Shape Memory Alloy Research and Development at NASA Glenn
Current and Future Progress

Othmane Benafan—NASA Glenn
High Temperature & Smart Alloys Branch
Materials and Structures Division

Jul. 16, 2015
Shape Memory Alloys: An Introduction

- Alloys that have a “memory.” These materials have the ability to remember and recover their original shapes with load or temperature.
- SMAs exhibit a solid-to-solid, reversible phase transformation

### Simplified 2D

#### Variant selection

1. Bain strain → (lattice deformation)
2. Lattice invariant shear → (accommodation)

### Microstructure

- Courtesy of A. Garg
Shape Memory Alloys: An Introduction

- SMA actuators can generate motion in one dimension (wire form), two dimensions (bending of a bar) or even motion in a more complex three dimensions (springs, honeycombs)

- Functionality: Tension (e.g., wires, springs), compression (e.g., rods, springs), bending (e.g., beams, plates), torsion (e.g., rods, tubes, and springs)
Research and Understanding of Shape Memory Alloys

1. Applied Research
2. Alloy Processing & Development
3. Testing and Modeling
4. Applications
Research and Understanding of Shape Memory Alloys

1. Applied Research
2. Alloy Processing & Development
3. Testing and Modeling
4. Applications
Development of Shape Memory Alloys: NiTi–Based HTSMAs

NiTiHf

![Graph showing strain vs. temperature for NiTiHf](a)
Processing and Workability of HTSMAs

NiTiPt

Induction Melt + Homogenization

Extrusion

Multiple-Pass Extrusion
60 mil NiTi-20Pt rod

Wire Grinding
44 & 5 mil NiTiPt

Wire Drawing
5 mil NiTiPt wire
Processing and Workability of HTSMAs

**NiTiHf**

High temperature extrusion proved to be problematic (C. Wojcik 2008)

Successful hot rolled button (C. Wojcik 2008)

Successful hot extrusion (rods and tubes)
Research and Understanding of Shape Memory Alloys

1. Applied Research
2. Alloy Processing & Development
3. Testing and Modeling
4. Applications
Thermomechanical Testing

Uniaxial (tension/compression)

- Isothermal monotonic
- Isothermal cyclic
- Isobaric cyclic
- Isostrain cyclic

Multiaxial

- Proportional/non-proportional loading
- 3D strain measurement
- Torque/force/twist/displacement control capability

Geometries

Torsion

Durability

- New frames for durability testing are underway
- Durability analysis of sample and components
- Generate data for existing materials

T = 3.4 N.m

Hot grip testing

www.nasa.gov
Research and Understanding of Shape Memory Alloys

1. Applied Research
2. Alloy Processing & Development
3. Testing and Modeling
4. Applications
SMA Existing and Potential Applications

Automotive

Aerospace

Robotics

Biomedical

Source: J. Mohd Jani et al. / Materials and Design 56 (2014) 1078–1113
Shape Memory Alloy Applications

**Space**

**SMA Bellows**
- Dynamic sealing
- Fluid handling
- Flexibility (structure alignment)

**SMA Spring Tire**
- Superelastic technology
- Lunar rovers
- Terrestrial tires

**SMA Docking Coupling**
- Cryogenic transfer coupling
- Orbital propellant depots
- Propellant handling/protection

**SMA Thermal Switch**
- Thermal management
- Clean & spark-free operation
- Passive or active control

**SMA Bearings**
- Corrosion resistant
- Non-galling properties
- High yield

**SMA rock splitters**

**RXN**
Shape Memory Alloy Applications

**Aeronautics**

### Adaptive Fan Blade
- Embedded SMA actuators
- Aerodynamic efficiency
- Specific fuel consumption reduction

### SMA Cellular Structures
- Airframe and engine components
- Morphing airfoils
- Light weight trusses

### The Mars Atmosphere and Volatile EvolutionN (MAVEN) mission.
- SMA Pinpullers (From TiNi Aerospace) were used to secure and release deployables

### Variable Area Nozzle
- High bypass turbofan
- SMA torque tubes provide flap rotation
- Engine noise reduction
Shape Memory Alloy Applications
Non-Aerospace Potential

**Oil and Gas Industry**
- SmartRAM™ actuators (*LMP*)
- SMA couplings (Aerofit Inc)
- Deep-water valves/shut off valves
- Self-torquing fasteners

**Other Applications**
- Home appliances
- Electronics
- Transportation
- Air conditioners

**Medical Industry**
- Surgical tools
- Stents and implants
- Glasses frames

**Automotive Industry**
- Louvers
- Quiet actuators
- Door handle
Development of Shape Memory Alloys: Challenges

High transformation temperatures
- Above 100 °C
- Good work output
- Thermal stability

Durability
- Loading history
- Functional fatigue
- Structural fatigue

Modeling
- Micromechanics
- Phenomenological
- Evolutions/transients

Workability/Processing
- Ductility
- Composition control
- Heat treatment
- Large scale

Dimensional stability
- Cyclic stability
- Stress-strain relationship

Deign Tools
- Testing standards
- Design handbooks
- Database

Challenges in microstructures
Micromechanics
Design
Applications
SMA Team at NASA GRC

• Santo Padula II
• Ron Noebe
• Glen Bigelow
• Anita Garg
• Darrell Gaydosh
• Timothy Halsmer
• Othmane Benafan

(Branch Chiefs: Joyce Dever, Bob Carter)