Public Summary

Shape memory performance of NiTi auxetic structures fabricated with laser metal deposition

Miles Herbst

This study investigates the deformation behavior and shape memory performance of 3D-printed auxetic structures made from Nickel-Titanium (NiTi) alloy. Using laser metal deposition with the Meltio M450 printer, single unit-cell samples of re-entrant honeycomb auxetic structures were manufactured and subjected to cyclic compression testing. The research aimed to evaluate the material's ability to recover large amounts of strain after deformation.

The main research question focused on the shape memory performance of 3D-printed NiTi auxetic structures. To answer this, three sub-questions were explored:

1. Identifying a suitable auxetic shape for manufacturing and testing.
2. Observing superelastic deformation behavior under cyclic compression.
3. Evaluating the results of compression tests.

The re-entrant honeycomb structure was chosen for its predictable deformation behavior and suitability for printing. The study involved manufacturing samples using laser metal deposition, followed by cyclic compression testing at 120°C, above the austenite finish temperature (Af) of NiTi. Finite Element Analysis (FEA) was also conducted to predict deformation patterns and stress concentration points.

Superelasticity in NiTi occurs when stress-induced martensite (SIM) formation allows for large, reversible deformations. The force-displacement curves from the compression tests showed an initial hysteresis loop in the first cycle, followed by stable shape recovery of up to 98% of the original height, indicated by looking at the residual strain remaining after each cycle. (see Figure) However, a distinct stress plateau region, where large deformation takes place at constant stress, indicating SIM formation was not observed, likely due to the applied force (8000N) being below the required critical stress level.

The study analyzed the maximum strain and residual strain for each cycle. The samples demonstrated consistent shape recovery, returning to nearly their original height after each cycle. Sample 3 exhibited yielding behavior in later cycles, likely due to non-uniform loading, while Sample 1 showed the most reliable results with stable superelastic behavior. An 11th cycle with increased loads (9000N and 9500N) suggested that higher force application might be necessary to fully activate SIM.

The study confirmed that the 3D-printed NiTi auxetic structures exhibited superelastic behavior but did not reach the full stress-induced martensitic transformation due to insufficient applied force. Future work should focus on optimizing testing conditions, increasing the applied force, and exploring alternative auxetic geometries. Additional research could also investigate the effects of temperature variations and post-processing techniques on shape memory performance. Scaling up the unit-cell structures and refining load application methods could provide further insights into the practical applications of NiTi auxetic materials.