Journal of Tribology

Discussion

Discussion: "Experimental Investigation of Fully Plastic Contact of a Sphere Against a Hard Flat" (Jamari, J., and Schipper, D. J., 2006, ASME J. Tribol., 128, pp. 230–235)

Robert L. Jackson

Itzhak Green

Department of Mechanical Engineering,
Auburn University,
270 Ross Hall,
Auburn, AL 36849-5341

The authors should be commended for tackling a subject that is in much need of additional experimental investigations. It is very difficult to make these measurements, and the authors have made a very significant contribution to the field by doing so. There are several issues in this work, however, that need to be addressed before a direct comparison between experimental and numerical results can be made.

First, the method outlined for measuring the real area of contact actually measures the deformed profile of the surface after it is unloaded. Due to some elastic recovery (even in the fully plastic regime), this profile will be different than the profile during contact. An alternative might be to compare this unloaded profile to the results of [1,2] (Refs. 21 and 22 of the authors' paper). It is known that the area that had been in contact (after unloading) is smaller than the contact area during loading. Moreover, since the contact area is proportional to the square of the radius, and the measured contact radius is fairly small, then what is the lateral resolution of the used profilometer (as this might affect the reported error)? It is also apparent from the deformed profile that the roughness of the surfaces could have an effect on the observed results since the profile is not "smooth."

The authors state that no strain hardening occurs in the material, while there is still a noticeable increase in the measured Vickers hardness from 1.15 to 1.2 GPa. Considering how close the experimental results are to the models, this seemingly slight change could make a meaningful difference. Since residual stresses or strains may affect the hardness test, it is unclear where the hardness of the surface was measured, as this could make a difference in the amount of observed strain hardening. At the center of contact the plastic deformation occurs only after a fairly large amount of deformation occurs (Refs. 12 and 13 of the authos' paper). This is because initially the stresses at the center of contact are mostly hydrostatic and not causing plastic deformation. Were similar hardness tests performed for the aluminum material?

Then, for use in the JG model, how is the yield strength determined? Has the "traditional" relationship $H=3S_y$ been assumed? As the authors indicate correctly, this relationship is not always true and, thus, it is unclear how the S_y value is determined to compare the model results to the experimental results.

Another question concerning the measurement techniques is how the interference is measured, or rather, calculated from the deformed surface profile. The authors state that the "before" profile is calculated by fitting a circular profile to the deformed area based on the "known" radius. It appears that this methodology artificially biases the experimental results to the AF or truncation model. This bias occurs because the geometric relation between the sphere shape and the flat is used to obtain the interference (this is essentially the same mathematics that the AF truncation model uses). Perhaps a more realistic methodology would be to measure the interference from the displacement of the base of the hemisphere as it is loaded.

A couple of points can be concluded from this work: (1) the theoretical models actually compare astoundingly well with the experiments (considering the fact that they have been obtained broadly and not been tweaked to match the current experimental results) and (2) the hardness is not always equal to the average contact pressure. This can be accounted for by the variation in hardness trend that was observed theoretically by [3] (Ref. 23 of the authors' paper and also Refs. 9 and 13) and experimentally by Ref. 20 of the authors' paper.

References

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[2] Etsion, I., Kligerman, Y., and Kadin, Y., "Unloading of an Elastic-Plastic Loaded Spherical Contact," Int. J. Solids Struct., 2005, **42**(13), pp. 3716–3729.
[3] Kogut, L., and Komvoppoulos, K., "Analysis of Spherical Indentation Cycle of Elastic-Perfectly Plastic Solids," J. Mater. Res., 2004, **19**, pp. 3641–3653.

