

Sustainable Manufacturing through the Integration of Additive and Subtractive Processes

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Abstract: *Sustainable manufacturing has emerged as a critical objective in modern industrial systems due to increasing concerns regarding resource depletion, environmental degradation, and energy consumption. Manufacturing industries are under pressure to reduce waste generation, improve material utilization, minimize carbon emissions, and enhance product quality while maintaining economic competitiveness. Additive Manufacturing and Subtractive Manufacturing represent two fundamental manufacturing paradigms with distinct advantages and limitations. While additive manufacturing offers material efficiency and design flexibility, subtractive manufacturing provides superior dimensional accuracy and surface finish. Recently, the integration of additive and subtractive processes into hybrid manufacturing systems has gained significant attention as a sustainable production strategy.*

Hybrid manufacturing combines the advantages of both approaches to reduce material waste, improve productivity, lower energy consumption, and enhance product performance. This review paper examines the principles, technologies, sustainability benefits, challenges, and future prospects of integrated additive-subtractive manufacturing systems. The study highlights how hybrid manufacturing contributes to sustainable development by promoting resource efficiency, circular economy practices, and environmentally responsible production.

Keywords: Subtractive Manufacturing, Hybrid Manufacturing, Industry 4.0, Energy Efficiency, Circular Economy, Green Manufacturing