Modelling of shape memory alloys hysteretic behaviour considering the loading cycle frequency

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Abstract

Shape memory alloys (SMAs) are unique materials that can restore their previous shape under certain conditions, such as temperature changes or mechanical stress. These properties make SMAs extremely useful in many areas, including aerospace, medicine, robotics and construction.

Shape memory effect (SME) is the property of an alloy to return to its original shape when heated after being deformed in the cold state. Superelasticity (SE) is the ability of an alloy to withstand large deformations and return to its original shape after the load is removed without heating. The frequency of loading can significantly affect the functional properties of SMA. This is particularly important for applications where alloys are subjected to cyclic loading, such as at vibration dampers. The frequency of loading can affect the thermal processes in the material. At high frequencies, self-heating can occur, which can cause undesirable phase transitions or loss of functionality. The cyclic loading frequency can affect the alloy's wear and fatigue resistance. High-frequency loading can accelerate fatigue processes, leading to a reduction in material life. Studying the effect of loading frequency on the functional properties of SMAs is critical to their successful application in real-world structures and devices. This helps developers and engineers choose the optimal parameters for using these materials, ensuring their reliability and durability.

The use of artificial neural networks (ANNs) to predict the hysteresis behaviour of shape memory alloys (SMAs), in particular nickel-titanium alloys (Nitinol), is an effective approach to understanding and predicting their behaviour under different loading frequencies. The study aimed to create models to predict hysteresis loops for different frequencies accurately. The input data for training the neural network were functional dependencies determined from experimentally obtained hysteresis loops for several frequencies. This included strain, stress, cycle number, and load frequency variables. The neural network was trained on experimental data, which allowed the model to recognise patterns and predict the material behaviour at different loading frequencies. This reduced the number of experiments required, saving time and resources.

Keywords: SMA; machine learning; Nitinol; ANN; hysteresis; frequency