Data-driven Magnetic Hysteresis Design Powered by Multiphysics-Multiscale Simulations

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Despite this progress, significant challenges remain—particularly related to the inhomogeneous morphology and complex thermal-mechanical and magnetic hysteresis behaviors observed in additively manufactured magnets. These issues arise from complex, interdependent physical phenomena that occur across broad temporal and spatial scales [1,2]. A deep understanding of how these behaviors is influenced by processing parameters and conditions [3, 4] is crucial for the reliable production of AM magnets.

In this study, we developed a powder-resolved, multiphysics-multiscale simulation framework to enable data-driven exploration of the processing-property relationship for hysteresis tailoring in additive manufacturing. The framework explicitly incorporates key physical phenomena—such as coupled thermal-structural evolution, chemical order-disorder transitions, and related thermo-elasto-plastic responses—while addressing the inherent differences in spatial and temporal scales. Particular emphasis was placed on analyzing the hierarchical influence of processing parameters, especially beam power and scan speed. These were investigated across multiple scales, including their effects on fusion zone geometry, residual stress development, plastic strain accumulation, and the resulting coercivity in the fabricated components.

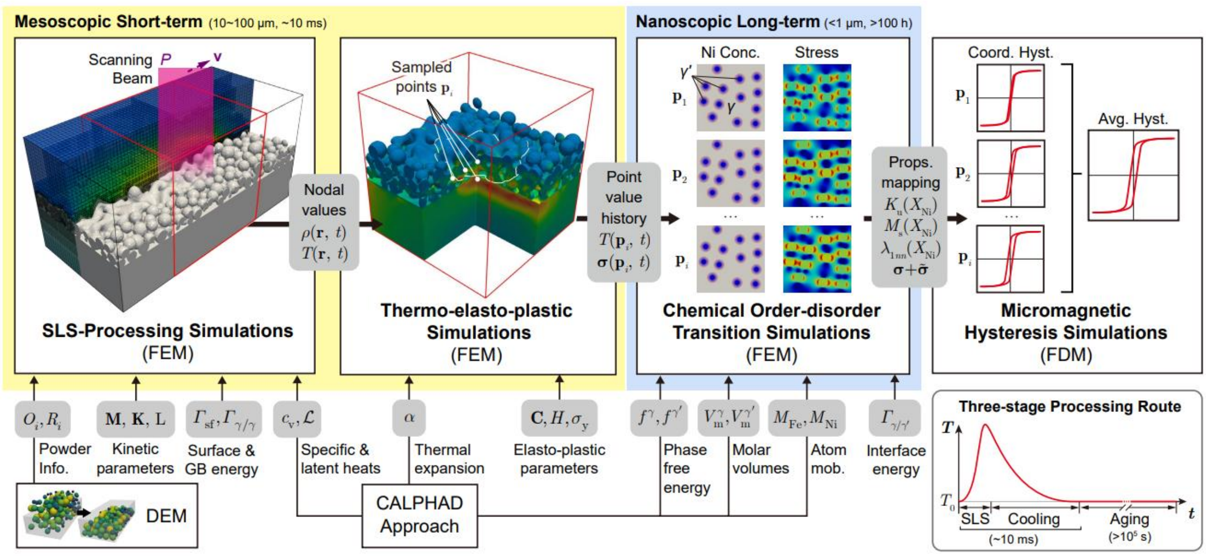

Figure 1. Multiphyscis-multiscale simulations scheme proposed in this work. Workflow and data interaction among methods are also illustrated schematically.

References

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