Contact Pressure and Yield Stress

In the case of point contacts (round or elliptical) that we may not be justified in using the Hertzian contact equations. For these to be true, it is assumed that the contact is elastic, that the contact zone is flat, that there are no shear stresses in the contact zone and that the contact radius is much smaller than the radius of the ball or cylinder. This will not be the case if the nominal contact pressure exceeds the yield stress of one or other side of the contact. In this case, we cannot sensibly use the Hertz equations and instead must use an elasto-plastic finite element model to evaluate the contact conditions. Such models lead to the perhaps slightly unexpected conclusion that increasing the load on our ball or cylinder simply increases the size of the plastic zone. If the ball is the harder surface, we simply have a brinell hardness test.

The mean pressure for FULL plastic contact (analogous to a hardness test) is about 3Y where Y is the uni-axial yield stress. Initiation of plastic flow starts at a lower pressure and occurs when the max shear stress reaches the shear yield stress k for the material. The maximum shear stress in a Hertz contact is buried at 0.47a below the surface and is approximately 0.47 * mean contact pressure. This all means that for a Tresca material the mean contact pressure for initiation of yield is about 1.1Y. But note that the surface material is still elastic - there is a miniscule plastic enclave under the surface.

If we now add mechanical shear, because of sliding action, we would expect a further decrease in either the applied load or temperature at which yield occurs.

The upshot of all this, is confirmation of the general pointlessness, pun intended, of running a matrix of tests with a ball on flat specimen configuration at different loads and temperatures. We learn nothing if our test simply produces the same result, regardless of test conditions. This is equivalent to trying to run a tensile test in which we try to control the load at levels in excess of the ultimate tensile strength of the material sample; it does not matter what load we attempt to apply, we always get the same answer.

- If you want to avoid plastic flow, do not exceed 1.1Y.
- If the contacts in your real application do not involve pressures close to or in excess of the 3*Y, do not use conditions that produce contact pressure in excess of 3*Y in your test system.

- If you choose to use test conditions that give contact pressures in excess of 3*Y, don’t bother running a matrix of tests at different loads.