Friction across the scale -from atom to earthquake-

Hiroshi Matsukawa

Department of Physics, Aoyama Gakuin University

Friction is one of the most familiar physical phenomena to us. It is hard to imagine a world without friction, because there is always friction going on around us. In fact, the ancient Greek philosopher Aristoteles believed that objects would remain stationary unless a force was continuously acting on them. Now we know that is due to the friction.

The behavior of friction has been studied since ancient times. See Fig.1. But it was put together as we know it today by Amonton and Coulomb during the Industrial Revolution, after the work of Da Vinci. This is what is called the Law of Friction, or the Amonton-Coulomb Law, which appears in high school physics textbooks. The Law concerns the dry friction between two solid objects and states, i) the friction force is independent of the apparent contact area, ii) the friction force is proportional to the normal force, iii) the kinetic friction force does not depend on the sliding velocity and is smaller than the maximum static friction force. At this time, the Law of Friction was only a phenomenological theory, and its microscopic mechanism did not become clear until the mid-20th century, when the atomic theory of the solids was established.

Since then, new experimental techniques, such as vacuum technology, friction force microscopy (FFM), and surface force measurement devices, have been ushering in a new era in friction research. It becomes possible to measure the frictions between clean surfaces on a well-controlled atomic scale, and between atomic scale asperity (Fig.2.), the peculiar behavior of "liquid" lubricants confined to a small area and "super-lubrication", in which the frictional force disappears within the range of experimental accuracy, all part of the study of friction. These phenomena have been the subject of intense research to date.

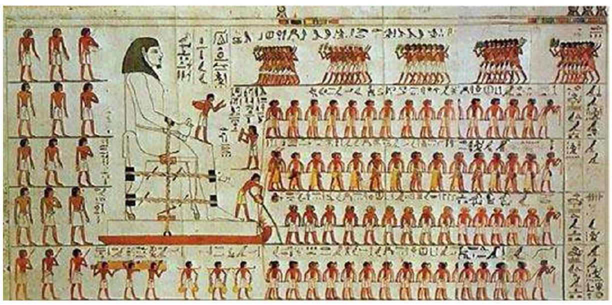

Fig. 1. Workers carrying a large statue on the sledge in ancient Egypt. The man on the front edge of the sledge is pouring a liquid in order to reduce the friction between the sledge and the sand floor.

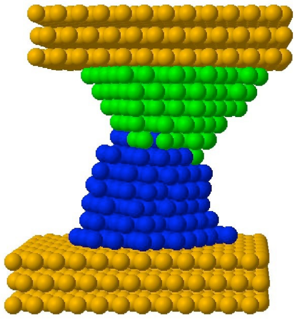

Fig. 2. Computer simulation of the friction of atomic scale asperity.

Some researchers have been trying to explain macro-scale friction from such microscopic phenomena. The largest scale frictional phenomenon on Earth is earthquakes. In earthquakes, the friction between rocks and debris at faults is one of the most important issues, and there has been a great deal of research in this field in recent years.

However, the research on the connection between micro- and macro-friction has not been sufficiently successful yet. On the other hand, new frictional problems have emerged one after another, which are waiting to be solved by the advances in energy conservation, environmental issues and nanotechnology.

In this talk, I would like to introduce the physics behind friction phenomena from the nanoscale to the macroscale, as well as various applications.

References

1) Hiroshi Matsukawa, The Physics of Friction, Iwanami Shoten (in Japanese).

*E-mail: matsu@phys.aoyama.ac.jp