Abstract

In response to the growing demand for sustainable and efficient manufacturing of complex metallic parts, this thesis presents a comprehensive study on the design, characterization, and environmental evaluation of a sustainable feedstock formulation for titanium-based additive manufacturing using the Pellet Additive Manufacturing (PAM) process. Driven by the need for more environmentally responsible and technically versatile fabrication methods for complex metallic components, this research investigates PAM as a promising alternative to conventional techniques such as Metal Injection Molding (MIM).

An initial qualitative assessment of energy consumption was conducted to compare PAM with MIM. Due to limited data availability, software-based modeling was not feasible. The study highlights PAM's advantages in terms of material efficiency, reduced tooling requirements, lower scrap rates, and suitability for small-batch or customized production. These sustainability drivers served as a strategic foundation for feedstock development.

A thorough literature review was conducted to identify the limitations of existing binder systems and the critical rheological and thermal requirements for feedstocks in metal AM. Based on this, a novel hybrid binder system was formulated, combining polyethylene glycol (PEG) and polyvinyl butyral (PVB) as the primary matrix, with methylcellulose (MC) and stearic acid (SA) as rheological and stabilizing additives. Several formulations were prepared with Ti6Al4V powder, varying MC and SA contents. Rheological tests revealed that the formulation with 3 vol.% MC and 3 vol.% SA achieved an optimal balance of shear-thinning behavior, structural consistency, and printability, without the instability observed at higher MC concentrations.

Thermogravimetric analysis confirmed the compatibility of the binder components and the feasibility of staged thermal debinding. Morphological and flow assessments indicated a well-homogenized system with minimal phase separation. Experimental printing trials demonstrated that the formulation with 3 vol.% MC and 3 vol.% SA outperforms commercial feedstocks in visual quality, dimensional accuracy, and ease of parameter tuning.

Beyond its technical contributions, this thesis adopts an integrated approach that aligns materials engineering with environmental responsibility. By incorporating energy and material efficiency considerations into the early design stages and validating performance through rigorous experimentation, this work contributes to the advancement of greener, high-performance feedstocks for emerging metal AM technologies like PAM.

The originality of this research lies in its dual focus—technological innovation and environmental responsibility—offering a holistic perspective on PAM's viability as a

sustainable solution for manufacturing complex titanium components. The outcomes are expected to support industrial adoption, inform future eco-design strategies, and inspire continued innovation in hybrid additive-subtractive manufacturing platforms.