Martensitic transformation in polycrystalline shape memory alloys using a phase field model

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ABSTRACT

Conventional processing of shape memory alloys (SMAs) produces an underlying polycrystalline microstructure. Like most materials, the properties of the material can be highly dependent on the polycrystalline microstructure, especially when the grain size approaches the nanometer regime. While the strength of polycrystalline materials generally increases with decreasing gain size (Hall-Petch relationship), it has also been recently reported that SMAs lose their memory effect for grain sizes smaller than a critical value (~50 nm for NiTi [1]). Obviously, as far as SMAs are concerned, losing or decreasing the memory effect is undesirable, yet applications may require good mechanical properties (high strength) obtainable by ensuring a small grain size. In order to optimize the grain structure and hence, the properties of SMAs, it is essential that we have a good understanding of the microstructural effects on the mechanical properties of SMAs.

We have developed a phase field model for martensitic transformation that takes into account the grain boundary energy of the polycrystalline SMA [2]. Incorporating grain boundary energy into the free energy functional of the system imposes additional penalty that suppresses martensitic transformation for very small grains – consistent with experimental observations [1]. A study of grain size effects show that upon quenching, grains remain in the austenite phase for very small grains, transform into a single martensite variant for intermediate grains, and forms twin martensite structures for large grains. We also study the effects of bimodal grain size distribution that aims at retaining shape memory properties, and yet possesses good mechanical strength.

REFERENCES

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