Wear Resistant PTFE Composites via Nano-scale Filler Particles

by

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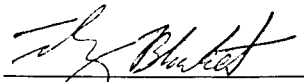

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ABSTRACT

Polytetrafluoroethylene, attractive for its low friction properties, is often used as a self-lubricating material in dry sliding contact applications. However, these low friction properties are countered by a high (10^{-3} mm^3/N-m) wear rate. The addition of hard micro-scale fillers has proven the ability to decrease this wear rate by multiple orders of magnitude, with conventional thinking indicating that this increased wear resistance is due to the ability of the micro-scale fillers to arrest subsurface crack propagation that would otherwise lead to the formation of plate-like debris particles of several microns thickness. This thinking would indicate that nano-scale fillers should not be effective as fillers, but would rather be swept away encapsulated within wear debris particles.

This study details the use of nano-scale alumina as an improved wear reducing filler material in PTFE over micro-scale alumina. Tests were performed on unfilled PTFE as well as composites with 5% alumina by weight at filler sizes of 40nm, 80nm, 0.5μm, 1μm, 2μm and 20μm, with an unfilled PTFE wear rate of $0.68*10^{-3}$ mm^3/N-m, wear rates in the nano-scale filled composites ranging from 0.75 to $1.70*10^{-7}$ mm^3/N-m and in the micro-scale composites from 0.42 to $1.38*10^{-5}$ mm^3/N-m. Friction coefficients for all tests were in the range of 0.16-0.23, standard for PTFE composites in sliding contact at ~0.1 m/s. Analysis indicates that the increased effectiveness of the nano-fillers may be due to a phase change to a tougher, more wear resistant phase in the PTFE, more fully induced by increased interfacial area between the alumina fillers and PTFE matrix at a constant 5% filler weight. Testing on composites with mixed 40nm and 20μm alumina fillers showed that the micro-scale alumina introduces a wear increasing mechanism not present in nano-filled composites, as these composites wore at rates in the range of 10^{-5} mm^3/N-m. This mechanism is possibly increased abrasive wear over nano-scale fillers, as the larger particles tend to accumulate on the wear surface and abrade away the otherwise adherent wear-reducing transfer films to a greater extent.

The use of alumina as a filler in Fluorinated Ethylene Propylene, a melt mixable fluoropolymer, is also studied, showing the potential for reduction in wear rates, with wear rate as low as $\sim 3*10^{-6}$ mm^3/N-m in a 40nm composite filled to 5% by weight. The use of functionalized alumina is also detailed, with the potential for increased wear resistance even at low filler fractions.