Decision Support Framework for Circular Additive Manufacturing: Stamping Die Production and Repair

Tugba Danaci*[1], Sayyed Shoaib-Ul-Hasan[1], Indraneel Kulkarni[1], Nawra Widodo[1], Amir Rashid[1]

[1] Department of Production Engineering, KTH Royal Institute of Technology,
Brinellvägen 68, Stockholm SE-11428, Sweden

*Corresponding author email: tugbad@kth.se , Ph: +46 34607258

Primary Topic: Building a Circular Economy for Products and Materials
Secondary topic: Systems Analysis - Techno-economic Analysis, Material Flow Analysis, & Life-cycle Analysis

Abstract: Additive Manufacturing (AM) holds significant potential for sustainability and circularity. Its near-net-shape production reduces material waste, enables the manufacturing of complex geometries, and extends product life through repair and remanufacturing. These capabilities make AM a key enabler of circular economy strategies such as reuse, repair, and remanufacture. However, current Life Cycle Assessment (LCA) methodologies are not fully adequate to capture AM's circular contributions. Most LCA models are designed for linear production systems and fail to incorporate AM-specific parameters such as powder reuse, repair frequency, and support structure recovery. Furthermore, data gaps in widely used databases limit the generalizability and reliability of LCA results, making it difficult to integrate AM into sustainability-driven decision-making frameworks in industry.

In this study, an industrial stamping die was evaluated by comparing conventional casting-based manufacturing with AM-based production and repair using Direct Metal Laser Sintering (DMLS) and Directed Energy Deposition (DED). The environmental impacts were modelled in SimaPro using ReCiPe Midpoint impact categories, and sensitivity analyses were conducted on critical parameters such as powder reuse rate, repair frequency, and transport distance. The results demonstrated that, compared with casting, AM significantly reduces material consumption and waste while extending die life and lowering the need for new die production.

Through this comparative assessment, the study provides a data-driven approach for monitoring circularity in real time and presents a decision-support framework that can be adopted by manufacturers to optimize repair strategies and material recovery in industrial tooling systems.