KYODO YUSHI TECHNICAL BULLETIN

No.8 January 27, 2017

INVOLVEMENT OF HYDROGEN PERMEATION INTO STEEL IN SHORTENED FATIGUE LIFE

In our previous issues, KYTB 6 and 7, the rolling four-ball tests demonstrated that the fatigue life in hydrogen was associated with white structure formation and the life can be effectively extended by use of rust inhibitors and anti-wear additives. In this issue, back to the basics yet again, similar tests were conducted in deuterium to study how surrounding deuterium permeates into steel. Deuterium was detected in areas around cracks at levels of up to 70 to 110 times higher than natural hydrogen, indicating that it permeates into the cracked area of the steel surface to be concentrated.

Fig.1 show the rolling four-ball tester used in this study. In the cup filled with lubricating oil, three freely-rolling bearing balls were rotated by another bearing ball placed on the top of them to make an evaluation of fatigue life in rolling contact under static load. Unlike our previous tests in hydrogen H_2 (KYTB 6), the tests in this study were conducted in deuterium to draw a clear distinction from hydrogen present inherently in the steel ball. Deuterium is a hydrogen isotope and accounts for about 0.015% of all the naturally occurring hydrogen.

Similar to the previous tests in H_2, flaking occurred at the surface of the upper ball in a very short time and cracks were accompanied by white structure in their vicinity.

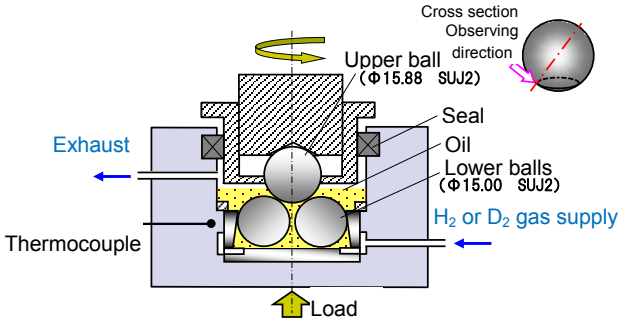

Fig.1 Main part of rolling four-ball tester

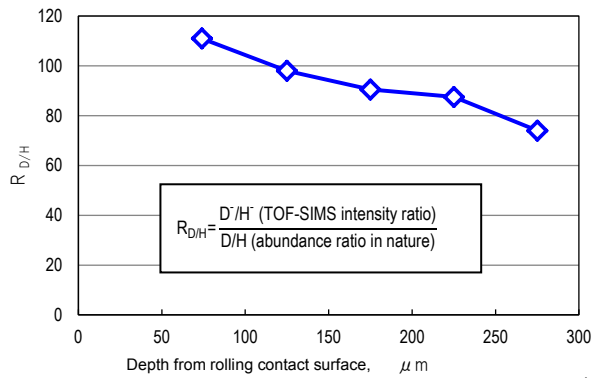

Fig.2 Deuterium abundance ratio for tested steel ball ($R_{D/H}$)

Okada, Nanao, Mori, Nakazawa, Ikejima, Muto, Endo, Imai, Aida: Proceedings of JAST Tribology Conference (Tokyo 2012-5) 277

TOF-SIMS analysis was carried out on the cross section as shown in the upper right in Fig.1 to study the existence and condition of hydrogen in tested steel ball. Fig.2 shows the difference in the abundance ratio, RD/H between deuterium in the steel ball and that in nature. Deuterium existed just beneath the ball surface at levels up to 70 to 100 times higher than hydrogen in nature but gradually reduced with depth to in the central part of the ball almost the same level as hydrogen in nature (1.6 times). Although deuterium in iron exhibited diffusion coefficients of about 0.7 to 0.9 times that of hydrogen, repetitive rolling contacts seemed to have induced scattering of hydrogen into the steel ball to produce a high-density subsurface layer.

Fig.3 (a) shows the cross section of flaked surface and Figs. 3 (b) and (c) show the chemical images of deuterium D- and deuterated iron FeD+ for the surface, respectively, which suggest higher levels of D- and FeD+ in the cracked area.

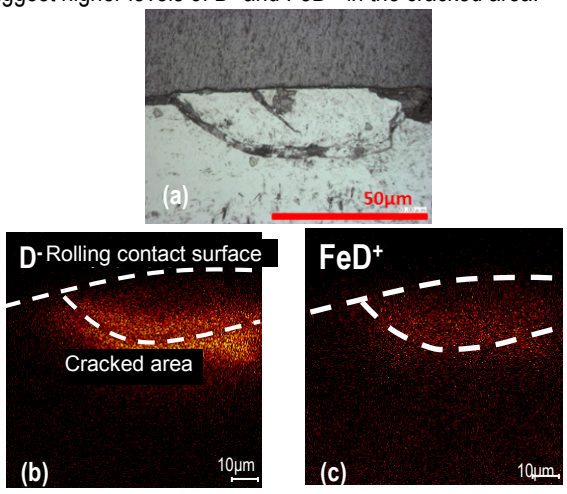

Fig.3 Chemical image of cracked area