Mechanical Engineering Thesis Defense

Polymer/Coal composites from Ink-based Additive Manufacturing

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Abstract

For the past two centuries, coal has played a vital role as the primary carbon source, fueling industries and enabling the production of essential carbon-rich materials, including carbon nanotubes, graphite, and diamond. However, the global transition towards sustainable energy production has resulted in a decline in coal usage for energy purposes, with the United States alone witnessing a substantial 50% reduction over the past decade. This shift aligns with the UN's 2030 sustainability goals, which emphasize the reduction of greenhouse gas emissions and the promotion of cleaner energy sources. Despite the decreased use in energy production, the abundance of coal has sparked interest in exploring its potential for other sustainable and valuable applications.

In this context, Direct Ink Writing (DIW) has emerged as a promising additive manufacturing technique that employs liquid or gel-like resins to construct three-dimensional structures. DIW offers a unique advantage by allowing the incorporation of particulate reinforcements, which enhance the properties and functionalities of the materials. This study focuses on evaluating the viability of coal as a sustainable and cost-effective substitute for other carbon-based reinforcements, such as graphite or carbon nanotubes. The research utilizes a thermosetting resin based on phenol-formaldehyde (commercially known as Bakelite) as the matrix, while pulverized coal (250 μm) and carbon black (CB) act as the reinforcements. The DIW ink is meticulously formulated to exhibit shear-thinning behavior, facilitating uniform and continuous printing of structures. Mechanical property testing of the printed structures was conducted following ASTM standards. Interestingly, the study reveals that incorporating a 2 wt% concentration of coal in the resin yields the most significant improvements in tensile modulus and flexural strength, with enhancements of 35% and 12.5% respectively. These findings underscore the promising potential of coal as a sustainable and environmentally friendly reinforcement material in additive manufacturing applications. By harnessing the unique properties of coal, this research opens new avenues for its utilization in the pursuit of greener and more efficient manufacturing processes.

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