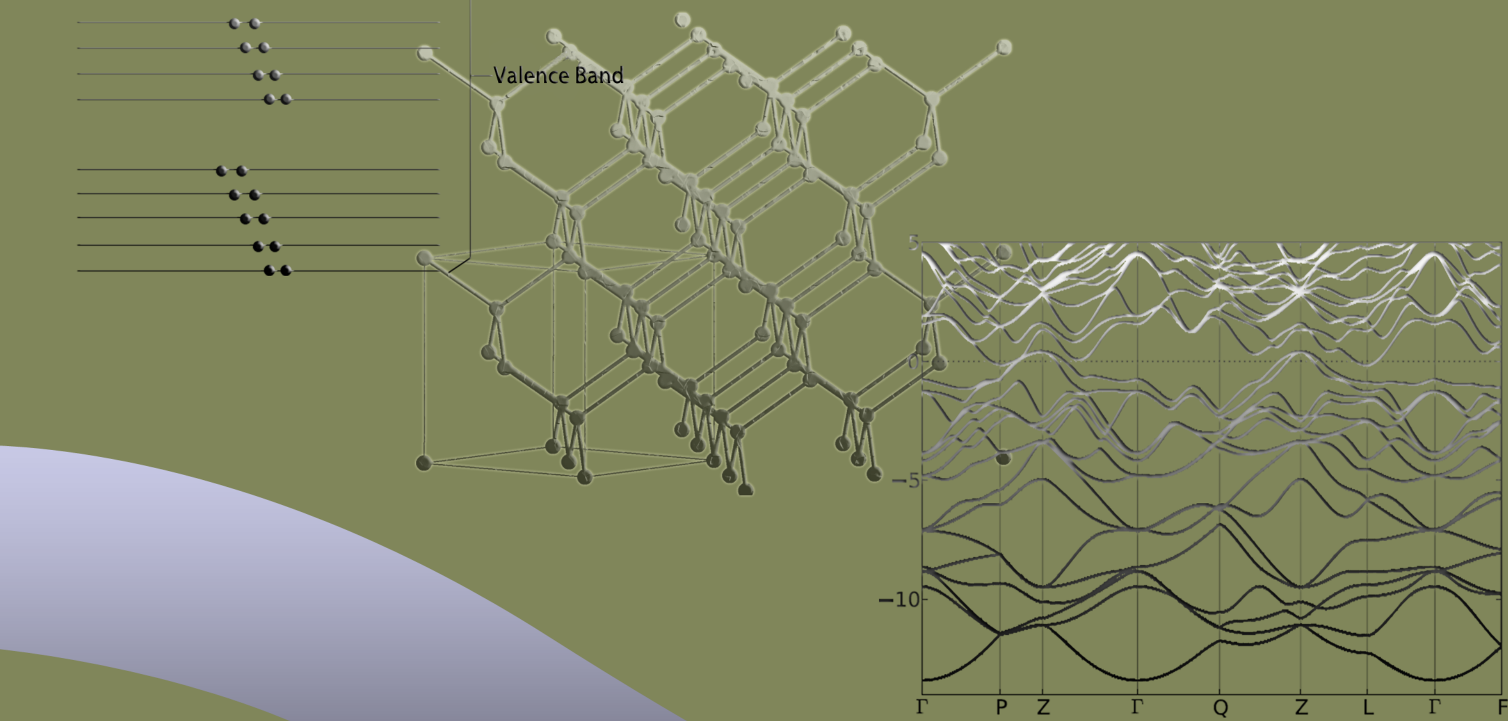
Queen Mary, University of London

School of Physics and Astronomy

About Rolling Resistance



Not like the sliding friction, for which we can easily imagine what is happening in between the two interaction bodies. For example, if we drag a box on the sandy ground, we could see the track and hear the sound of the 'friction', which are both the effect of sliding friction that can be 'seen' by our eyes, but it is not the case for rolling motion. Although the effect of rolling and sliding friction is the same - to retard either the rolling or sliding motion, we cannot easily 'see' the rolling friction. Exactly speaking, the name of rolling friction is not correct since the way that rolling 'friction' retards the rolling motion is different from the case in sliding problem. The exact expression should be *rolling resistance*, and the resistance comes from the so-called hysteresis effect. Basically, hysteresis effect means that for any real object, the energy obtained during its deformation is larger than the released energy during recovery, and the energy loss transforms to heat. In rolling motion, it is just the energy loss caused by hysteresis effect that is contributing to the retarding of the rolling.

The following graph (from Wikipage 'Hysteresis') gives the idea of elastic hysteresis effect in rubber band. Basically, it tells us the changing of force exerted by the rubber band is different during

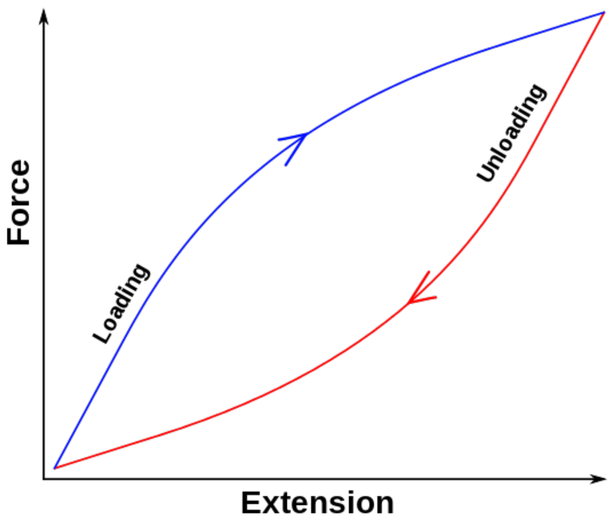


Figure 1. Elastic hysteresis effect.

loading or unloading weight. The area between the loading and unloading curve is just the energy loss during the loading and unloading process.

On Wikipedia, there is an example to show the rolling resistance (see Wikipage 'rolling resistance'), which is depicted by Fig. 2., in which the two equal cylinders are pressed together and the contact area is flat regardless of sliding friction. When a small ball goes in between the two cylinders, the reaction force exerted on the small ball is shown in Fig. 2. As can be observed, the changing of force along the way from coming-in till going-out is asymmetric. The reason for the asymmetry is just due to the elastic hysteresis effect, and later we can see that this clearly shows where the rolling resistance comes from.

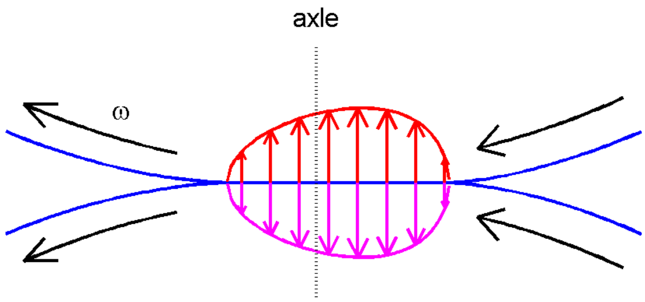


Figure 2. The two contacting cylinders. Rolling to right.

Using the force-extension relationship given by Fig. 1. in the case shown in Fig. 2., we could know that the reaction force exerted on the small ball increase quickly when it just goes in between the two cylinders. And then the force smoothly increases to its maximum. After that, the force firstly decrease quickly and then smoothly to zero till the ball totally goes out of the system. So it's natural that the force is asymmetric since if we have symmetric force diagram in Fig. 2., the maximum force should be just at the position of axle, and then how is it possible that the changing rate of force when the small ball comes in and goes out is different as above? Thus we can see that it is the hysteresis effect that makes the force diagram in Fig. 2. asymmetric.
The direct result of the hysteresis, as we can see from Fig. 2., is that large force is 'concentrated' to the right-hand side, which means the resultant force could cause a moment that tends to retard the rolling of the two cylinders. And that's basically where the rolling resistance comes from!