# Residual stresses in additively manufactured FeSi-Inconel composites using hot isostatic pressing

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This study investigates residual stresses in additively manufactured FeSi-Inconel 625 composites produced through hot isostatic pressing (HIP). X-ray diffraction analysis was used to assess residual stresses, while a finite element model (FEM) of the HIP cycle was developed to understand their formation better. The model considers key factors, including differences in thermal expansion, thermal conductivity, and plasticity limits of the materials. The findings provide valuable insights for optimising the manufacturing process of multi-material components.

*Keywords:* residual stress; modelling; composites; additive manufacturing

## 1. Introduction

The advancement of additive manufacturing in electromechanics enables the creation of complex and highly efficient components for electrical machines [1]. This includes topologically optimised stators, rotors, and windings, enhancing performance while optimising material usage and recyclability. A key challenge in 3D printing remains the fabrication of multi-material components, particularly the integration of magnetic and non-magnetic materials within a single structure. Successfully implementing this approach could revolutionise the production of rotors for high-speed synchronous reluctance machines, significantly expanding their operational speed range.

Hot isostatic pressing (HIP) is a promising technique for bonding dissimilar materials into a single component [2]. However, like other manufacturing methods, HIP introduces residual stresses due to differences in material properties and thermomechanical processing conditions. This study examines a multi-material composite comprising electrical steel with 3% silicon (FeSi) and Inconel 625, with a focus on the residual stresses generated by the HIP process and their implications for performance and structural integrity.

## 2. Results and discussion

Using HIP, several series of multi-material samples were fabricated, featuring layers of electrical steel oriented both vertically and horizontally. Residual stresses were analysed using the X-ray diffraction (XRD) technique (Figure 1) at multiple locations on the sample.

Figure 1: X-ray diffraction residual stress technique.

To gain a comprehensive understanding of residual stress formation, a finite element model (FEM) of the complete HIP cycle was developed using COMSOL Multiphysics (Figure 2).

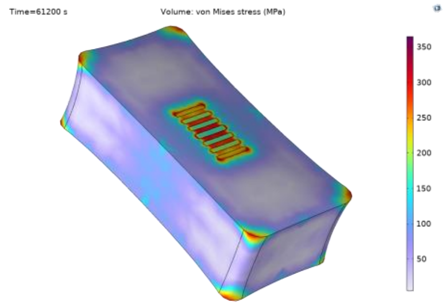


Figure 2: von Mises Stresses (in MPa) in developed HIP model.

In Inconel 625, residual stresses were experimentally measured at 310 MPa parallel to the horizontal layers and -80 MPa in the perpendicular direction. The FEM model predicted residual stresses of 260 MPa and -88 MPa in the respective directions, showing good agreement with the experimental results.

The primary sources of residual stress include differences in the coefficients of thermal expansion between materials, variations in thermal conductivity that generate additional temperature gradients, and disparities in yield strength. The latter is particularly significant, as the HIP process relies on the plastic consolidation of the powder.

## References

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