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Finite - element modelling of NiTi shape - memory wires for morphing aerofoils

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Abstract

This paper presents the development and implementation of a user-defined material (UMAT) model for NiTi Shape - Memory Alloy (SMA) wires for use in LS-DYNA commercial explicit finite - element analysis software. The UMAT focusses on the Shape - Memory Effect (SME), which could be used for actuation of aerostructural components. The actuation of a fundamental structure consisting of an SMA wire connected in series with a linear spring was studied first. The SMA thermomechanical behaviour obtained from the finite - element simulation was compared with that obtained from the analytical solution in MATLAB. A further comparison is presented for an SMA-actuated cantilever beam, showing excellent agreement in terms of the SMA stress and strain as well as the tip deflection of the cantilever beam. A mesh sensitivity study on the SMA wire indicated that one beam element was adequate to accurately predict the SMA thermomechanical behaviour. An analysis of several key parameters showed that, to achieve a high recovery strain, the stiffness of the actuated structure should be minimised while the cross-sectional area of the SMA wire should be maximised. The actuation of an SMA wire under a constant stress/load was also analysed. The SMA material model was finally applied to the design of morphing aluminium and composite aerofoils consisting of corrugated sections, resulting in the prediction of reasonably large trailing-edge deflections (7.8-65.9 mm).

Author keywords

Keywords: Shape - memory alloy (SMA); LS-DYNA; morphing structures; shape - memory effect (SME); UMAT

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Substances

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NiTi View details

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Engineering controlled terms
Binary alloys; Cantilever beams; MATLAB; Nanocantilevers; Shape - memory alloy; Titanium alloys; Wire
Engineering uncontrolled terms
Actuated structures; Cross sectional area; Explicit finite element analysis; Finite element modelling ; Finite element simulations; Fundamental structures; NiTi shape memory alloys; Thermomechanical behaviour
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