THE EFFECT OF ROUGHNESS ON TRACTION BETWEEN CONTACTING BODIES

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ABSTRACT
We develop a model, based on a perturbation of the Lennard-Jones law, to estimate the effect of surface roughness on the relation between mean gap and mean traction.

INTRODUCTION
The traction-gap relation between two parallel plane surfaces is often characterized by the Lennard-Jones [LJ] law. However, if the surfaces are rough, the mean traction-mean gap relation is modified, generally resulting in a reduction in the pull-off traction and in the effective interface energy.

In a previous paper [1], we addressed this question by tracking the evolution of the probability density function [PDF] for the gap as roughness is added incrementally from coarse to fine scale. This is a modified version of Persson's model [2] in that the LJ law is used instead of classical non-adhesive contact mechanics. We found that the gap PDF converged at large wavenumbers, in contrast to non-adhesive contact theories, which typically require arbitrary truncation of the roughness spectrum [PSD].

This method can only be applied to fine-scale roughness, since long wavelength sinusoids exhibit a contact instability associated with the maximum negative slope of the LJ law. Here we develop a method which can circumvent this difficulty.

METHOD
In [1] we suggested that the fine scale roughness could be characterized by a modified [reduced] interface energy, which could then be used in a JKR formulation of the remaining [macroscopic] contact features. However, if instead we use the method to determine the entire modified traction law, we can then use this to replace the LJ law in determining the effect of the next lower tranche of the PSD. Since the maximum negative slope of the modified law is lower than that of the LJ law, this permits the method to be extended to longer wavelength features of the roughness. This approach can then be applied iteratively to describe the effect of an extended roughness spectrum.

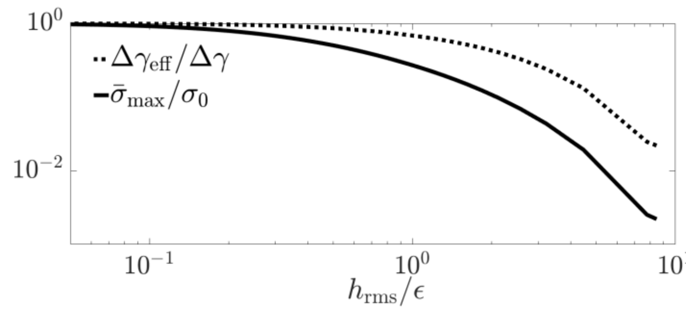

Fig. 1 Effect of surface roughness on $\bar{\sigma}_{max}$ and $\Delta\gamma_{eff}$, both normalized by the corresponding LJ values for a smooth plane surface.

RESULTS AND DISCUSSION
We define the dimensionless PSD as $\tilde{P}_S(\tilde{q})=P_S(q)/(\varepsilon\chi)^2$, where $\tilde{q}=\chi q$, $\chi=3\varepsilon^2E^*q/16\Delta\gamma$, ε is the equilibrium spacing in the Lennard-Jones law and E^* is the composite elastic contact modulus. Figure 1 shows the mean pull-off traction $\bar{\sigma}_{max}$ and effective interface energy $\Delta\gamma_{eff}$ for a surface PSD $\tilde{P}_S(\tilde{q})=0.0122\tilde{q}^{-3.6}$, $\tilde{q}_1 < \tilde{q} < 0.736$. The lower cut-off $\tilde{q}_1$ was varied resulting in a corresponding change in the RMS roughness h_{rms}. The results show that $\bar{\sigma}_{max}$ falls more rapidly than does $\Delta\gamma_{eff}$ as the roughness amplitude increases.

Although the new method extends the range of permissible wavenumbers $\tilde{q}$, instability is still predicted at very low $\tilde{q}$. However, in this [long wavelength] range it will generally be appropriate to describe the macroscopic geometry explicitly and use the JKR formalism with the appropriate value of $\Delta\gamma_{eff}$.

CONCLUSION
By applying the method of [1] iteratively, we are able to circumvent difficulties over elastic instabilities and hence predict the effect of broad spectrum roughness on mean adhesive tractions. The results show that pull-off tractions and effective interface energy correlate quite well with the RMS surface roughness.

REFERENCES
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