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Stick-slip friction

The frictional properties of a lubricant are critical to ensuring a successful operation.

In TLT we've discussed static, dynamic, kinetic, sliding and rolling friction. Now let's move on to stick-slip friction.

For two contact surfaces, stick-slip friction can occur whenever the coefficient of kinetic friction is lower than the coefficient of static friction, resulting in some elasticity in the system. When a driving force is applied to one surface, high static friction prevents motion until the force is sufficient to overcome the elasticity. As a result, the surface then starts to move and, with the change from static to dynamic friction, the elastic force accelerates the surface while the elasticity unloads rapidly.

The moving surface slows down and friction grows rapidly until the surface finally comes to a halt and the cycle starts all over again. Therefore, the relative motion of the surfaces is intermittent.

There are several examples of stick-slip friction. The sounds made by bowed instruments (violins and cellos) and grasshoppers are caused by stick-slip. When the bow is moved over the strings or the grasshopper rubs its legs together, the vibrations that result from stick-slip motion cause characteristic sounds. Other examples of stick-slip friction include noises made during honing, heavy braking and screeching tires or chalk on a blackboard. The behavior of seismically active faults is also explained using a stick-slip model, with earthquakes being generated during the periods of rapid slip.

Three cases in which stick-slip friction is particularly important are machine tool slideways, aircraft simulators and textile manufacturing.

Smooth and precise operation of a slideway is very important during machining to maintain dimensional accuracy and correct surface finish of machined components. Loss of frictional control causes inaccuracies, which can result in rejected components and lost productivity. Slideways are not like plain bearings. The motion is linear, not rotational. Plain bearings are designed to operate under hydrodynamic conditions, but slideways have to stop when the end of travel is reached and then start moving again in the opposite direction. Consequently, because slideways typically operate in a stepwise manner, mixed lubrication plays a more important role, so they are far more susceptible to stick-slip.

When hearing the sounds of a violin, stick-slip motion occurs when the bow moves over the strings.

As for hydraulic cylinders in aircraft simulators, any stick-slip in the lip seals of the cylinders is likely to be felt by the pilots, who are being trained to fly using the simulator. If a pilot feels an unusual vibration in his or her seat, the intended realism of flying in a plane may be lost.

During textile manufacturing, particularly in the spinning of yarns, stick-slip friction can cause significant variation in the quality of the yarn, particularly with regard to uniformity and strength. Stick-slip is a characteristic of the overlapping nature of boundary, semiboundary and hydrodynamic lubrication regions under the different speed conditions during textile fiber processing.

In all three cases, attention to the frictional properties of the lubricant is critical to successful operation. Modern slideway lubricants usually contain a synergistic mix of friction-modifying additives that enable accurate and smooth operation of the slideway over a range of operating conditions.

Optimum selection of base oil viscosity, load-carrying (usually extreme-pressure) additives, corrosion inhibitors and friction modifiers enable the formulation of high-performance slideway lubricants. Similarly, the hydraulic fluids used in aircraft simulators are carefully formulated with the correct balance of base oil viscosity and antiwear, oxidation inhibiting, corrosion inhibiting and friction-modifying additives. Formulating high-performance textile lubricants is just as difficult since allowances must be made for static discharge and removability in addition to friction control.

Furthermore, recognized tests to demonstrate the frictional properties of slideway lubricants and hydraulic oils include the Cincinnati Lamb Friction Test, the SKC Tribometer and University of Darmstadt Rig Test. Tests for textile lubricant frictional properties include the Rothschilde Frictometer and the Capstan Frictometer.

So the next time you hear a violin, remember the importance of stick-slip friction.

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