There's something in the way you move

Horse-racing and skiing are two sports where a better understanding of friction could help

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Have you ever had the experience of gliding effortlessly across a dance floor with a partner of rugby-player proportions, yet endured a swollen ankle minutes later from the quick-step of someone half the size? Why does one twin sister seem to be "hard" on shoes while the other can make a pair last twice as long? The explanation for counterintuitive phenomena like these lies in the study of friction and wear – a field known as tribology – and an increasingly rich source of tribological data come from the science of sport.

Take, for example, horse-riding. For centuries, horseshoes have been used to protect horses' hooves from wear and tear. But traditional steel horseshoes reduce the natural shock-absorbing properties of the hoof and can therefore cause damage to the animal's lower limbs, especially on hard surfaces such as roads. As a result, modern-day "blacksmiths" have been developing an alternative to steel shoes based on polymers, which are lighter and more elastic. Polymer horseshoes can therefore accommodate the deformation of the hoof during movement, but they have one major drawback: they wear much more quickly than steel shoes.

Fighting friction – waxing your skis is not the only way to increase your speed on the slopes.

To increase the performance and lifetime of polymer shoes, tribology researchers have been studying the rate at which wear occurs in relation to the way horses move. The results, which were presented at a meeting on tribology in sport in London last month, are surprising.

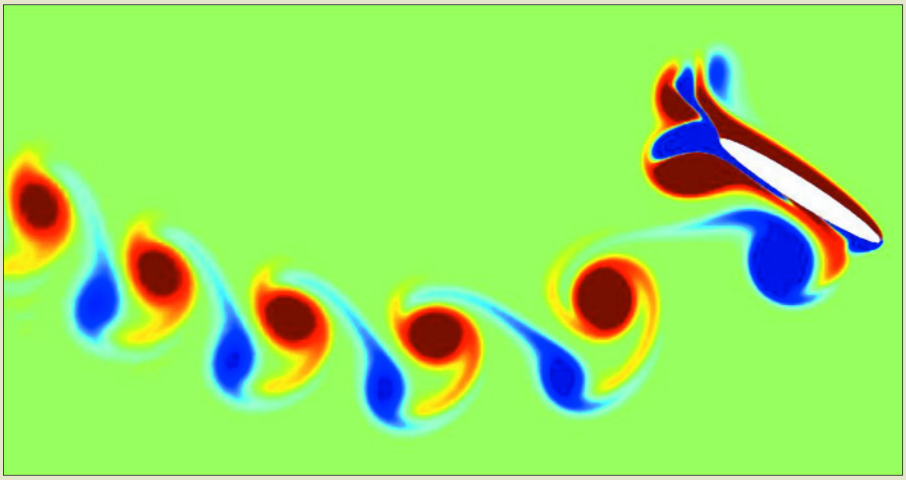
Equine experiments

Normally engineers turn to the "Archard" equation to study the friction and wear of surfaces. Here, the wear rate of a surface is directly proportional to the applied load: $V = kW/H$, where V is the wear volume per unit sliding distance, k is a constant, W is the load and H is the hardness of the surface. In other words, the heavier the object, the larger the impact it has on a stationary surface and the quicker it deteriorates.

But by measuring the wear performance of polymer horseshoes for a given exercise such as cantering, Stefano Mischler of the Swiss Federal Institute of Technology in Lausanne and co-workers have found that the wear rate is independent of the mass of the horse. This is in stark contrast to the wear rate of components in industrial machines, which follows the Archard equation (at least in the absence of significant frictional heating).

There are some indications that a similar situation might occur in humans. Studies of the biomechanics of running by Colin Walker and colleagues at the University of Strathclyde show that the "heel strike" and contact time of running shoes on the ground changes depending on the running style of the individual athlete. These factors will

Passive-flight simulator



As anyone who has watched a leaf or a piece of paper flutter to the ground is aware, it is impossible to accurately predict where it will land. But this has not prevented physicists and mathematicians from trying. This simulation shows the vortices created by a plate (white disc) as it tumbles through a fluid, which was obtained by Umberto Pesavento and Jane Wang of Cornell University by solving the Navier–Stokes equation (*Phys. Rev. Lett.* **93** 144501). In particular, their calculation reveals that the aerodynamic lift that causes a falling object such as a leaf to momentarily rise (as can be seen on the right of the image) is due to the coupling between translational and rotational motions. The different colours represent the "vorticity" of the fluid (the curl of the velocity): red indicates high vorticity, while blue indicates low vorticity. Pesavento and Wang are now using their model to investigate the transition between fluttering and tumbling motion. The rich dynamics of such passive flight represents more than just interesting physics; it could also help researchers learn more about insect flight (see *Physics World* April 1999 pp21–25). **MC**

ultimately affect the wear rate of the outer surface of the running shoe.

It seems as if animals adjust their movement so as to reduce the overall impact on a surface. For example, early studies of the biomechanics of running revealed that the body limits the vertical force on a limb by quickly rotating the lower limb on impact. As the time over which this force is applied and the area of contact may vary depending on running style, the wear rate of running shoes – and, indeed, of joints such as the knee – may also vary accordingly. This has interesting consequences for the design of materials for sports shoes, since using harder or tougher materials may not be the only factor that improves the longevity of the product.

Looking at these results from the opposite end of the spectrum – i.e. with a view to designing engineering processes to reduce wear – suggests that machines could be designed to automatically change speed or motion at high applied loads in the same way that animals do. Using knowledge-based routines, such as artificial intelligence, may therefore be a better way of reducing component wear than regularly replacing materials.

Slippery surfaces

The wear and tear of horseshoes is one of many examples of how tribology can improve sports performance. Another, perhaps more obvious example, is skiing. Skiers and snowboarders often wax the surfaces of their equipment to reduce friction on snow surfaces, but what is less well known is that the temperature of the snow can affect how quickly they make it down a slope. Moreover, the faster you go, the less friction you experience.

Recent measurements of the frictional performance of ski surfaces made by Stéphane Ducret and co-workers at the Ecole Central de Lyon in France have demonstrated that friction is highest at very low temperatures of about −15 °C, but is at a minimum at −5 °C. This minimum is thought to be due to an "elasto-hydrodynamic layer" of melted snow, which forms due to frictional heating. As work is converted into heat at high speeds and large loads, it means the faster the skier goes (at low temperatures), the easier it will be to form this melted surface layer. So, when you wonder how your ski guide skims the slopes in a matter of seconds, when it takes minutes for you to reach the bottom, you should bear tribology in mind. The high speed at which the skier is travelling indirectly helps them to go even faster due to a self-lubricating action on the ski surface.

The combined effects of mass and speed, in addition to the friction and wear resistance of the materials in contact with a surface, all play a significant role in how you and your sports kit will fare during the coming winter months. So when you are checking the soles of your running shoes before a morning run, or lugging skis up a chairlift, remember that your performance may not only be due to the friction and wear characteristics of the materials; it may also have something to do with the way you move.

Highlights from PhysicsWeb

Superstructures and superconductors

The discovery of oxygen "superstructures" in cuprate materials by two independent teams of physicists could help shed new light on the origins of high-temperature superconductivity. X-ray scattering experiments have shown that oxygen defects and vacancies form an ordered superstructure with a periodicity of four unit cells. The results suggest that the "stripes" of charge found in some cuprates might not be responsible for their ability to carry currents without resistance. The existence of superstructures in the cuprates was first predicted by theorists in 1990.

Earthquake shakes up gravity

Geophysicists in Japan have detected a change in the Earth's gravitational field caused by an earthquake for the first time. The team used an array of superconducting gravimeters to detect an increase of less than $10^{-8}\,\mathrm{m\,s^{-2}}$ in the acceleration due to gravity near the epicentre of an earthquake that occurred in September 2003. The results agree with theoretical predictions and could help with the interpretation of measurements of the Earth's gravity made by satellites.

Fingerprint model makes impression

Everyone has a unique set of fingerprints, yet scientists are still unsure about how these patterns form. Now two applied mathematicians in the US have developed a model that is able to reproduce real-life fingerprint patterns. The model suggests the patterns have their origins in the stresses that build up in the basal layer of skin (the layer between the outer epidermis and the inner dermis) while we are still in the womb. These stresses cause the basal layer to buckle inwards, creating ridges on the surface of the skin.

Nanotubes shape up for spintronics

Scientists at IBM have shown that nanotubes made of vanadium oxide are magnetic at room temperature. Moreover, the magnetic properties of the nanotubes can be controlled by doping them with electrons or holes. The work could have applications in "spintronics", and the IBM team now plans to develop devices in which spins can be controlled by a voltage rather than by doping.

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