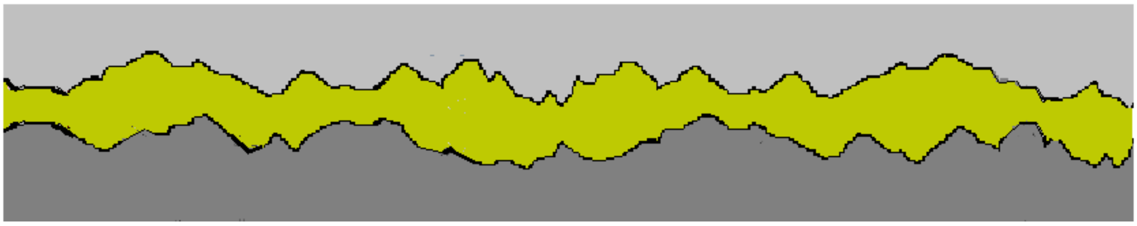
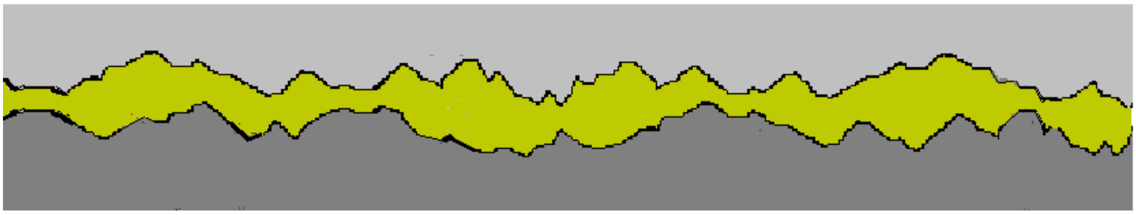
Electrical Contact Resistance Signal

If we have two surfaces separated by a thick, non-conducting, fluid film, we effectively have an open circuit "switch", so nominally an infinite resistance. The contact resistance signal will thus be the open circuit voltage of the system.

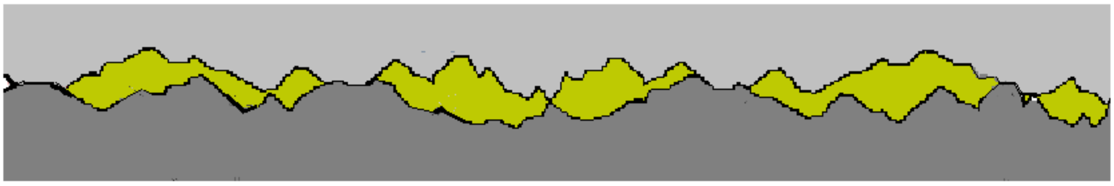


If the fluid is a mineral oil, it will have very high electrical resistance; oils are good insulators. If the surfaces are brought together, but still remain out of contact at an asperity level, the "switch" will still be open circuit, so the contact resistance signal will still be high. In effect, once there is no metal-metal contact in the "switch", it does not make any difference whether the surfaces are separated by 100 microns, 100 mm or 100 m!

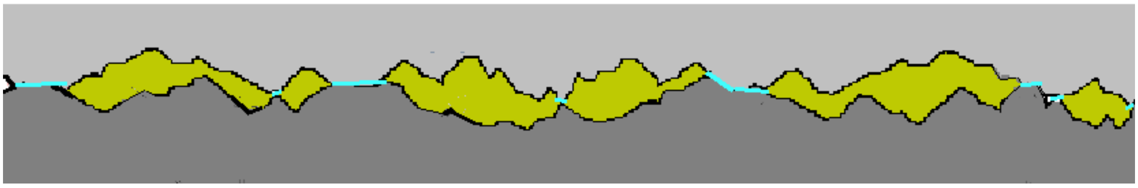


As the surfaces are brought together still further, electrical contact is made through the film at an asperity level, at which point the "switch" is closed, producing a short circuit between the surfaces. As a result of this, the voltage across the contact falls to zero.

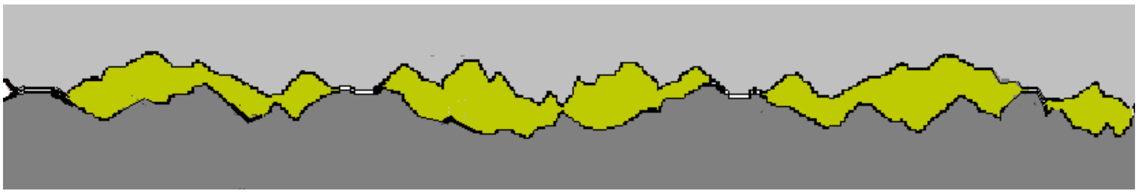
Now, if will be obvious that each asperity is in effect an individual "switch", so just one asperity coming into contact will be sufficient to short circuit the contact. However, we may actually have many more than one asperity in contact, in other words, we may have multiple "switches" in parallel. There is no way of telling from the contact resistance measurement how many closed "switches" there are; it could be one, it could be one hundred.

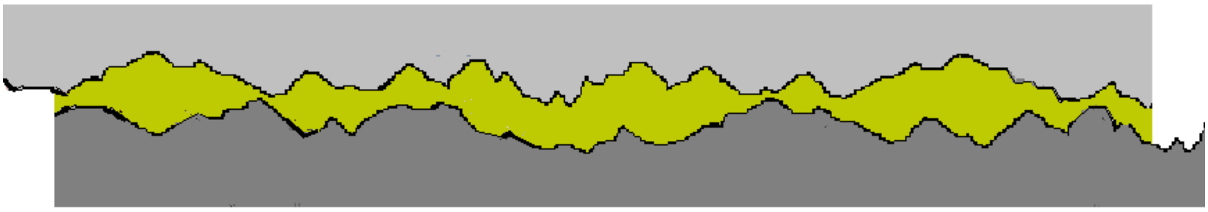


But we also have to consider what happens if as well as our non-conducting lubricant, we also have non-conducting surface films, in other words, the equivalent of a non-conducting coating. These could be formed either as physisorped or chemically reacted films, depending on the additive present. These films will of course have different electrical properties from the bulk lubricant. If we have a high contact resistance signal, in other words, open circuit, how do we know whether our surfaces are being electrically insulated by the bulk fluids or the non-conducting surface film? The answer is that we don't.

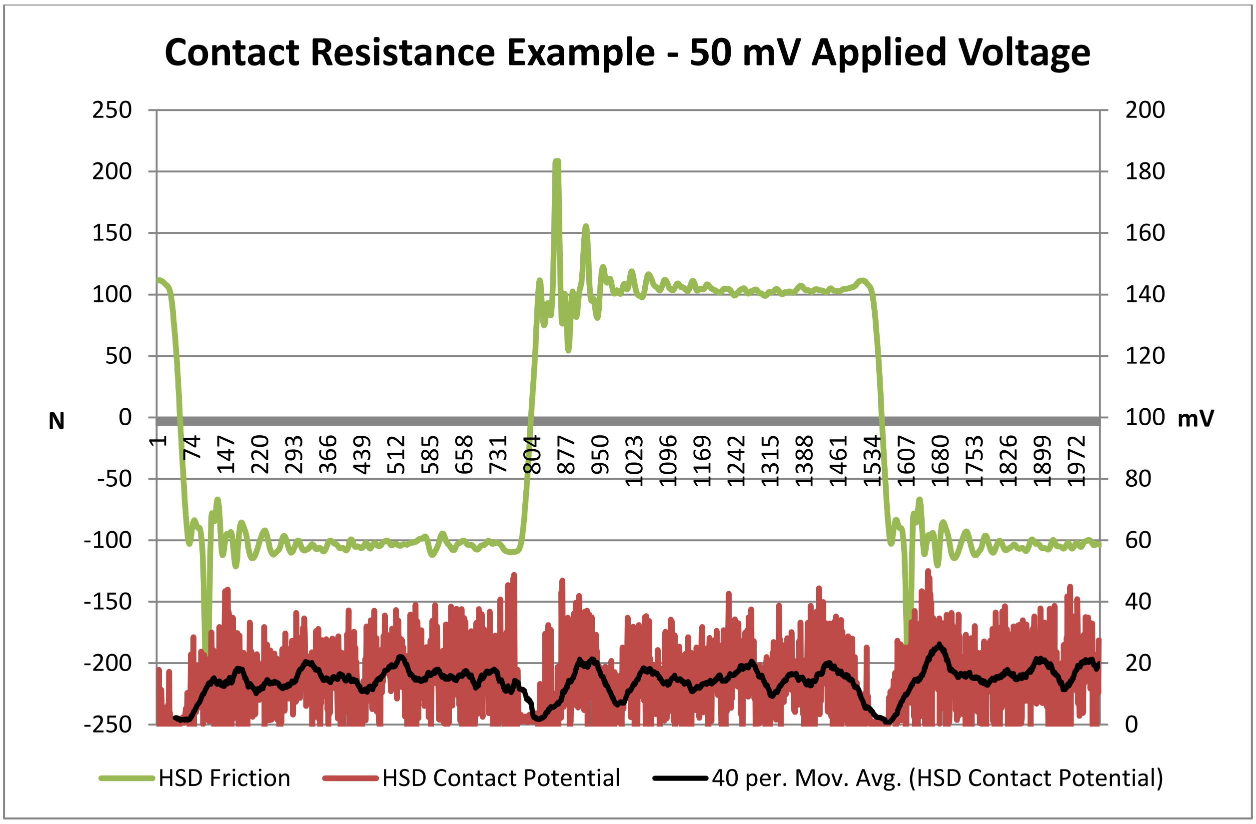


Now, these previous examples have not considered what happens when there is movement between the surfaces. It is perfectly conceivable that we could have a situation in which multiple asperities slide in and out of contact. We would particularly expect to see this when operating in a mixed lubrication regime.





In this case, the asperity "switches" temporarily close, causing the contact resistance to fall to zero, then moments later, open, causing the signal to rise to open circuit voltage. Hence we have a process that involves opening and closing of multiple asperity contact "switches".



We can see this sort of behaviour if we look at high speed data from a reciprocating test. In this case, a 50 mV "up" spike in the instantaneous contact resistance represents all the asperity "switches" being simultaneously open circuit; all the 0 mV "down" spikes indicate one or more of the asperity "switches" being short circuit. Intermediate values may be as a result either of the speed of events exceeding the response time of the electronic circuit, or it could, indeed, be the result of some actual, localised, resistance variation, the equivalent, say, of having a dirty contact in a switch!

Now, to finally complicate matters, it will be apparent that the parameters affecting electrical contact resistance response will change, depending where we are on the Stribeck curve, in other words, on the lubrication regime, but this matches exactly the tribological response of the contact.

Under boundary lubrication, where surfaces are in contact at the asperities, a high contact resistance value can only result from the presence of non-electrically conducting surface additive films. The bulk properties of the lubricant have no role to play in separating the surfaces, so they have no role to play in insulating the surfaces.

Under hydrodynamic lubrication, where the surfaces are fully separated by a thick lubricant film, with no possibility of asperity contact, so no possibility of a "switch" closing, a high contact resistance value will be directly dependent on the electrical properties of the lubricant, but as most lubricants are good insulators, once the "switch" is open, it does not make much of a difference as to by how much. All we can sensibly deduce from the measurement is that the surfaces are fully electrically separated and therefore most probably fully mechanically separated.

Of course, under mixed lubrication, things are more complicated, as both lubricant additive and bulk fluid properties affect the contact, but this is exactly the same problem we have to address with tribological response under mixed lubrication. The nearer to the boundary regime, the more important the effect of the surface active additives and the less important the bulk fluid effects. The nearer to the hydrodynamic regime, the more important the bulk fluid properties and the less important the surface active additive properties.

A G P 11th October 2019