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Influence of humidity in evaluation for load carrying capacities of DLC film using high-frequency, linear-oscillation tribometer

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A method of evaluating the load carrying capacities of DLC films by a reciprocating wear test using a high-frequency, linear-oscillation tribometer under a step loading condition was developed as an intermediate test between a scratch test and a wear test. In this study, the effect of humidity on delamination was discussed, and it was cleared that the delamination with the embedment of wear debris caused by severe wear was dominant in the low-humidity condition, while the delamination with the wear out of the film caused by mild wear was dominant in the high-humidity condition.

Keywords: diamond-like carbon, friction, wear, delamination, adhesion

1. Introduction

The load carrying capacity is one of the most important characteristics of a hard-coating film. We have been developing a method to evaluate the capacity of DLC film by investigation of its anti-adhesion characteristics from an intermediate viewpoint between a scratch test and a wear test[1)]. In this study, the effect of humidity on the failure load and the delamination mode of DLC film was discussed by tests in which the humidity was precisely controlled.

2. Methods

In this test, a ball was pressed and rubbed against a film on a plate, and then the friction coefficient was calculated on the basis of force signals obtained from load cells installed directly under the stage of the plate and attached to the loading system of the ball. The DLC film (a-C:H) with a thickness of 0.9 µm was deposited on the plate of bearing steel (JIS SUJ2) by pulsed glow pulsed glow discharge plasma method. The aluminum oxide ball with a diameter of 9.525 mm for rolling bearing was used as mating material. The tribometer was run under a step loading condition with an oscillation frequency of 10 Hz, an oscillation stroke of 1 mm and a plate temperature of 40 Celsius degree in a dry environment. The normal load was increased with stepwise of 10N every 1 min. The target humidity in the test chamber was set at 20, 50 and 70%. By introducing dry and wet air into the chamber while adjusting each flow rate of them, the humidity was kept within ±7% of the target humidity throughout the test time. The test was terminated when rapid and large fluctuations on both the friction coefficient and the oscillation stroke were observed. The load when the test was terminated was evaluated as the failure load, which was considered to be the load carrying capacity of the DLC film.

3. Results and Discussion

The failure loads for each humidity condition were plotted on Weibull probability paper as shown in Fig. 1. The failure loads for the humidity conditions of 20 and 70% were distributed on low load side below 400 N and high load side above 700 N, respectively. On the other hand, the failure load for the humidity condition of 50% was distributed across them. Here, it was presumed that the delamination mode changed with increasing humidity. The main causes of delamination at low and high humidities seemed to be embedment of wear debris generated by severe wear and gradual wear out of the film induced by mild wear, respectively.

Weibull slope and the failure probabilities at cumulative failure probability of 10 and 50% for each humidity condition are summarized in Table 1. The order of representative values of the failure load in each humidity condition was 20 < 50 < 70%. Weibull slope corresponding to the variation of the failure load was minimum (that is, the variation of the failure load was greatest) at humidity condition of 50%. In that time, the delamination mode was considered to be in transition between the above-mentioned delamination modes.

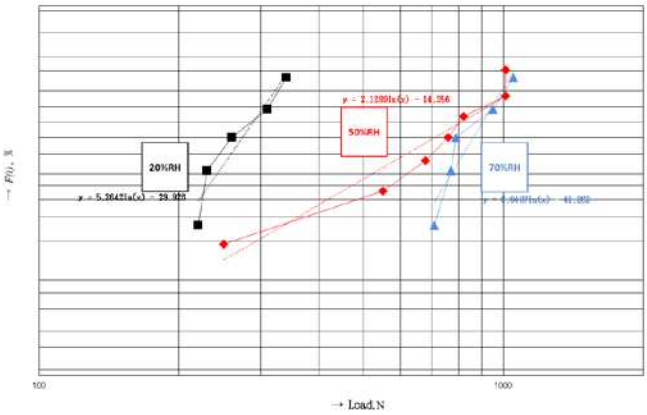

Fig. 1 Weibull plots of failure loads in tests under relative humidities around 20%, 50% and 70%

Table 1 Weibull slopes and failure loads at cumulative failure probabilities of 10% and 50%

Relative humidity, %	Number of tests (Number of failures)	Weibull slope	Failure load, N	
			Cumulative failure probability of 10%	Cumulative failure probability of 50%
20	5 (5)	5.26	192	275
50	7 (7)	2.13	295	714
70	5 (5)	6.05	632	863

4. References

[1] H. Mano and T. Ohana, "Evaluation of anti-adhesion characteristics of diamond-like carbon film using high-frequency, linear-oscillation tribometer," Wear, 386-387, 2017, 188-194.