Ultrahigh-Strain-Rate Tribological Nonlinearity and Adhesion Behavior of Copolymer Powders for Cold Spray

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While ductile metals have long been used in cold spray, polymers have become emerging cold-sprayable materials due to their versatile functionalities. However, polymer-related cold spray studies have focused on polymers' metallization and deposition enhancement under ultrahigh-strain-rate (UHSR) collision conditions. Furthermore, the UHSR behaviors originating from their macromolecules have not been explored sufficiently. The typical compression-dominant UHSR experiments with a perpendicular incidence angle have provided limited knowledge of interfacial responses between a feedstock powder and a substrate resulting from the collision-induced shear flow during impact. Specifically, the impact-induced tribological nonlinearity at the collision interface is essential in determining adhesion, as polymers have inherent complexities resulting from the low phase transition temperatures and rate-dependent macromolecule dynamics. The up-to-date experimental method using the angled laser-induced projectile impact test (θ-LIPIT) with an off-normal incidence angle is conducted to comprehensively understand the dynamic interfacial responses at the UHSR regime.

Polystyrene and polystyrene-polydimethylsiloxane deblock-copolymers microparticles are produced by ultrasonic spraying of polymer solutions. The microparticles are investigated through the θ-LIPIT with a 45-degree incidence angle. The spectra of rebound velocity and coefficient of restitution reveal that the collision-induced thermal softening of the glassy-domain in their microphase-separated morphologies governs their tribological nonlinearity. The rheological changes strongly influence the interfacial adhesion and instability by amplifying the ductility. Moreover, the rheological transition of the polymers is quantitatively understood by a semi-empirical friction model depending on the adhesion and viscosity effects. These nonlinear tribological responses explain the adhesion mechanism of polymers under the UHSR collision with the perpendicular incidence angle.

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