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Influence of Temperature on the Friction of Contact Surface Treated in case of the Bolted Joints

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Bolt fastening is a joining technique that depends on frictional forces. The coefficient of friction is known to change under the influence of various factors, and temperature is considered one of these influencing factors. Because vehicles can be exposed to high temperatures, understanding how temperature affects the frictional behavior of contact surfaces is important to secure reliability of the bolted joints. In this study, a test equipment to measure the coefficients of friction μ under high temperatures is developed. The coefficients of friction μ are measured by rotating a cylindrical specimen and a disk specimen in surface contact. The material of both of specimen are SCM steel, and those surfaces are treated by zinc-aluminum composite resin coating (Zn-Al coating) which is anti-corrosion coating. Additionally, disk specimens both with (Zn-Al coating with topcoat) and without a topcoat applied are used.

Each measurement result on the coefficients of friction μ is shown in figure1 and figure2 relatively. The horizontal axisx is the test time (s), and the vertical axis is the coefficients of friction μ. The sliding tests are performed for six revolutions.

In case of Zn-Al coating, Figure1 shows that the value of the coefficient of friction μ at RT (room temperature) is approximately between 0.25 and 0.3, which can be confirmed that this value is nearly equivalent to the measurement results obtained using bolts and nuts. And the value at 160°C is approximately between 0.40 and 0.45. It is shown that the value of μ increases, when temperature increases. In case of Zn-Al coating with topcoat, the change of the value of the coefficient of friction μ depends on temperature. In case of RT, it remains constant at approximately 0.1, which is also the same value obtained by using bolts-nuts. In case of 80°C, it remains constant at approximately 0.08. In case of 120°C, after initially decreasing to about 0.7, it gradually increases. In case of 160°C, after initially decreasing to about 0.5, it gradually increases to about 0.13 and become constant. It is shown that the minimum value of the coefficient of friction μ_{min} is smaller at higher temperatures, and that the coefficient of friction μ tends to increase at higher temperatures as sliding time increases.

In order to investigate the cause that temperature affects the coefficient of friction μ, measurements of the cross-sectional profiles and nanoindenter tests are conducted. Figure3 shows the relationship between temperature T [°C] and hardnessis H[GPa] of surface of specimen obtained by the nanoindenter tests. In case of Zn-Al coating, the hardness H [GPa] decreases as temperature increases. In case of Zn-Al coating with topcoat, the value of H [GPa]is smaller than Zn-Al coating, and it indicates that the topcoat is covering the surface.

In case of the Zn–Al coating, the increase in the coefficient of friction μ at 160°C is thought to be due to the microasperities on the contact surface becoming more easily deformed under the rotational shear force, which increases wear and leads to repeated wear and adhesion.When the topcoat is present, the surface becomes more easily deformed than the Zn–Al coating alone, which lowers the coefficient of friction μ. Even if the surface wears, it remains covered by the topcoat and is not prone to adhesion. At lower temperature, μ is reduced due to the temperature-dependent properties of it. However, it is considered that above 100°C the surface becomes more affected by the underlying Zn–Al coating, and μ increases with sliding time.

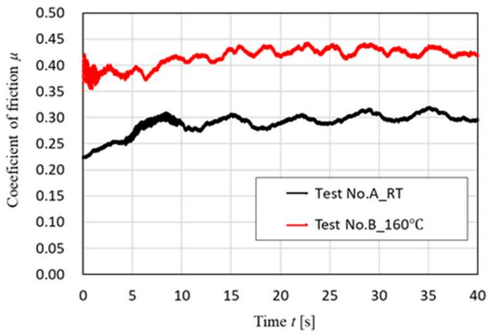

Fig.1 μ in case of Zn-Al coating

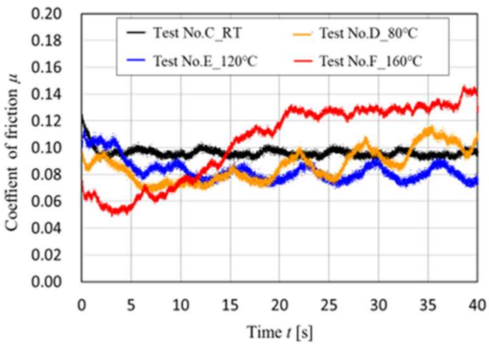

Fig.2 μ in case of Zn-Al coating with topcoat

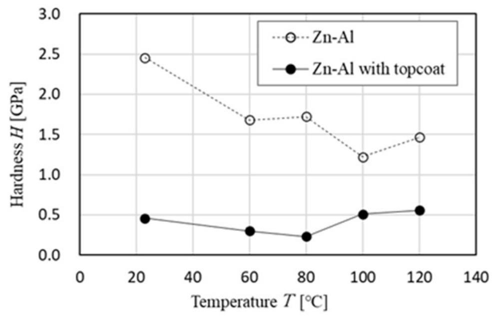

Fig.3 Relationship between Temperature T and Hardness H by nanoindenter tests