Tough Turbines: Exploring the Physical Properties of Epoxy Coatings With Graphene Nanoplatelets and Silicon Carbide for Hydropower Systems in Untapped Flows

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Mini hydropower is rarely used in wastewater treatment because of expensive yet critical thermal blade coatings and maintenance in grit-filled, turbulent flows. This project tested whether cold-cure epoxy reinforced with graphene nanoplatelets (GNP) or silicon carbide (SiC) could improve hardness, adhesion, and erosion resistance for stainless steel turbine components. Four coatings were mixed: epoxy control, epoxy + 1% GNP, epoxy + 7.5% SiC, and a GNP/SiC hybrid. Properties were measured by mass loss in an erosive rotary tumbler for 3 days, pencil hardness (ASTM D3363), and crosshatch adhesion (ASTM D3359). Using measured angular velocity of the tumbler, particle Reynolds number was calculated as $134<Re<355$, revealing transitional, non-laminar flow consistent with inertial particle conditions in calculated Bay Area wastewater flows. Tumbling showed significant mass differences among coatings (ANOVA $p=0.013$, ?^{2}=0.60). GNP preserved mass about 6x better than the control (0.15% vs. 0.97% loss). GNP and C had thickness loss rates of approximately 12 μm/d and 84 μm/d in accelerated conditions, with a Froude number of 1.43. Bootstrap resampling (10,000 iterations, C++) confirmed repeatability of mean mass loss differences. SiC-containing coatings had the highest hardness (Kruskal–Wallis $H=16.125$, $p=0.001$). However, because GNP eroded less despite its lower hardness, stress distribution may matter more than hardness alone. Adhesion was slightly higher for SiC, but not statistically significant (ANOVA $p=0.32$). Combined fillers may not have an advantage due to inhomogeneity. Composite score models favored single additive coatings. GNP epoxy showed the strongest potential to extend turbine lifespan and improve wastewater hydropower viability.

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