ABSTRACT

This thesis investigates the effects of counter surface topography on wear of engineering polymers. Both theoretical and experimental approaches are taken up to address the main objectives of the thesis. A semi-analytical wear model has been developed for polymers rubbing against metal counter surfaces. The model is based on so called mechanistic processes comprising both low cycle fatigue and abrasive wear mechanisms which are prominent in polymer–metal sliding interfaces. Repeated elastic contact causes localized fatigue to form wear particles; whereas abrasive wear is an outcome of plastic deformation of soft polymer surface by hard metal asperities. Further, wear involves creation of new surfaces; this leads to consideration of surface force interaction in the formulation of mechanistic wear mechanisms. Thereby, asperity based elastic-plastic-adhesive contact theories with necessary modifications were analyzed to assess load–separation characteristics for their subsequent use in elementary wear correlations. Both Gaussian and Weibull distributions of asperity heights were considered to incorporate statistics of surface micro-geometry. Shape parameters of Weibull distribution were estimated from both skewness and kurtosis values of asperity heights according to a customized methodology, and a new categorization of the non-Gaussian surfaces was proposed. Preliminary study has revealed that skewness and kurtosis of hard steel counter surface substantially influence wear of soft polymers. Finally, volumetric wear was expressed in terms of surface topography parameters, material properties, and sliding distance.

A systematic methodology, based on spectral analysis, was developed for multi-scale characterization of the disc surface topography to reveal a panoramic structure of micro-geometric features of engineering surfaces. This is of practical importance in order to understand length scale effects in real contact problems. Surfaces from variety of processes were examined to validate this method. Mainly optical profilometry has been used to collect roughness data at five different cut-off bandwidths according to a prescribed standard; and then analyzed to plot auto-correlation and power spectral density functions. Nature of power spectrum has been analyzed, and the discussion extended to the estimation of fractal characteristics based on specific spectral information. Higher moments of power spectrum were extensively used to estimate topography parameters of geometric significance such as asperity curvature, asperity density, etc. Experimentally evaluated topography parameters using this approach hold the well established theory of surface roughness as random process. This methodology has been found to be readily applicable for high resolution profilometry techniques using atomic force microscope. A few cases were studied with the help of AFM. Overall analysis showed that the intrinsic bandwidth parameter as per Nayak's definition is closely to be a value of 2 for all cases. Additionally, an idea of defining *band width limited fractal characteristics* has been introduced while characterizing surfaces as an equivalent to fractal processes.

Experimental validation of wear prediction was conducted extensively with the help of pin-on-disc set-up using PEEK pins and 316L stainless steel discs. Tests were conducted in air-conditioned room ambience as well as in vacuum (25-10 mPa) ambience. Counter surface discs with different topographical characteristics were prepared by polishing, emery-processing, turning, milling, and grit-blasting. Experimental wear agreed well with the predictions for many cases with some notable exceptions. Overall, predictions were likely to fall short in some cases such as anisotropic surface topography, presence of thick wear debris, and under the influence of vacuum ambience. Further, fatigue to abrasive wear ratio was identified as a useful analytical tool to predict dominant wear mechanism for polymer-metal tribo-systems. In this context, the ratio of asperity heights standard deviation to average asperity radius was found to be instrumental to determine both wear severity and governing wear mechanisms. After examining the considered cases, it was both interesting and physically intuitive to observe a complete changeover in wear mechanisms following simply an alteration of roughness characteristics.