Key Points

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$85,000

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Tran-SET
Texas A&M University
Fort Wayne Metals

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$170,000

Disaster-Resilient and Self-Assessing Multifunctional Transportation Structures

Brief Project Description

The objective of this study is to design and characterize multifunctional materials, in particular inexpensive shape memory alloys, for transportation structures that possess excellent mechanical properties and self-sensing capabilities for strengthening and health monitoring.

Problem Statement

Shape memory alloy (SMAs) can produce large recoverable deformations triggered by stress in a response known as superelasticity. This response has been shown to limit the damage sustained by the structure from adverse events such as earthquakes, and have been considered in a range of civil engineering applications. The most commonly used SMA candidate for such applications is the NiTi SMA, which is cost-prohibitive for large scale applications. However, a low-cost and easily processed iron-based SMA exists as an alternative. Furthermore, the Fe-SMA shows an interesting meta-magnetic shape memory response, where a change in induced magnetization of the material occurs from applied stress, and can be easily detected using commercial magnetometers. This property can be harnessed to create a method to monitor the stresses and strains on structural systems with Fe-SMAs remotely and in a non-destructive fashion. The combination of these properties enable a new kind of structural health monitoring framework where the load-bearing and sensing elements are the same and quantitative information could be collected in real-time with simple instruments.

Objectives

The goal of this study is to create large dimension Fe-SMA rods and that are suitable for structural and transportation applications and determine the maximum part size. Bulk-Fe-SMA rods and cables that are capable of sustaining high stress and elongation will also be demonstrated. Optimal configuration of rods and sensors will be computationally determined through combined magnetic-mechanical modeling and validated through experiments. More concisely, the main objectives are to:

- Design topology and configuration of bulk Fe-SMA rods and cables in cementitious composites for optimal magnetic sensing capabilities.

- Determine maximum Fe-SMA component size through microstructural characterization and validation experiments.
- Demonstration of self-assessing capabilities in a realistic infrastructure system.

Intended Implementation of Research

Education and Workforce Development

Training of graduate students will be coordinated with the recently awarded NSF-NRT-DESE program at Texas A&M University (TAMU) on the design and discovery of smart materials. Each year, support for two undergraduates will be sought through the Summer Research Experience for Undergraduate Students Program and recently awarded NSF-REU site on multifunctional. Research findings will also be used to develop experimental learning modules for a graduate-level course.

The research team has previously given short courses on SMAs to engineers from numerous Texas companies (oil and gas focused). This course will be updated based on the study findings. Knowledge generated from the research study will also be incorporated into educational and training activities. Examples include:

- Preparation of educational materials to train students and to prepare them for the use of the developed technologies in their academic studies and professional career.
- Development of new courses to meet the identified training/education needs, taking into account the diversity of the student educational level and learning ability.
- Delivery of seminars/webinars and workshops for workforce development initiatives.

Outreach

Outcomes will be promoted amongst K-12 students on various occasions to attract them to pursue a degree in one of the STEM disciplines, including: STEMFest to mentor Girl Scouts and the Women in Mathematics and Sciences (WIMS) community, “Kids Career Day” Camp, and “Summer Experience in Engineering” (SEE).

Anticipated Impacts/Benefits of Implementation

Through a combined approach of physics-based modeling, optimization and materials design, this research aims at simultaneously achieving advantageous mechanical properties and self-monitoring capabilities in a single material for transportation structures. The developed multifunctional composites will transform the design, construction, and rehabilitation of infrastructure systems. Additionally, the project will define a viable path for technology transfer by establishing substantive partnerships with commercial alloy manufacturers, and cultivate the awareness.

Weblinks:

- Tran-SET's website (http://transet.lsu.edu/research-in-progress/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/View/1505437)