

Deformation Behavior of Additively Manufactured AISI 316L: Experimental Compression Tests and Numerical Rolling Simulations

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Introduction

The Laser Powder Bed Fusion (L-PBF) process enables the production of metal components with complex geometries and high dimensional accuracy. However, materials produced by this method often exhibit microstructural anisotropy, residual stresses, and porosity, which significantly affect their mechanical behavior. For applications involving further plastic deformation, it is therefore essential to understand the deformation mechanisms of additively manufactured alloys. Austenitic stainless steel AISI 316L is one of the most studied L-PBF materials, yet its response to plastic deformation and subsequent forming processes remains not fully understood. Numerical simulations provide an efficient tool for predicting stress-strain behavior and optimizing processing parameters in forming operations such as rolling. The combination of experimental data and finite element simulations enables validation of material models and a deeper understanding of deformation mechanisms in additively manufactured 316L stainless steel.

Methods

L-PBF 316L samples

Commercially procured as SS 316L-0407 (RENISHAW, UK) in two conditions: HT0 (as-built) and HT2 (1050 °C / 1 h + WQ)
Density – 99,2%

Compression tests

Compression tests were conducted on a Tinius Olsen H300KU.
Crosshead speed: 0.2 mm/min and specimen dimensions: h = 8 mm, d = 4 mm



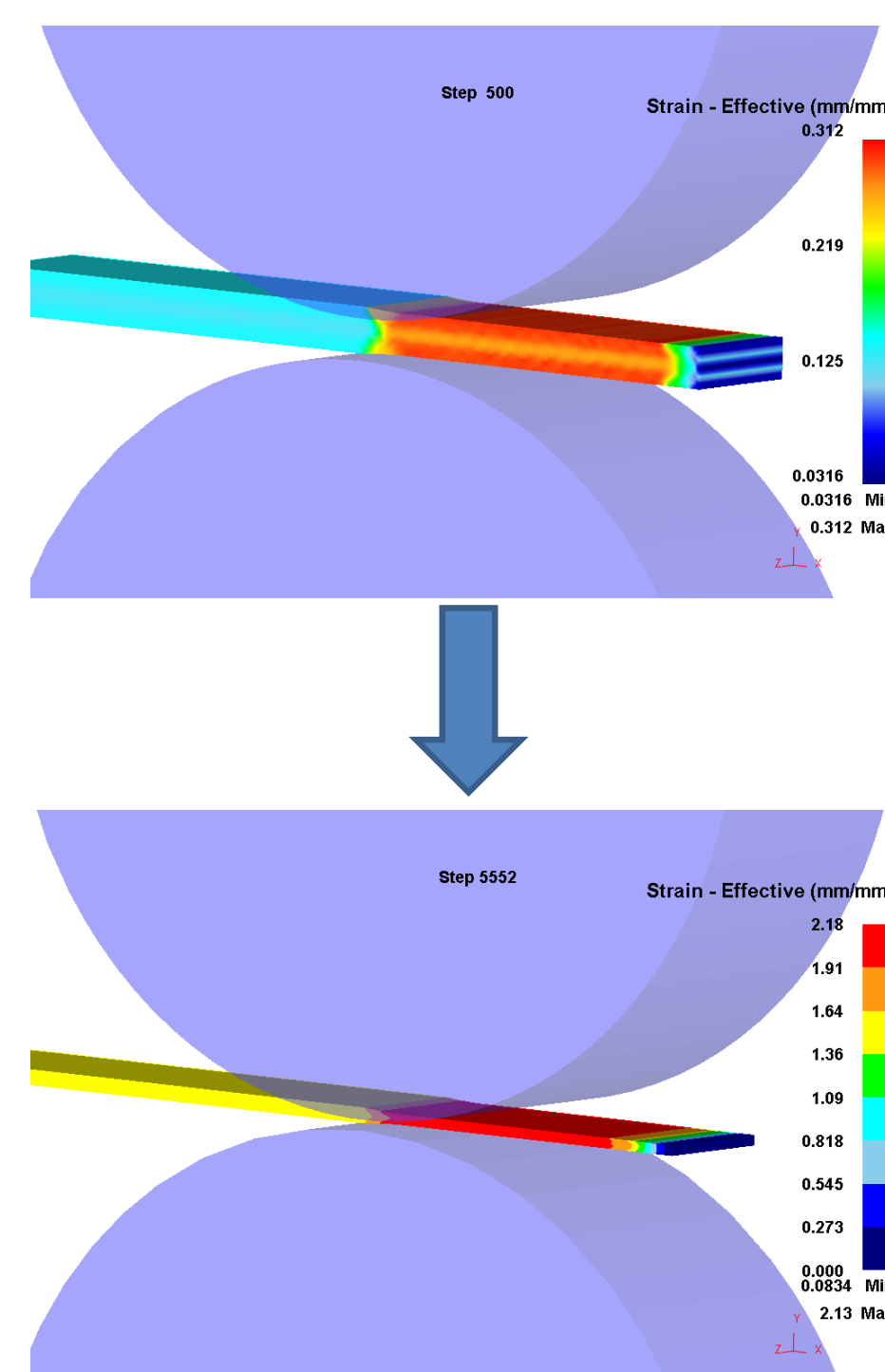
DEFORM simulation (rolling)

Material model: plastic, based on experimental true stress-strain data.
Element type: 4-node quadrilateral, mesh refined with 10 elements across thickness, and automatic remeshing activated.
Friction: Coulomb $\mu = 0.2$.
Roll rotation speed: 50 rpm.
Symmetric rolling configuration with 20 %, 40 %, 60 % and 80 % thickness reductions was analyzed.

Results

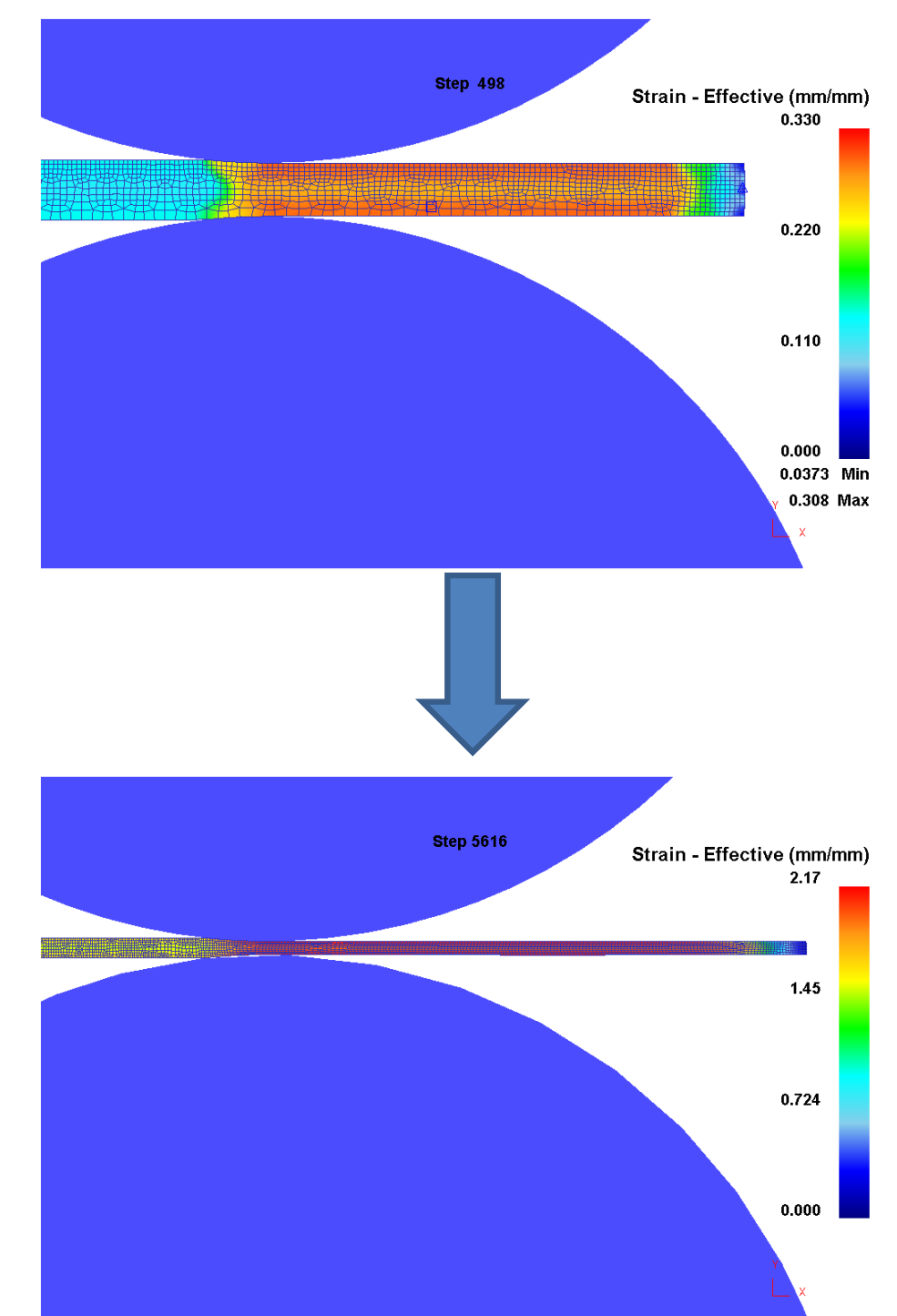
The true stress-strain curves obtained from compression tests show a higher flow stress for the as-built (HT0) condition compared to the heat-treated state (HT2), confirming the softening effect of the 1000 °C/1 h heat treatment (Figure 1). These data were used as input for the numerical rolling simulations. The simulated rolling forces increased progressively with thickness reduction. The HT0 material exhibited higher force levels, reflecting its higher strength and resistance to plastic deformation (Figure 2). The effective strain profiles across the sample thickness indicated that symmetric rolling ensured a relatively uniform strain distribution, with only minor surface gradients caused by friction. Heat-treated (HT2) material showed a more homogeneous deformation field than the as-built state, consistent with the experimental findings (Figure 3).

HT0 – Strain – Effective distribution (20-80% reduction)



Higher strain localization observed in HT0 samples due to higher flow stress.

HT2 – Strain – Effective distribution (20-80% reduction)



More uniform strain distribution after heat treatment (HT2).

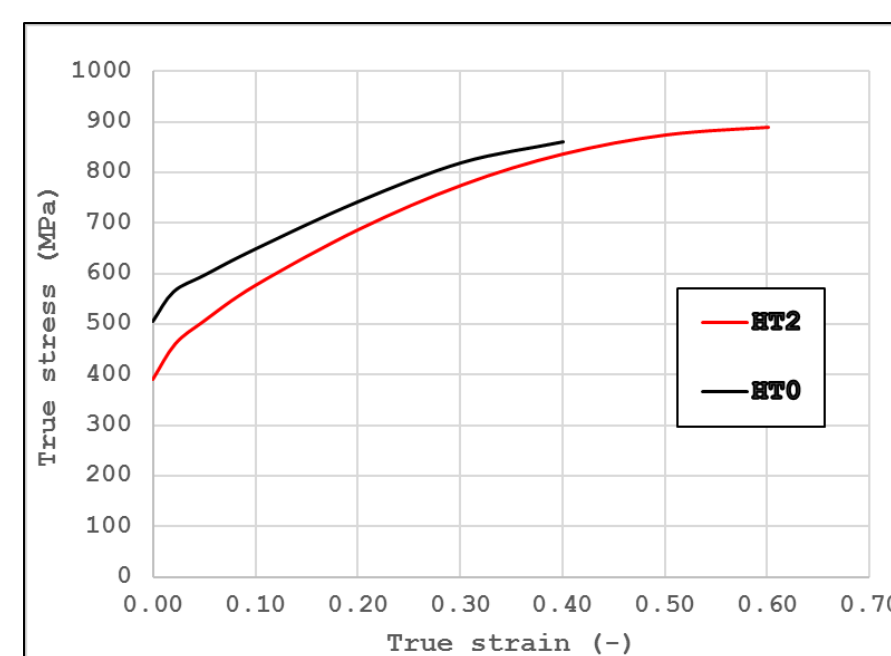


Figure 1 True stress-strain curves showing higher flow stress for HT0 and softening after heat treatment (HT2).

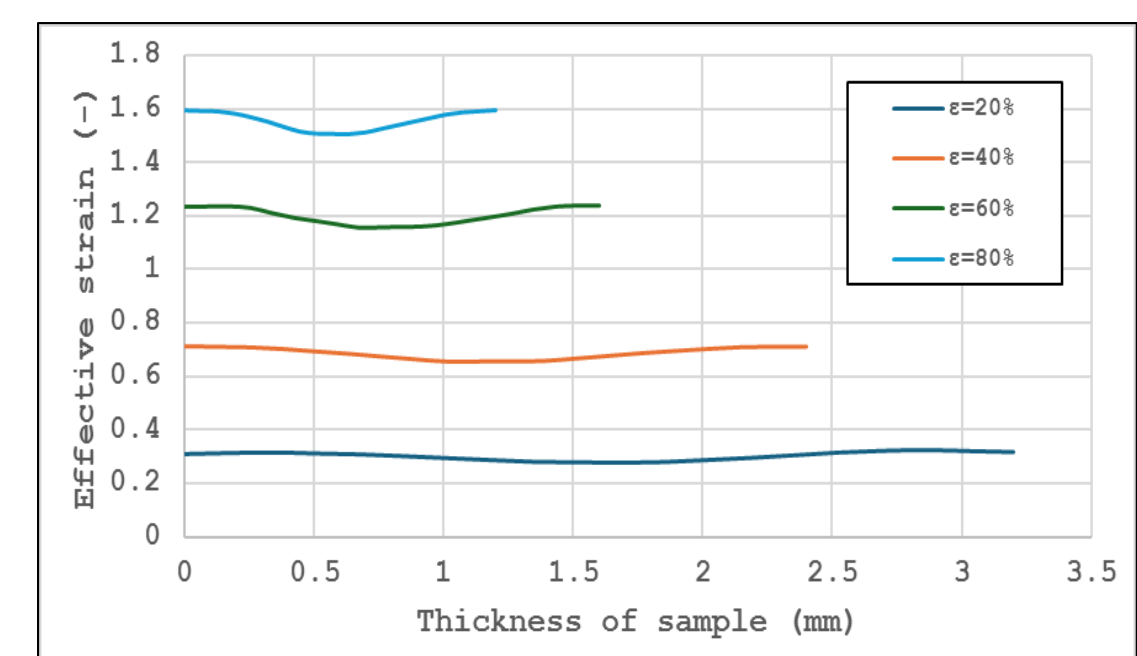


Figure 2 Effective strain distribution across the sample thickness shows nearly uniform deformation for all reduction levels.

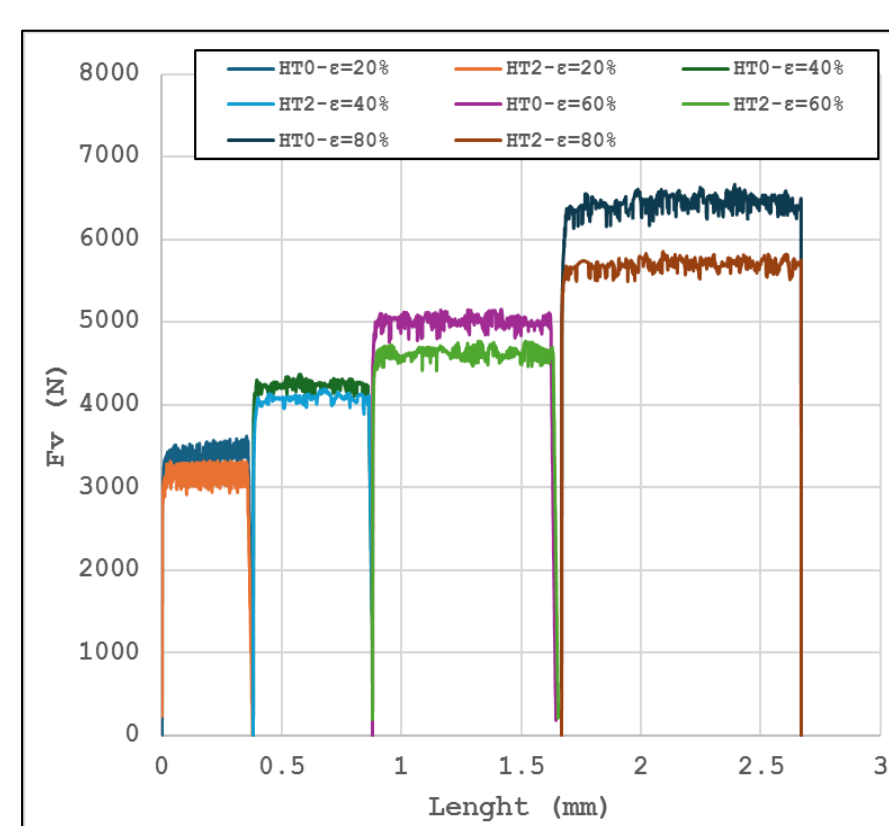


Figure 3 Rolling force increased with higher thickness reduction; HT0 samples required higher forces due to greater material strength.

Conclusion

Heat treatment at 1000 °C/1 h (HT2) led to a reduction in flow stress and promoted more uniform deformation during symmetric rolling. Numerical simulations correlated well with experimental data, confirming the validity of the applied material model. The results demonstrate that combining experimental testing with FEM simulations is an effective approach for optimizing forming parameters of additively manufactured 316L stainless steel.