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Editorial Corner

Surface Quality and Surface Integrity Aspects in Additive Manufacturing

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The advancement of additive manufacturing (AM) has greatly benefited industries and society, particularly in the design and production of complex geometries. AM offers industries the flexibility to print parts tailored to specific needs and applications. However, the challenge of poor surface properties, particularly surface quality (SQ) and surface integrity (SI), remains a significant concern. Surface quality is primarily evident on the exterior of the manufactured part, including aspects such as surface texture, roughness, lays, laps, tears, pits, and other geometric deviations [1]. In contrast, surface integrity pertains to the material's subsurface, typically 0.1-0.5 mm below the surface, encompassing microstructural changes, intergranular variations, heat-affected zones, microcracks, hardness alterations, residual stresses, and material inhomogeneities. For engineering applications where fatigue failure is critical, the demand for precision manufacturing—characterized by excellent SQ and SI—is high, as most failures stem from deficiencies in these areas. Among the various parameters of SQ and SI, roughness, residual stress (particularly compressive), microstructure, and microhardness are crucial in determining the service life of both AM and conventionally manufactured components. Controlling SI adds extra cost to manufacturing; hence, it is essential when producing highly stressed parts used in applications where human safety, high costs, and predictable component life are of primary concern. Surface integrity plays a key role in describing and managing potential alterations within the surface layer of any engineered part during manufacturing, influencing material properties and the performance of the finished product [2]. SI offers a comprehensive assessment of the engineering characteristics of a surface and its ability to perform its intended functions. Typically, SI complements SQ—covering dimensions, tolerances, and surface texture—as a critical specification for highly engineered components, ensuring they meet modern standards for safety, reliability, and life cycle cost efficiency. Integrating SI into manufactured components enhances service life, reduces maintenance costs, minimizes manufacturing scrap, and improves control over the production process by understanding how process parameters affect SI. Recognizing the impact of SI on component service life also leads to better production quality control by analysing process limits, thereby providing clearer producibility definitions for the part.

All the available manufacturing processes significantly impact the material and properties of a workpiece, though most available data pertain to traditional and non-traditional material removal processes. In the context of newly developed additive manufacturing (AM) processes, literature shows that the surface quality of additively manufactured parts often requires extensive post-processing due to poor roughness, burrs, and visible pits. From a surface integrity (SI) perspective, AM processes typically fail to impart compressive residual stress because of their layer-by-layer deposition method. Consequently, several post-processing operations, such as hardening, deburring, finishing, and peening (either shot or laser), are necessary to enhance both SQ and SI to meet industry and application standards [3].

Subsurface characteristics can vary across different layers or zones of a part, with changes primarily resulting from alterations in the mechanical, metallurgical, electrical, chemical, and thermal properties during manufacturing or processing. These alterations depend on the type of energy used to produce or machine the part or component. Mechanical defects may include plastic deformations, tears, laps, hardness changes, cracks (both macro and micro), redistribution of residual stress over the surface layer, voids, pits, inclusions, burrs, and the inclusion of foreign material on the surface layer. Metallurgical changes may involve phase transformations,

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variations in grain size and grain boundary distribution, twinning, recrystallization, untampered martensite (UTM) or over-tempered martensite (OTM), austenitic reversion, and the inclusion of foreign materials.

Alterations due to electrical factors primarily affect a material's conductivity, resistivity, and magnetic properties due to the passage of current or voltage. Chemical changes are often critical as they fundamentally define material properties, including intergranular attack (IGA), intergranular corrosion (IGC), intergranular oxidation (IGO), preferential dissolution of micro constituents, embrittlement by chemical absorption (e.g., hydrogen and chlorine), stress corrosion, and the formation of pits and etchings. Thermal changes in the manufactured part can be assessed by examining heat-affected zones (HAZ), recast or redeposited layers, splattered particles, or remelted material on the surface.

Post-processing is a crucial component of manufacturing engineering since there isn't a manufacturing or machining technique, no matter how sophisticated, that can produce a part entirely defect-free. Concrete post-processing techniques that may concurrently address the issues of Surface Integrity and Surface Quality are therefore desperately needed. By effectively improving both surface and subsurface qualities, such techniques would expedite the manufacturing process and, in the end, guarantee that components satisfy exacting application and industry requirements.

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