Measuring Contact Stiffness

R.J.H. Paynter[a], K. Parel and D. Nowell

Department of Engineering Science, University of Oxford
Parks Road, Oxford, United Kingdom

[a]robert.paynter@eng.ox.ac.uk

Abstract. Typical idealisation of mechanical contacts in component models consists of perfectly smooth surfaces; this is clearly not the case in reality. Real surfaces are rough so mechanical contact is actually made across many small asperities, each with highly stressed loading. The resulting high strains when taken together are in effect a thin but relatively compliant layer, this gives rise to the phenomena of contact stiffness, which is less than if the material is continuous across the contact. This needs measurement for better understanding and to feed in into engineering analysis of mechanisms.

We have been advancing our methods which are based on microscopic optical measurement of displacements neighbouring a contact while loaded. The method separates the deformation of the substrate material from the displacement of the contact.

Different surface forms and roughnesses give different stiffnesses and, a contact has history – generally getting stiffer as it develops from its first to subsequent cyclic loads – these effects apply both for normal and shear load. Recent measurements will be presented, focusing on the effects on the stiffness.

Experiment

The experimental work is done with a testing machine where both the normal and shear load can be varied while observing the side of the contact with a microscope. A sequence of loads is applied with an image captured for each step. Views of the experimental equipment are shown in Fig 1. The images are subsequently post processed with DIC software to obtain displacements in the whole field; these are further processed to find the displacement attributable to the contact separate from the general deformation.
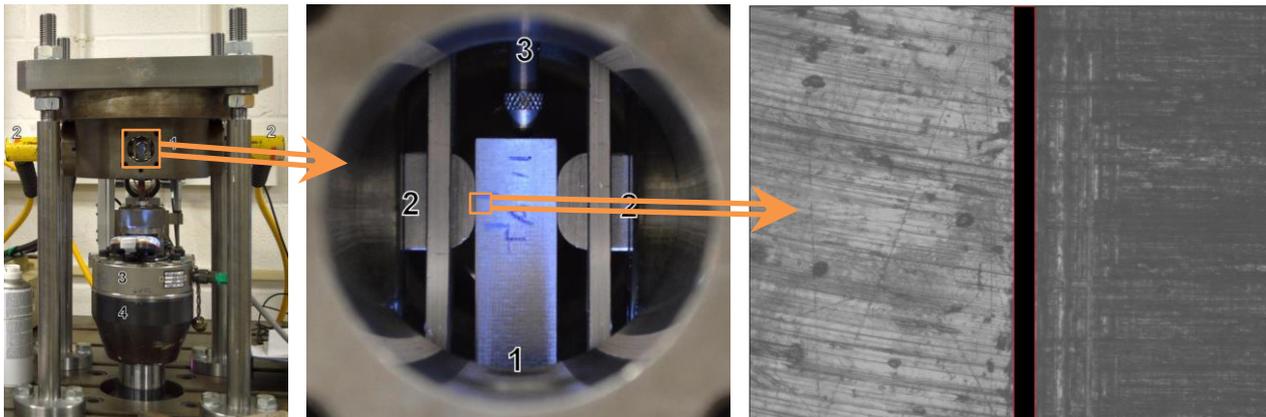

Figure 1. Left to Right: Loading rig, Specimen and pads, Microscope view of contact.

Results

Analysis based on modelling the contact as a field of hemispherical asperities gives the result that the stiffness is proportional to stress and thus, for a fixed contact area, to overall load [1]. The expected response of force due to displacement results in the form shown in Eq 1.

$$P = Ae^{bu} + C,$$
(1)

where A and C are essentially offset parameters, the proportionality is embodied in the value of b.
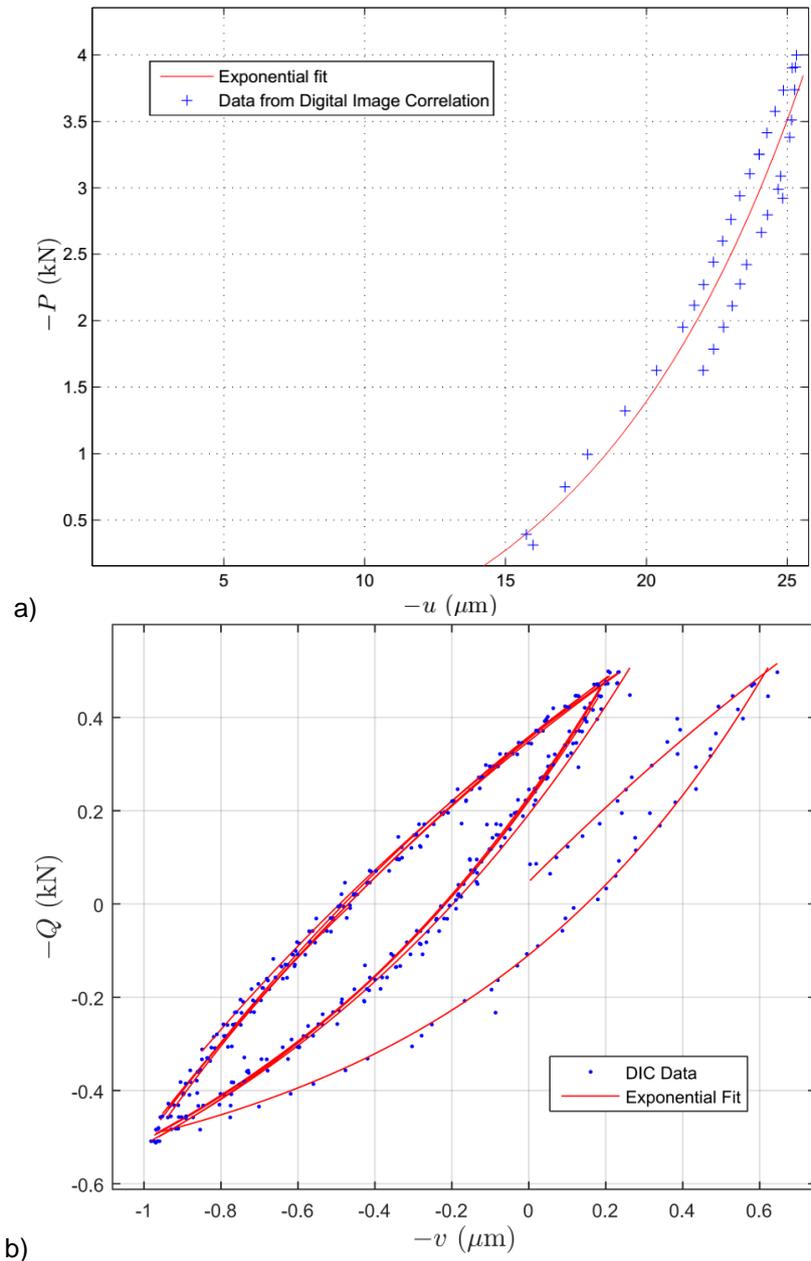
a)

b)

Figure 2. Force versus displacement plots. a) Normal Load, b) Tangential Load – initial and 3 cycles

The relationship developed above was initially applied to normal loading and subsequently has been found to be reasonable for tangential loading [2]. As the contact goes through subsequent loading there seems to be an evolution to a limit cycle in only a few repeats. Plots of the data with this function fitted are shown in Fig 2. Clearly there is some change occurring at the surface, most likely the sharpness of the asperities is rounded by plastic deformation as the contact "beds in".

It is expected that tangential stiffness increases with increasing normal load, this dependence is also under investigation through these methods. We will present explanations and estimates of these effects based on the data collected so far.

Conclusion

The measurement of contact stiffness is only possible with a fairly complex preparation of samples and processing of the raw data obtained. This has been achieved and results are found that match with analysis.

References

[1]   S. Medina, D. Nowell, D. Dini: *Analytical and Numerical Models for Tangential Stiffness of Rough Elastic Contacts.* Tribology Letters, Vol:49 (2013), pp103-115

[2]   K.S. Parel, R.J.H. Paynter, D. Nowell: *Measurement of Contact Stiffness.* Post Grad Experimental Mechanics Conf. (2016) Oxford