Normalised model-based processing diagrams for additive manufacturing of soft magnetic materials

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Introduction

- Laser beam melting (LBM) is an additive manufacturing technique that uses a laser beam to melt powdered materials to produce metal parts.
- Benefits : LBM excels at producing parts with desired magnetic properties, especially in the area of soft magnetic materials such as high silicon steel.
- Goal : Create a concise chart integrating normalized energy density and provide a comprehensive overview of materials and parameters from multiple research articles.

Normalised process parameters and normalised energy density

Normalised process parameters : A global expression of normalized energy, as defined by Thomas, consists of four dimensionless quantities:

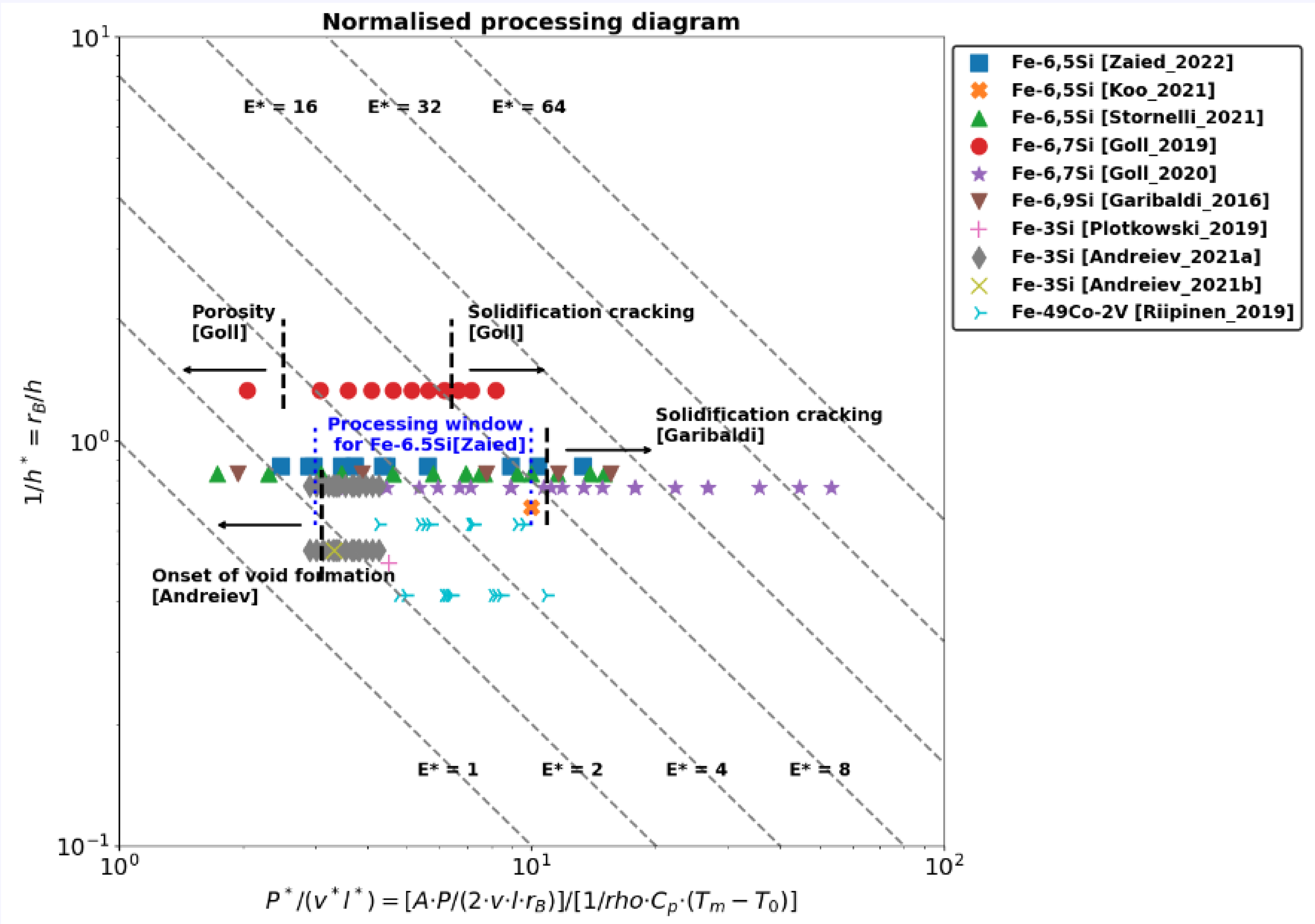
- Dimensionless laser power ($P^* = \frac{AP}{r_B \lambda \Delta T}$)
- Dimensionless laser scanning speed ($v^* = \frac{v r_B}{\alpha}$)
- Dimensionless hatch distance ($h^* = \frac{h}{r_B}$)
- Dimensionless layer thickness ($l^* = \frac{2l}{r_B}$)

where A is the powder absorptivity, λ is the thermal conductivity, ΔT is the temperature difference between the melting point temperature and the temperature of the base plate, $\alpha = \frac{\lambda}{\rho c_p}$ is the thermal diffusivity, ρ is the material density, and c_p is the material heat capacity.

Normalised energy density equation:

$$E_0^* = \frac{P^*}{v^* h^* l^*} = (\frac{P}{2vhl})(\frac{A}{2\rho c_p \Delta T})$$

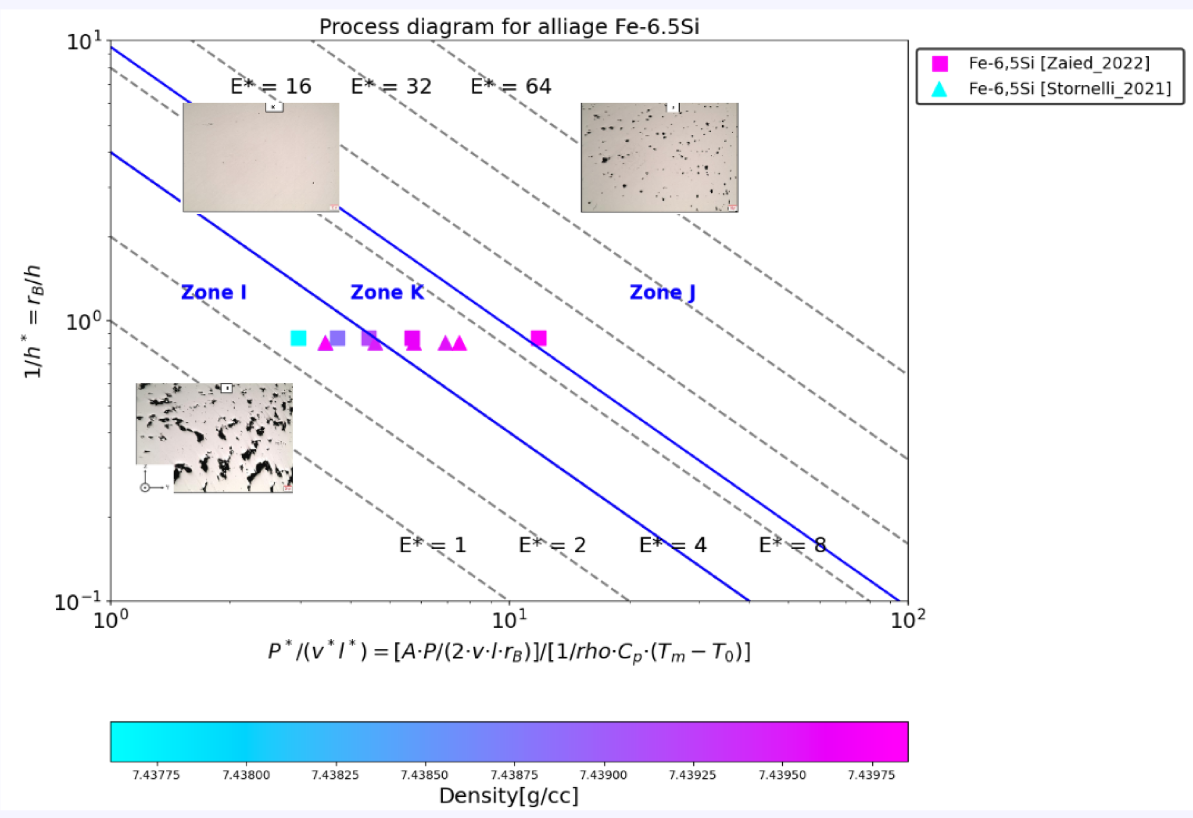
The dimensionless parameter E_0^* is he average laser energy applied to the powder bed per volume of material and corresponds to the dashed lines in the diagram.

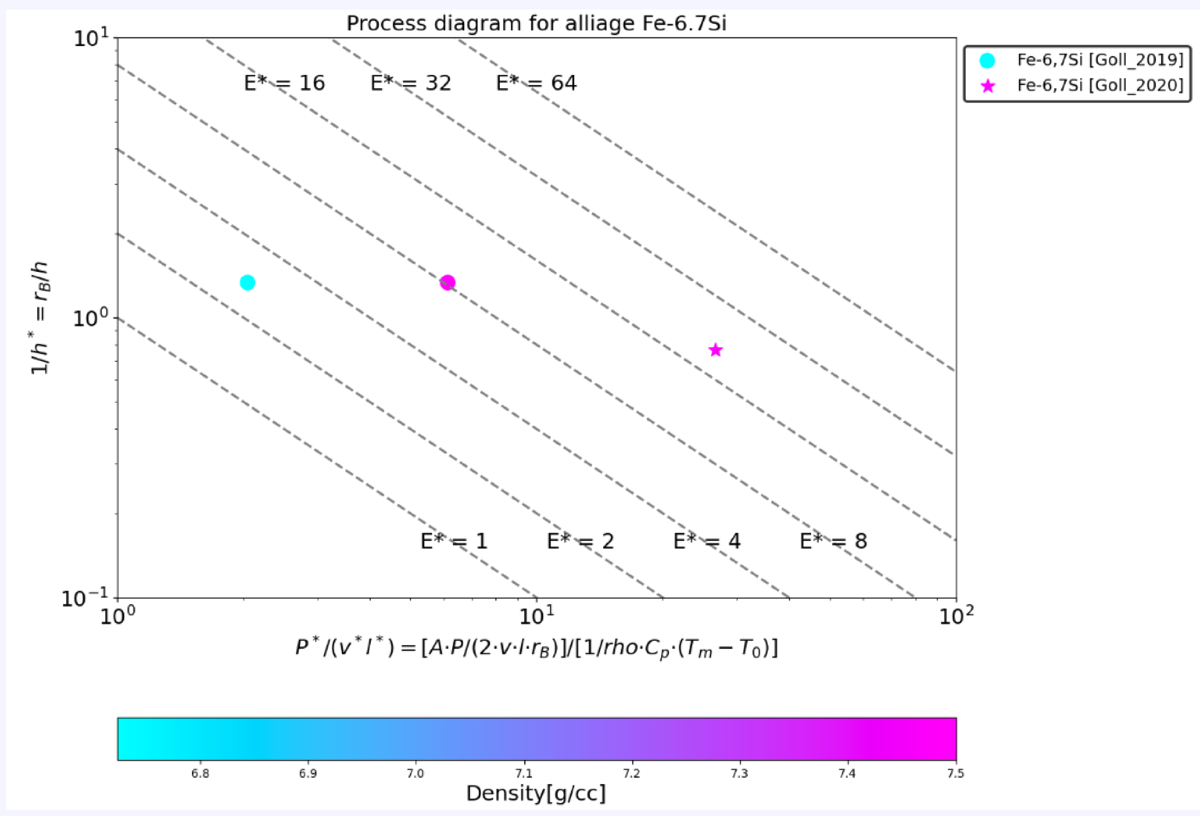


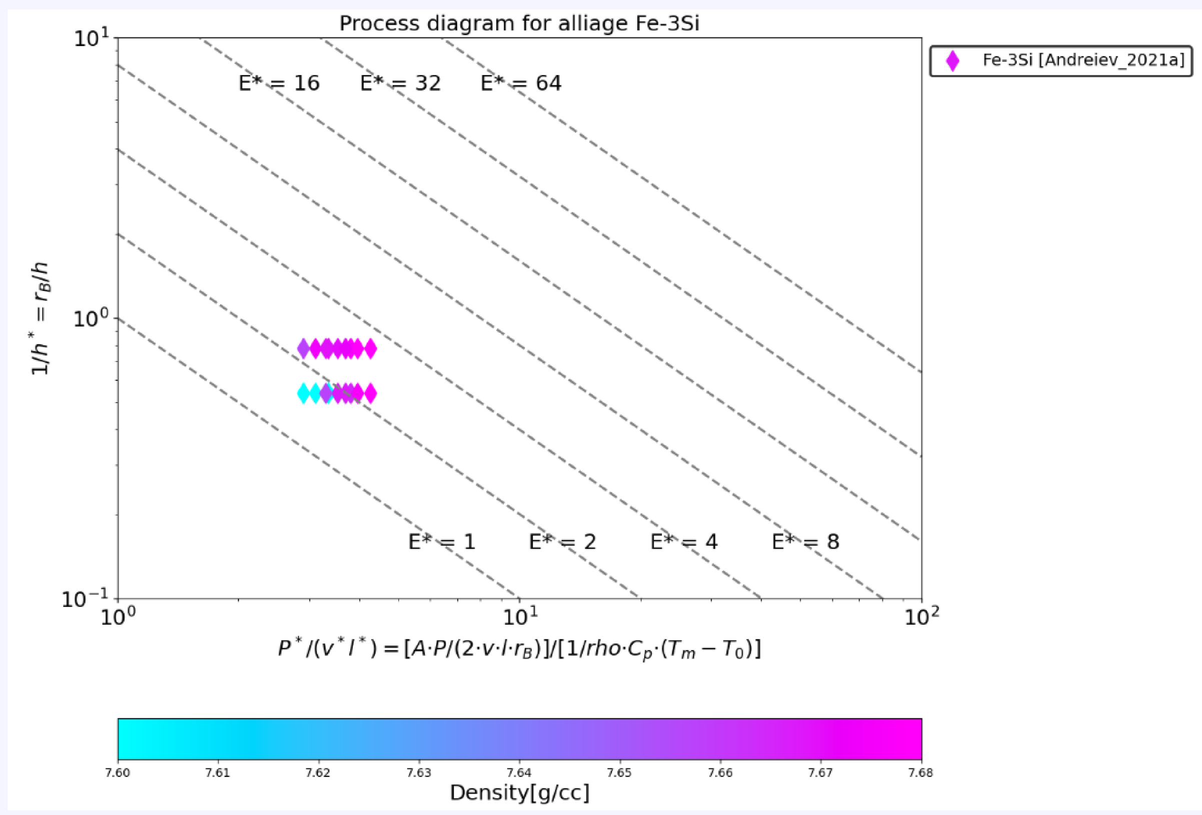
Evaluation of Density and Porosity

By incorporating density into the normalized processing diagram, a clear correlation can be established between the energy input delivered by the laser and the resulting density of the component. The diagram is structured into three distinct regions based on the density of the components:

- **Region I** corresponds to incomplete melting of the powder due to insufficient energy input, with large irregularly shaped porosity in the components.
- **Region J** corresponds to a high residual stress in the fully melted layer due to high energy input, with many visible cracks and spherical porosities.
- **Region K** corresponds to a completely dense component with a low defect rate.







Conclusion

- The summarized normalized processing diagram provides a practical framework for comparing and categorizing data on alloy materials and processing parameters from existing literature. It offers valuable information for decision-making purposes.
- These diagrams offer insights into how energy input affects the density, porosity, and crack evolution of components. They help identify suitable processing parameters in early research and development programs.

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