Solitary waves in quasi-incompressible dispersive hyperelastic materials: An application to martensitic alloys.

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In the framework of martensitic transformations, the dynamic evolution of the separation zones between the various phases is an important aspect of research. Falk [1] was the first to find localized solutions of the domain-wall type between austenite and martensite phases, or between martensitic twins, using a Ginzburg-Landau model. This phenomenon has since been observed experimentally in various contexts [2].

Falk [1] obtained a minimal model for this kind of phenomena by considering a one-dimensional model of the crystal, built by stacking atomic planes parallel to the habit plane and by considering the shear strain in the stacking direction as the order parameter. It is known that martensitic phase transition relates to a nearly-volume-conserving spontaneous deformation of the crystal lattice [3]. This fact is fundamental because thermoelastic effects cannot be neglected and therefore the incompressibility constraint must be relaxed. A model taking account this relaxation was proposed by Maugin and Cadet [4]. By considering the continuum limit of a minimal discrete model, they determined the possibility of pulse propagation in austenite phase, and in martensite phase, and of kink propagation between martensitic twins and between austenite and martensite phases. These results were based on methodological considerations obtained previously by Cadet [5]. In our recent work [6], the results of Cadet [5] have been rigorously re-analysed and generalised. Using the general theory of phenomenological elasticity, and a model to describe the inherent characteristic length in the material, we shed new light on the role of the dispersive terms in the description of the separation zones between phases.

[1] Falk, F. (1983). Ginzburg-Landau theory of static domain walls in shape-memory alloys. Zeitschrift für Physik B Condensed Matter, 51(2), 177-185.

[2] Feng, P., & Sun, Q. P. (2006). Experimental investigation on macroscopic domain formation and evolution in polycrystalline NiTi microtubing under mechanical force. Journal of the Mechanics and Physics of Solids, 54(8), 1568-1603.

[3] Delaey, L., Krishnan, R. V., Tas, H., & Warlimont, H. (1974). Thermoelasticity, pseudoelasticity and the memory effects associated with martensitic transformations: Part 1 Structural and microstructural changes associated with the transformations. Journal of Materials Science, 9, 1521-1535.

[4] Maugin, G. A., & Cadet, S. (1991). Existence of solitary waves in martensitic alloys. International journal of engineering science, 29(2), 243-258.

[5] Cadet, S. (1987). Coupled transverse-longitudinal envelope modes in an atomic chain. Journal of physics C: Solid State Physics, 20(30), L803.

[6] Saccomandi, G., & Vergori, L. (2023). Waves in isotropic dispersive elastic solids. Wave Motion, 116, 103066.