Machine learning based mechanical characterization of rough metallic surfaces

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Application of instrumented indentation testing (IIT) on industrial metallic structures can be limited due to the presence of significant surface roughness Ra. This requires further research on analyzing the influence of surface roughness on indentation techniques. This study aims at developing a machine learning (ML) based dual flat-spherical indentation (DFSI) approach to substantially reduce the effect of surface roughness on the indentation-based material characterization. We also demonstrated that almost identical load-depth curves can be obtained via DFSI even under significant residual stress (RS). Finite element (FE) models with an arbitrary rough surface topography are created to perform DFSI simulations, in which the rough metallic surface is flattened by flat indentation and then spherical indentation is performed on the flattened surface. Load-depth responses of different rough surfaces are investigated for various combinations of metallic properties. A database of load-depth curves is generated via systematic FE simulations. Machine learning models are developed, and then trained by using the database for mechanical property evaluation (yield strength, strain hardening exponent, elastic modulus) from the dual indentation load-depth curves. The sensitivity of trained ML models is assessed for random indentation parameters and rough surface profiles. The proposed ML-based dual indentation techniques can be integrated with industrial robots to perform automated in-situ and ex-situ material characterization at various stages of manufacturing and structural integrity monitoring.