

PHYSICS IN ACTION

imagination of science-fiction writer Frank Herbert, numerous ripples and drifts of dust and sand dotted the landscape.

The rocky landscape offers many opportunities to visit individual rocks, which have been mostly excavated by countless meteorite impacts and strewn around the craters. Most of the rocks are coated with bright materials and have been eroded and shaped by the incessant Martian winds. Adirondack, for example, stuck out because of its size and its two-toned appearance, which is reminiscent of a 1950s automobile. The upper part has a fresh and dark-appearing tone, while the lower part is paler and coated, indicating that some of the surrounding soil has been removed by wind.

Anticipating such rock coatings from the earlier Viking and Pathfinder missions, engineers had designed a rock-abrasion tool to penetrate through the coatings and investigate the composition of the solid rock. Adirondack provided the first surprise: the local rocks were not, in fact, sediments from an ancient lake, but volcanic rocks of basaltic composition analogous to lava flows on, for example, Hawaii. This finding was later confirmed by analyses of other rocks along the journey.

So where were the anticipated sedimen-

tary deposits? Impact craters provide natural drill-holes into planetary surfaces, and Spirit explored several of these in order to examine materials brought up from shallow depths below the surface. But here too, there appeared to be nothing but volcanic rocks.

The summary of the mission findings to date suggest that the geological history of the Gusev crater floor explored by Spirit is dominated by three processes. The first is the volcanic extrusion of lava flows, which cooled and hardened to create a region of smooth, dark plains. The second is the subsequent cratering events, which disrupted and excavated portions of the underlying lava-flow bedrock. Finally, wind-related abrasion modified the surface and ejected impact blocks, and also deposited dust from distant sources. Although coatings and veins that may have resulted from reactions with aqueous fluids were found, no evidence for ancient lake deposits was revealed.

Opportunity

These unexpected results are the true rewards of exploration. As the late planetary scientist Tom McGetchin used to say, the geological processes that were thought to have shaped Mars turned out not to be option a, b or c, but option d – “none of the

above”. These results provide important confirmation that areas showing evidence of water erosion have also been heavily influenced by lavas. Furthermore, they have prompted significant rethinking in the research community.

Some researchers now think that many of the channels extending into and out of ancient craters could be caused by lava flows, not water erosion. Others believe that the lava flows on this part of the Gusev crater floor are simply a surface coating on ancient lake deposits, some of which may be exposed at the Columbia Hills. Still others believe that the evidence for ancient flowing water is overwhelmingly demonstrated by ever-higher-resolution views of the surface from orbit, including strong evidence for river channels and Mississippi-like sedimentary deltas.

Spirit's twin spacecraft, Opportunity, is searching for evidence of ancient water in a totally different geological environment. Preliminary findings include evidence of rock layering, which could be the result of running water, and several minerals have been discovered that might have formed due to the action of Martian groundwater. We now anxiously await the first official reports from the Opportunity team.

There's something in the way you move

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

From **Margaret Stack** in the Department of Mechanical Engineering, University of Strathclyde, Glasgow, UK

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



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

wear much more quickly than steel shoes.

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.

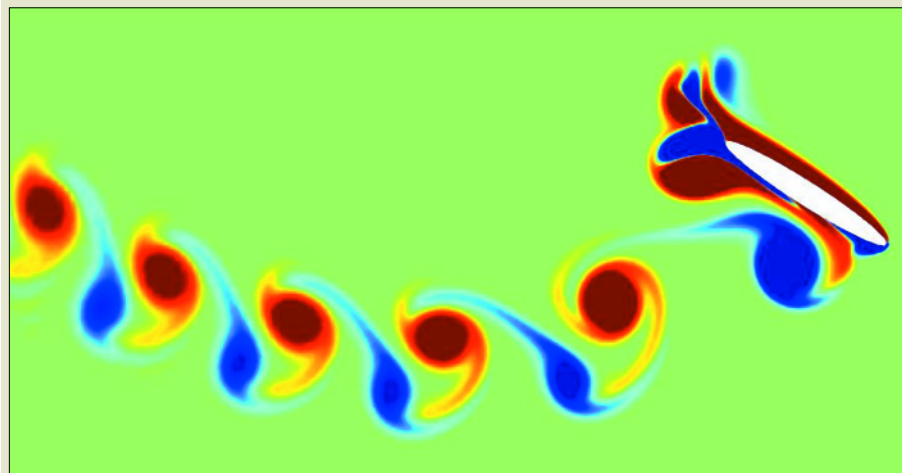
Equine experiments

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**

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} 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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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.