Influence On Thermo-mechanical Properties of Nitinol with Temperature Variation

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***Abstract*—A significant amount of research in last several years has greatly advanced the field of control of flexible structures through use of smart materials.Recently, each and every field of research utilizing the properties of NITINOL. It was only few years later when the NITI alloy was discovered and observed to be most efficient (with respect to mechanical energy to heat energy ratio) shape memory alloy known. However, it was going to be more effectively applied in design application , characterizationof the material had to become more extensive.In this paper, we try to provide recent basic conclusion of properties which is purely dependant on transformation temperature.**

***Keyword*— Diffusionless martensite transformation, shape memory alloy hybrid composite(SMAHC), pseudoelasticity, constrained-restrained recovery.**

I. INTRODUCTION

Shape memory alloys are class of materials that exibits a diffusionless martensitic transformation when cooled from the higher-temperature austenitic state. The interacton of temperature and applied stress in driving the martensitic and reverse transformation can be use to exploit phenomenan such as shape memory effect (SME) and pseudoelasticity.

Although there are several system who exibit shape memory effect , nitinol has most engineering significance.The name for this family of alloys was derived from Nickel, Titanium, and Naval Ordnance Laboratory and was patented by Buehler and Wiley. The SME for this family of alloys is limited to nearly equiatomic compositions, i.e., Nickel content from 53 to 57 percent by weight.

Nitinol is considered to be the shape memory alloy with the most potential for engineering application beacause of its ductility at low temperaturehigh degree of shape recovery capability, large pseudoelastic hysteresis,corrosion and fatigue resistance,biomedical compatibility and relatively high electrical resistance.

Nitinol exhibited attractive features such as excellent corrosion resistance, high strength and being non-magnetic due to the absence of iron.But the most remarkable feature found was the alloy ability to fully recover plastic strain upto 8 percent while going through its phase transformation.During transformation the alloy showed unique mechanical properties such as a 300 percent increase in young's modulas and recovery stress as high as 100 (ksi) [6689 MPa]. Unlike the ordinary metals, there is no diffusion or large displacement of atoms involved. Therefore the transformation can occur almost instantly depending on how fast heat energy is added to the material.

LITERATURE REVIEW

The effect of noise and vibration transmission and propogation proliferate throughout our everyday experience.These effects range from annoyance with other activities to mechanical failure , loss of hearing as well as loss of life. Methods of noise reduction typically involve increases in one or more three things : Mass , Stiffness , Damping. Conventional noise/vibration attempts typically consist of post-design treatments to reduce noise/vibration at source or reducethe perception of noise/vibration. These add-on treatments can be adequate for some application where weight is not an issue and system parameters do not vary widely. However , there are other applications where weight efficiency and adaptability are all important. One class of such application arises in area of high performance aerospace structure.

Excitation level for many aerospace vehicle structure are high due to engine noise and turbulent boundary layer fluctuating pressure. The ever increasing need for weight – efficient structures in these application leads to significant sonic fatigue and interior noise issues. Conventional aerospace structures typically employ passive treatments such as structural stiffening, constained-layer damping and acoustic absorption materials to reduce the structural response and interior acoustic level. These tratments suffer from substantial weight penalty and are often limited to relatively low temperature or high frequencies.

- Early potential for application in self-erecting structures , thermally actuated devices , and energy-coversion systems was identified by Buehler and Wang.

- Other potential applications including damping or energy absorbing devices, thermally actuated couplings and fasteners and biomedical devices were briefly described by Way-man and Shimizu. Later way-man , Otsuka and Shimizu gave more detailed description of specific devices such as pipe coupling, thermostats , a robot hand and various biomedical systems.

- An entire new field of application was created when Rogers and Robertshaw introduced the idea of embedding SMA actuators in composite laminate. A structure of this type has been termed a shape memory alloy hybrid composite (SMAHC).

- Numerousresearchers have investigated the use of SMA actuators, either external to a structure or embedded within the structure, for static and dynamic control. Studies have considered SMA actuators external thestructure, for active vibration control and shape control of cantilever beams. Other studied have proposed nitinol actuators for vibration control of space structures.

- A different approach was offered by Ro and Baz where thermal,static, and dynamic analysis was developed for NITINOL actuators. These have also been devoted to studying the dynamic response tuning capability ofNITINOL actuators and predicting the structural acoustic behavior r of NITINOL panels.

- Shape memory alloys have been investigated for a variety of applications since their discovery. There are some common experimentally concluded results came out from literature shown below:

- Increasing applied constant load , transformation temperature increased using linear variable differential transformer(LVDT).
- Dynamic modification of auto- parametricsystem with NITINOL spring includes Young's modulas , spring stiffness.
- Variation in shape recovery temperature in NITINOL alloy includes final annealingtemperature,annealing time, amount of strain , effect of thermal cycling.
- Thermo-mechanical behaviorofNITINOLwire, effect of different types of pre-strain on fatigueproperties of NITINOL under variety of deformation modes.
- Thermo- mechanicalanalyzerhasbeenemployed to identify crystalline phases of NITINOL though temperature variation of thermal expansion and determine associated transformation temperature. Differential scanning calorimeter (DSC) study carried out for similar heat treated samples to confirm transformation temperature.
- Thermal expansion co-efficient undergoes large variation whenever phase transformation occurs in NITINOL.
- Thermal expansion co-efficient of Martensiteand Austenite phases are independentof heattreatmenttemperature.

In 1989, a survey was conducted in the United Stated and Canada that involvessevenorganizations. The survey focused in predicting the futuretechnology, market and application of Shape Memory Alloys. It was meant to assist marketing managers and application engineers in the area of Shape Memory Alloys. The companies predicted following application of NITINOL in decreasing order of importance.

[1] Coupling
[2] Biomedical and medical.
[3] Demonstration, novelty items.
[4] Actuators
[5] Heat engines
[6] Sensors
[7] Cryogenically activated die
[8] Lifting device.

I will describe basic principle, co-relation and expression of properties behind some of these application ofNITINOL in order of their popularity as the professionals predicted it almost two decades ago. The purpose of this abbreviation is to develop and experimentally valid analytical expressions of properties which are only depends upon transformation -temperature that captures material non-linearity and complexthermo- mechanical behavior of Shape memory alloy. The manner in which detailed discussion will be carried out is as follows:

- Static and dynamic stability [Actuators]
- Stress/strain calculation [Coupling]
- Energy expressions [Heat engines]

- Co-efficient of thermal expansion [coupling]
- Thermal buckling ; post buckling
- Transformation thermodynamics and temperatures.
- Investigation of one-dimensionalthermo- mechanical relationship for NITINOL.

CONCLUSION AND FUTURE-WORK

Each experiment conducted to identify thermo- mechanical behavior of NITINOL leads to the fact that , there are properties which contributes to shape memory are highly sensitive to temperature difference. The main objective of this work was to develop a thermo- mechanical model for predicting the behavior of composite structures with embedded NITINOL and to validate that model with experimental measurements. The model captures the material non-linearity of NITINOL with temperature and is valid for constrained , retrained or free recovery behaviour with appropriate measurement of fundamental engineering properties.

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