Title: Controlling Wettability of Materials via Surface Plastic Deformation through Friction-Based Post-Processing

Background: Wettability significantly impacts cleaning and anti-icing properties of aerospace components. Traditional methods like chemical coatings or etching often fail to balance surface strengthening with wettability control. Peening techniques, such as mechanical shot peening (MSP) and laser shock peening without coating (LSPwC), offer dual benefits by inducing surface plastic deformation and modifying roughness, but their effects on wettability and roughness measurement standardization remain underexplored.

Objective: This study investigates how MSP and LSPwC alter surface roughness and wettability of titanium alloys (Ti60, TC11), establishes sampling criteria for roughness measurement, and explores mechanisms linking surface morphology to hydrophobicity.

Key Results:

- Surface Strengthening and Roughness: Both MSP and LSPwC introduced residual compressive stress and grain refinement. LSPwC produced periodic micro/nanostructures (e.g., ~200 μm pits) with higher roughness (Sa/Ra) than MSP. Roughness increased with laser energy in LSPwC, while MSP surfaces showed irregular, lower roughness.
- Wettability Modification: Peening enhanced hydrophobicity. LSPwC-treated samples achieved higher contact angles (up to 109.2° for TC11) than MSP-treated ones (93.5°). TC11 exhibited greater hydrophobicity than Ti60. Aging (50–100 days) further increased contact angles due to organic adsorption on rough surfaces.
- Mechanistic Insights: MSP followed the Wenzel model (roughness amplifies intrinsic wettability), while LSPwC aligned with the Cassie-Baxter model (air pockets reduce solid-liquid contact). Micro/nanoscale roughness dominated hydrophobicity, while waviness had minimal impact.
- Sampling Range Impact: Accurate roughness measurement required sampling within 0.5–1.5 cycles of surface features. Overly small or large ranges distorted results by ignoring micro-roughness or incorporating waviness.

Significance: This work demonstrates that peening processes, particularly LSPwC, enable tunable wettability and surface strengthening for aerospace alloys. By linking roughness parameters to wetting behavior and establishing standardized sampling protocols, it provides a framework for designing materials with tailored hydrophobicity and durability. The findings highlight the potential of LSPwC for creating anti-icing surfaces and stress the importance of controlled aging and roughness characterization in functional surface engineering. This study advances the development of multifunctional aerospace components combining mechanical robustness and environmental resistance.