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# Low thermal expansion machine frame designs using lattice structures

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**Abstract**
The aim of this work is to develop an optimised design for a machine frame, which minimises thermal expansion. The work presents a study of a design concept for a lattice structure with a tailorable coefficient of thermal expansion (CTE). The proposed design is an assembly of two parts: a lattice and a cylinder which fits inside the lattice (Figure 1). The two parts are made of different homogenous materials with different positive CTEs. Nine different models were investigated and their thermal and structural behaviour analysed using a finite element method. The relationship between the size of the cylindrical inner part and the lattice outer part was mapped out to understand their relationship and the effects on the CTE. The simulation showed that for a lattice design, using nylon 12 and ultra-high-molecular-weight polyethylene, the thermal expansion can be reduced from $109 \times 10^{-6}$ K$^{-1}$ to $12 \times 10^{-6}$ K$^{-1}$. An experimental rig was designed to measure the thermal expansion of the model for a range of temperatures. One model has been physically built and the CTE was measured experimentally. The lattices were fabricated using powder bed fusion. The dimensions of the built specimen were measured using X-ray computed tomography. This paper proves that the combination of design optimisation and additive manufacturing can be used to achieve low CTE structures and, therefore, low thermal expansion machine frames at low cost.

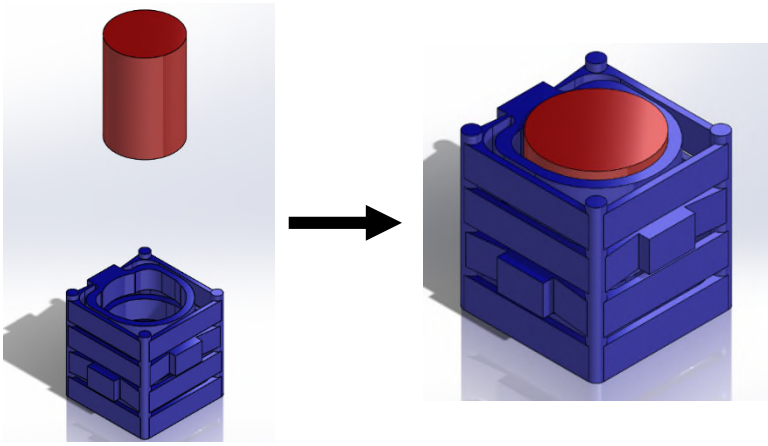

Figure 1. The proposed design.

Coefficient of thermal expansion, lattice structure, metrology frame, finite element analysis, powder bed fusion, additive manufacturing