Journal of Tribology Discussion

On Stick-Slip and Velocity Dependence of Friction at Low Speeds[1]

N. V. Gitis.[2] In this interesting paper the authors have described their experiments with the hoop apparatus. Their friction measurements in vacuum at low speeds have shown a more complicated dependence of friction on the speed than they had expected: friction is sharply decreased in a speed range from 0 to about 0.1 mm/s, then is increased for the speeds up to about 5 mm/s, then is decreased again.

Such intermediate friction maximum, which stabilizes sliding and so was called by the authors a "negative stick-slip", is considered by them as a completely new observation. They said, "Neither of such dependence of friction on speed seems to have ever been reported before".

There were however a few earlier investigations which mentioned this effect.

B. Lurje (ENIMS, Moscow, USSR) observed and described it in his dissertation thesis in 1962. Of course, this thesis is hard to find in the American libraries. Also, because of the unusual character of this effect, Dr. Lurje has never mentioned it in his journal articles. So, it is not surprising that the authors are not familiar with it.

In 1986 M. Weck and U. Rinker (Industrie Anzeiger. B. 108. No. 28. pp. 56–58) observed this effect for relatively rough surfaces, while there was no effect for relatively smooth surfaces.

In 1987 N. Gitis, B. Chizhov and A. Lapidus (Soviet Engineering Research vol. 7. No. 11. pp. 67–72) not only observed and described it in detail, but developed the first theoretical model explaining this effect. Their friction model at boundary and mixed lubrication takes into account micro-displacements (MD) of a slider in the perpendicular direction, even the macro-uniform sliding and macro-constant friction force.

According to that model, as the speed increases from zero, the friction force drops because of a reduction of the MD height (which is a sum of the engagement of the real contact spots and of their elastic deformation). The friction force then rises because of adhesion growth (a rate-dependent viscous component as well as a capillary force become significant). It was noted in that paper, that the speed range of such effect (which was in general from 5 to 60 mm/s) was constant for the same oil with different materials (metals, polymers, composites), which confirms the main role of a lubricant (or of other layers on the surfaces in a case of unlubricated friction) in this effect. When the speed increases still further, friction is reduced, again, because of further reduction of the MD height as well as an adhesion decrease (see the paper quoted: the thicker lubricant layers produce the lower adhesion force between the surfaces). At high enough speeds a second friction increase may take place because of either hydrodynamic effect (at lubricated contacts) or heating (at dry friction).

That theory explains both an elimination of this effect with the roughness reduction, found earlier by M. Weck and U. Rinker, and a drift of this effect to the lower speeds when less viscous lubricants are used, which was observed in that work.

Of course, my remarks do not reduce the quality and importance of the work done by C. Gao and D. Kuhlmann-Wilsdorf.

[1]By C. Gao and D. Kuhlmann-Wilsdorf, published in the April 1990 issue of the JOURNAL OF TRIBOLOGY, Vol. 112, pp. 354–360.

[2]IBM Corporation, San Jose, CA 95193. Mem. ASME.

Authors' Closure

Thanks are due to Dr. Gitis for pointing out several papers on velocity dependences of friction at low speeds which we missed, and for his particular suggestion that oscillations normal to the interface, as studied by himself and coworkers in *Soviet Engineering Research,* Vol. 7 No. 11, pp. 67–72, may be responsible for the "negative stick-slip" described in our paper. This hypothesis merits serious consideration, especially since the very brief episodes of lowered friction which we dubbed "negative stick-slip" often appear to be triggered by sudden jerks of the samples. However, while the effect was observed for copper fibers sliding on copper in a 0.01 torr vacuum, it was not found in subsequent otherwise identical tests of gold-plated copper fibers sliding on gold-plated copper, which suggests that the extremely thin oxidation layers on the copper surfaces made the decisive difference. The probability that these can play "the main role of a lubricant (or of other layers on the surface in a case of unlubricated friction) in this effect," as would be required by Dr. Gitis's explanation, appears to be low. Incidentally, an intermediate friction maximum does not stabilize sliding but limits the slip excursions, as explained in our paper. At any rate, it will be interesting perhaps for others to supply additional relevant observations, and for us to keep Dr. Gitis's suggestion in mind in our future investigations.