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Separation of the Formation Mechanisms of Residual Stresses in LPBF 316L

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Rapid cooling rates and steep temperature gradients are characteristic of additively manufactured parts and important factors for the residual stress (RS) formation.
This study examined the influence of heat accumulation on the distribution of RS in two prisms produced by Laser Powder Bed Fusion (LPBF) of austenitic stainless steel 316L.
The layers of the prisms were exposed using two different border fill scan strategies: one scanned from the centre to the perimeter and the other vice versa. The goal was to reveal the effect of different heat inputs on samples featuring the same solidification shrinkage. RS were characterised in one plane perpendicular to the building direction at the mid height using Neutron and Lab X-ray diffraction. Thermography data obtained during the build process were analysed to correlate cooling rates and apparent surface temperatures with the residual stress results. Optical microscopy and micro computed tomography were used to correlate defect populations with the residual stress distribution.
The two scanning strategies led to RS distributions typical for additively manufactured components: compressive stresses in the bulk and tensile stresses at the surface. However, due to the different heat accumulation, maximum RS levels differed.
We concluded that solidification shrinkage plays the major role in determining the shape of the RS distribution and the temperature gradient mechanism appears to determine the magnitude of peak RS.

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