Development of a new type of metal packing for high-pressure hydrogen and hydrogen-assisted fatigue failure at the contact part between components

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Strength of materials forms the basis for operating machines. In this presentation, two topics associated with strength of materials will be provided. We spent the past three years developing a new type of packing for high-pressure hydrogen. The development of the new packing has been successfully completed, and the packing is then commercialized (Fig. 1). Another topic is related with hydrogen-assisted failure, which is specific to the contact part between mechanical components in hydrogen equipment. The phenomenon is called fretting fatigue. The packing we developed involves contact with component in order to seal hydrogen. Fretting was considered in the process of the development.

The development of the packing is done by the R&D grant from Fukuoka Strategy Conference for Hydrogen Energy. There are many ways of sealing gas. Hydrogen causes specific problems. Polymer seal materials cause several modes of failure due to permeation of hydrogen. Many kinds of metallic material suffer from hydrogen embrittlement. Furthermore, each existing sealing method has its own specific problems in terms of usable pressure range, cost, delivery time, size, reuse, assembling, etc. The sealing method of our new packing is unique that elastic deformation is used. Since the material is SUS316L, which is hydrogen compatible, the effect of hydrogen embrittlement is minimized. But the mechanical properties of SUS316L is relatively poor, it was very challenging to achieve the balance between sealing performance and metal fatigue performance. The performance of the packing is verified by high-pressure hydrogen tests at HyTReC. The pressure capacity is greater than 340MPa. The packing accomplished the provided test conditions for the equipment in hydrogen station.

Machines consist of many component. Mechanical joints, which involve contact between materials, are frequently used to build machines. When a fatigue load is transmitted through the contact part between components, the mating materials cause cyclic relative micro slip. This brings about a special wear damage. This is called fretting. Thus, the contact part suffers from fretting and fatigue simultaneously. Fretting reduces the fatigue strength down to 1/3 to 1/30 compared with the fatigue strength without contact. Furthermore, hydrogen can influence both contact and fatigue. Therefore, fretting fatigue is one of the critical issues in the design of hydrogen equipment. We carried out the fretting fatigue test in hydrogen gas (Fig. 2). The fretting fatigue strength in hydrogen gas is significantly lower than that in air (Fig. 3). The reason is adhesion between contacting surfaces and following formation of small cracks. Besides these, hydrogen assists crack nucleation. The adhesion causes severe plastic deformation. It results microstructure change from austenite to martensite. These are possible reasons for that hydrogen participates in the crack nucleation. Fretting fatigue test of hydrogen charged materials were also done. The internal hydrogen reduced the fretting fatigue strength.

Fig. 1 New type packing

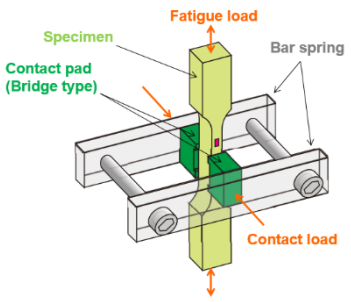

Fig. 2 Fretting fatigue test method

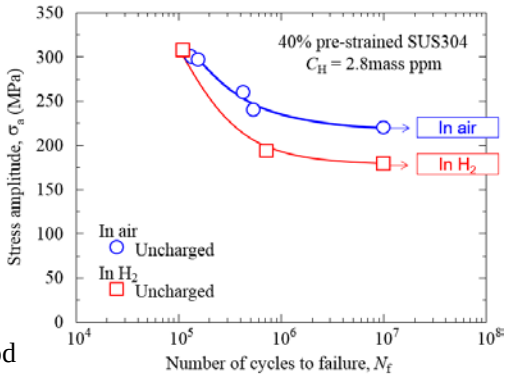

Fig. 3 Effect of hydrogen on fretting fatigue strength of SUS304