred on the PPG disk, and voids were confirmed.

Conclusions

- ✓ PPG has a large amount of water and has a large amount of hydrogen permeation into the steel.
- ✓ POE is hard to deteriorate, PAO and PPG deteriorate relatively.
- ✓ Formation of surface film on the contact surface and water content in the lubricating oil affects the amount of permeation of hydrogen.

Acknowledgment

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References

1. H. Tanaka et al., Tribology Online, 8, 1(2013) 90.
2. H. Fukuoka, H.Tanaka, M.Ratoi, J.Sugimura : “Formation of surface film and hydrogen permeation under rolling/sliding contact”. Tribology meeting 2016 Autumn in Niigata. Japan Society of Tribologist., 2016-10.

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