Issue No. 86 – February 2016 **New Publication**

Love Hertz? – A brief discussion of what affects Hertz stress, and why those factors are important in connector design (even if Hertz stress itself is not).

- **Contact Mechanics**
- **Hertz Stress**
- **Constriction Resistance**
- **Asperities**
- **Hertzian Contact**

The next issue of Technical Tidbits will discuss stress relaxation.

Hertz Stress

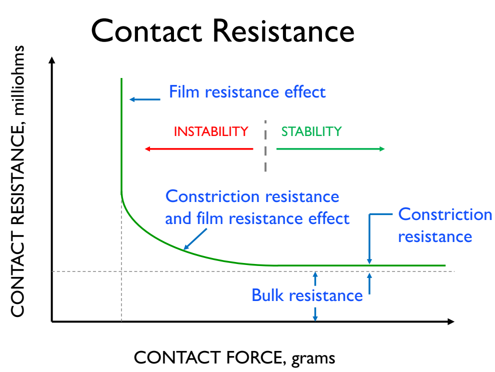
This edition of Technical Tidbits discusses the concept of Hertz stress. There is plenty of literature in public domain on this topic, but it has not been previously discussed in this forum.

You might be tempted to believe that the field of connector design is one that is free of controversy, and has been for a long time. If so, you would be wrong. One controversy that popped up in the 1990's was in regards to Hertz stress, and whether or not it could predict reliability of electrical contacts.

Let's go back to the beginning. Heinrich Hertz was among the first to study (or at least among the first to publish about) deformation occurring at the interface between two bodies in contact. This field would later come to be known as **contact mechanics**, and is of interest where multiple bodies come into contact and exert forces on each other (basically, in every branch of engineering where the action does not occur on the subatomic level.) Hertz came up with calculations to describe the shape of the contact area and the pressure distribution in the contact zone based on elastic deformation of the two surfaces. The **Hertz stress** is a function of the applied load as well as the radius of curvature, elastic modulus, and Poisson's ratio of the two surfaces. Hertz used several assumptions in his calculations, published in the 1880's:

- The surfaces are perfectly smooth and frictionless.
- The bodies in contact are homogeneous, isotropic, and elastic (i.e., they do not yield).
- The size of the contact area is small relative to the radius of curvature of the contacting surfaces.

Fast forward to the present and recall from previous discussions how the contact interface of an electrical connector behaves. Contact resistance is the chief predictor of reliability of a connector system. As long as the resistance is low enough, the connector will function as designed. Failures occur when the resistance increases beyond the allowable maximum, or even to open circuit, if things really get bad. Figure 1 below shows how the contact resistance changes with normal force, driven largely by **constriction resistance**.



Recall that on the microscopic level, no surfaces are perfectly smooth. Contact only occurs between the **asperities** (high spots) on each surface. As the contact force increases, the asperities deform, and flatten out, increasing the contact area between each asperity, and more asperities come into contact. The current passing through faces less constriction, and thus less contact resistance, and improved reliability. Therefore, it is the deformation of the asperities governs reliability. This deformation depends on the normal force, contact geometry, and hardness (stiffness) of the plating material.

Figure 1. Contact Resistance vs. Normal Force. Higher Hertz stress is associated with the contact force being distributed across a smaller apparent contact area, where a smaller number of asperities bears the load. The asperities under higher pressure deform more, closing the distance between the contact surfaces and allowing even more asperities to touch, thus lowering constriction resistance and overall contact resistance.

So, if high deformation due to high stresses in the contact interface is desirable for better electrical performance, would an electrical contact design with higher Hertz stress indicate improved electrical performance over a design with lower Hertz stress? Would Hertz stress be a better indicator of performance than contact force? The short answer is "No, not by itself, anyway." However, there are some principles from a discussion of Hertz stress that can actually be used to improve contact performance.

Hertz Stress (continued)

Mroczkowski (reference 4, right) noted that designs with different geometries that had equivalent Hertz stress did not always show the same performance. In reality, the assumption of true **Hertzian contact** (isotropic, homogenous, frictionless, perfectly elastic bodies) is completely unrealistic in the world of contact physics. However, it can be shown that designs that concentrate the applied force in a smaller area show greater wipe, and greater contact stability. Higher hertz stress, greater contact force, and softer, more deformable plating do tend to improve static contact resistance. (But watch out for vibration and fretting corrosion with those soft tin platings!)

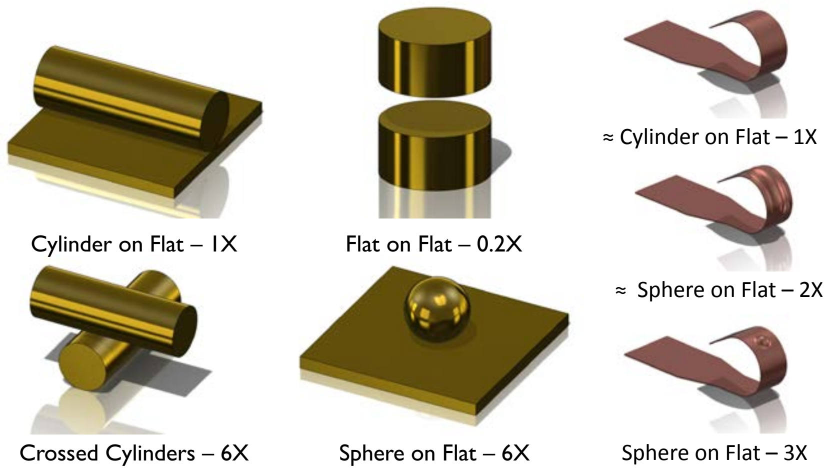


Figure 2. Relative Hertz Stress of Various Generalized (Left) and Typical (Right) Contact Configurations. The left side of the image shows that a crossed cylinder or sphere on flat configuration would produce 6x more theoretical Hertz stress, and thus more deformation per unit force than the cylinder on flat configuration. The flat on flat configuration spreads the contact force over too wide an apparent area. On the right side of the image, the lowest contact stress is associated with the configuration on the top, and the highest with the spherical embossment (often referred to in the past as a Hertz dot) in the contact on the bottom. The design in the middle is intermediate, but offers the advantage of increased beam stiffness without increasing the amount of material used.

One final interesting side note: on a microscopic level, all unbonded contact is ultimately Hertzian in nature (with the exception of the assumption of elasticity). From the smallest connector between the circuit board and an IC package, to the tallest skyscraper in the world resting on solid bedrock, contact only occurs between the asperities on either side. Contact is no longer Hertzian only when the two halves of the interface weld together, and the two separate parts become one.

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