FRICTIONAL BEHAVIOR OF PAPER WIPER IN PARTIALLY WET CONDITIONS: SIGNIFICANCE OF THREE DIMENSTIONAL WETTING

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KEYWORDS
Friction; Paper wiper; Water content; Nonuniform wetting

ABSTRACT
Soft materials such as rubber [1] and human fingers [2] exhibit high friction under the nonuniform wetting condition that both lubricant and air exist at the contact interfaces. On the other hand, soft materials such as paper and cloth may exhibit unique frictional behavior, because these materials can absorb water and distribute water in three dimensions within themselves, i.e. three dimensional nonuniform wetting. This study conducted friction tests between a paper wiper specimen and a flat glass plate by varying the water content in paper wiper to show the significance of the three dimensional nonuniform wetting.

Fig. 1 shows schematic diagram of experimental set up. The size of a paper wiper specimen is 10.0 mm × 10.0 mm, thus the apparent contact area A_0 = 100.0 mm^2. The normal load W was 0.098, 0.49, and 0.98 N, resulting in the apparent contact pressure P = 0.98, 4.9, and 9.8 kPa, respectively. The sliding velocity v was 10.0, 50.0, and 100.0 mm/s. Each friction test started at the dry condition, and then water containing 100 ppm fluorescein sodium salt was dropped onto the paper wiper specimen, i.e. under partially wet conditions. Finally, the interface was filled with 50.0 mL of fluorescein salt solution that's how the fully wet condition was made. During the friction tests, water distribution in the contact interface was captured using a camera. Based on Otsu's binarization method [3], the area covered with water A_w was calculated.

Fig. 2 shows the relationship between dynamic friction coefficient μ and ratio of water covered area A_w/A_0 at the steady state when P = 0.98 kPa and v = 10 mm/s. As shown in Fig. 2, μ increased with A_w/A_0 and then decreased. The result indicates that the paper wiper specimen exhibited high friction by containing particular amount of water. The smaller the apparent pressure and the faster the sliding velocity, this high friction effect was enhanced. This high friction effect may be attributed to meniscus formation at the contact interface and inside the paper wiper specimen, i.e. three-dimensional wetting (Fig. 3), because the negative pressure due to the meniscus can promote the expansion of the real contact area.

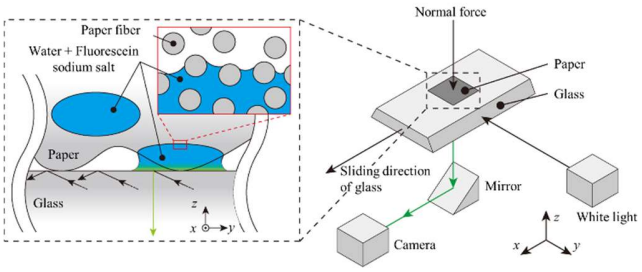

Fig.1 Schematic diagram of experimental setup

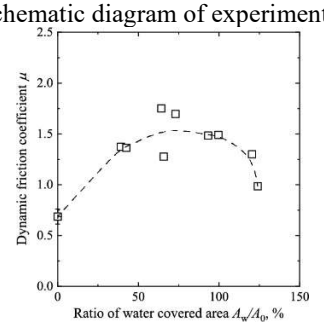

Fig. 2 Relationship between dynamic friction coefficient and ratio of water covered area at the steady state (P = 0.98 kPa, v = 10 mm/s)

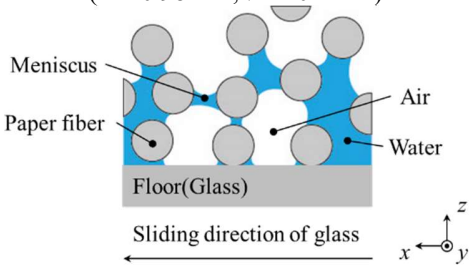

Fig. 3 Schematic of three-dimensional wetting in paper and glass contact under partially wet conditions

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