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MODELING OF ABRASIVE WEAR AS MULTISCALE COHESIVE FRACTURE

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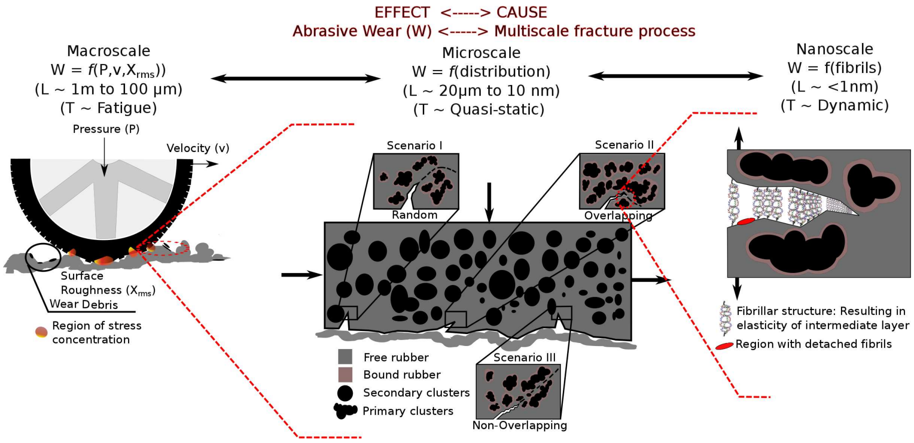
The prolific work of John F Archard (in 1953) on abrasive wear, based on theories much ahead of his time like single asperity contact mechanics, resulted in Archard Wear Law [1]. The subsequent decades have seen a rapid growth in literature aimed at understanding abrasive wear but, to this day, this has largely remained an empirical art. The 1950-60s saw development of wear laws/equations based on experiments relating weight loss to macroscopic parameters through one or more constants of proportionality (called wear constant(s)) [2]. With an increased interest in contact mechanics, the 1970-80s saw evolution of simple relationships considering topography of contacting surfaces. However their dependence was limited to simple material properties like Youngs modulus or Hardness. The compulsion to include material failure to model abrasive wear led to complex equations in the 1990s relating abrasive wear to fracture/ fatigue properties [3]. With growth of computational power, several authors in the recent decade have considered this as an inverse problem aimed to optimize contacting surfaces for minimal wear [5].

A review by Meng & Ludema [4] in 1995, surveyed the literature and revealed that there were about 182 equations of wear using over 100 different variables and constants. Most of these constants (like area of molecular contact/fatigue life of asperity etc) are not by themselves readily measurable. Thus, in spite of all the development, the usage of Archard wear law (or modified form) to relate loss of material to *adhoc* macroscopic parameters has remained. These equations neither consider the inherent microstructure nor the interaction across the length & time scales. These capture the abrasive wear behavior relatively well in laboratory conditions but severely fall short in providing a scientific explanation for the origin and cause of wear processes in real-life conditions.

This work is motivated to understand abrasive wear as a multiphysics problem of fracture, surface physics, material modeling etc. Here, we consider cohesive cracks (due to contact stresses) resulting in material separation across lower length (and faster time) scales

Figure 1: Description of modeling of abrasive wear as multiscale 3D cohesive fracture process



(Fig.1) and thus eventually leading to appreciably noticable material loss at the macroscale (over much larger timescales). Already developed, Cohesive Zone Model (CZM) considering finite thickness and elasticity of interface [6, 7] are considered to mimic the fibrillar behavior prevalent in polymeric materials and provide for a physically realistic crack patterns. The effect of filler distribution and concentration towards assisting/impeding crack growth (and thus micro-wear) is demonstrated and shall be discussed throughly. Validation shall be provided by comparing surface morphologies of cracked surfaces in microscale due to single asperity contact with simple nanoindenter experiment results. Homogenization and upscaling of microscale to macroscale is beyond the scope of this work.

REFERENCES

[1] J. F. Archard. Contact and rubbing of flat surfaces. *J. Appl. Phys.*, Vol. **24**, 981–985, 1953.

[2] S. K. Rhee. Wear equation for polymers sliding against metal surfaces. *Wear*, Vol. **16**, 431–445, 1970.

[3] N. P. Suh. The delamination theory of wear . *Wear*, Vol. **25**, 111–124, 1973.

[4] H. C. Meng and K. C. Ludema. Wear models and predictive equations: their form and content. *Wear*, Vol. **181–183**, 443-457, 1995.

[5] I. Paczelt and Z. Mroz. On optimal contact shapes generated by wear. *Int. J. Numel. Meth. Engng.*, Vol. **63**, 1250–1287, 2005.

[6] M. Paggi and P. Wriggers. A nonlocal cohesive zone model for finite thickness interfaces Part II: FE implementation and application to polycrystalline materials. *Comput. Mat. Sci.*, Vol. **50**, 1634–1643, 2011.

[7] A. B. Harish and P. Wriggers. Computational Implementation of Finite Thickness Non-Local Cohesive Zone Element for Crack Propagation in Filled Elastomers. *5th GACM Colloquium on Computational Mechanics*, Hamburg (Germany), 2013.