Effects of Filler Materials in Polymer Composites on Hydrogen Sealing Ability and Wear Characteristics

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Background

Flow Regulating Valve

- In high pressure hydrogen gas infrastructures, polymers are used in control valves and stop valves and they are sliding against their metal counterface in hydrogen gas environment.
- Their friction and wear behavior in the hydrogen environment should be important as well as their hydrogen sealing ability since the increased friction and excessive wear can induce the efficiency degradation and increase in the maintenance cost.
- Optimized friction and wear characteristics of polymer seals are important factors for the development of the high performance valves for the hydrogen gas infrastructures.

Hydrogen Station

- http://www.jhfc.jp
Purpose of this study

- Polytetrafluoroethylene (PTFE) is preferably used as a material for dynamic seals in control valves since it has unique self-lubrication ability and can keep the friction coefficient very low even under the unlubricated condition.
- On the other hand, PTFE exhibits poor wear resistance and large creep deformation.
- The mechanical properties and wear characteristics of PTFE can be improved by adding filler materials, such as graphite, bronze and carbon fibers.
- However, there are little knowledge about the relationship between the characteristics of filler materials and the gas sealing ability of composites.
- Polymer sealing materials should have not only the excellent tribological performance but also reliable gas sealing ability.

In this study

- Examine the effect of filler materials on hydrogen sealing ability of PTFE composites by using the annular type face-contact tester.
- The wear characteristics of PTFE composites was also evaluated in the same test configurations.
- The final goal is to develop a design guide line for the high performance control valve used in the high pressure hydrogen gas infrastructure.

Comparison of the volumetric wear rate of unfilled PTFE and PTFE composites evaluated in high pressure hydrogen gas
Gas pressure: 40 MPa, Gas temperature: 373K
Experimental test rig

Annular type face-contact tester

- Both the hydrogen sealing ability and volumetric wear rate of PTFE composites were evaluated sequentially with the same specimen and the same test apparatus.
- The upper polymer specimen is loaded against the lower metal disc specimen by a spring and internal space between polymer and metal counterface is filled with pressurized hydrogen gas.
- The hydrogen sealing ability is estimated by the gas leakage rate through polymer/metal interface calculated from the mass change in the sealed hydrogen gas.
- A steady state sliding can be applied between specimens by rotating the disc specimen and the wear property of polymer specimen can be evaluated.
Specimens

Polymer specimen

• Material:
  • Unfilled PTFE
  • 15wt% graphite filled PTFE
  • 15wt% carbon-fiber filled PTFE

• Dimension:
  • Outer diameter = 30 mm, Inner diameter = 20 mm, 10 mm
  • Height = 20 mm

Metal disc specimen

• Material:
  • Martensitic stainless steel (SUS440C)

• Dimension:
  • Diameter = 58 mm, Thickness = 3 mm
  • Ra= 0.02 ~ 0.05 µm
Result

Effects of filler materials and polymer surface roughness on the hydrogen leakage rate

- The gas leakage was clearly affected by both differences in the polymer surface roughness and the type of polymer materials.
- The higher elastic modulus of polymer material and the larger polymer surface roughness would be responsible for the increased gas leakage rate.
- Improved wear resistance of PTFE composites could be confirmed in the hydrogen environment.
Gas leak model

The average gap between polymer and metal specimens was estimated from measured gas leakage rate by using the radial flow model expressed by the above equation.

Theoretical average gap was calculated from elastic modulus and surface roughness of polymer specimens by using Hertz’s contact model.

There are linear relationships between the experimentally estimated average gap and the theoretically predicted average gap.

Experimental average gap was greatly larger than theoretical average gap in the case the polymer surface became smoother by sliding.

Contact conditions between polymer and metal surface might be effected by the exposure of filler material after sliding.
Conclusion

✓ Both graphite and carbon-fiber functioned as a filler material of PTFE composites and successfully reduced wear of polymers in hydrogen environment.

✓ The hydrogen sealing ability of polymer composites was inferior to that of unfilled PTFE.

✓ The model analysis based on the Hertz’s contact theory indicated that the gas leakage through the interface between polymer and metal surfaces are mostly depended on both elastic modulus and surface roughness of polymer specimens.

✓ Therefore, the hydrogen sealing ability of relatively hard PTFE composites could be improved by regulating its surface roughness.

✓ The exposure of hard filler materials, such as carbon-fiber, during wear process deteriorated the gas sealing ability significantly.

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