Nitinol Commercialization Accelerator – Ohio Third Frontier

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ABSTRACT

The Ohio Third Frontier Wright Projects Program recently funded a collaborative effort between the Cleveland Clinic, CWRU, University of Toledo, NASA Glenn Research Center, and Norman Noble, Inc. in order to develop a better understanding of the metallurgical processing and mechanical characterization of nitinol for use in biomedical and aerospace applications. Biomedical applications range from orthodontia to implantable devices while higher temperature shape memory alloys are of interest for aerospace. The collaboration is designed to create synergy amongst collaborators in the research and development of nitinol products. CWRU is developing a facility wherein the effects of composition changes on mechanical performance can be determined. The CWRU facility is described herein while additional details can be found at http://mds.clevelandclinic.org/Services/Nitinol-Center.aspx.

PROCESSING EQUIPMENT

Vacuum Arc Melter:
Thermal Technology LLC Model BJ5 Arc Melter

Vacuum Arc Melting

- Maximum temperature: 2000ºC
- Hearth: Water-cooled copper with 9 in O.D.
- Bell Jar: Stainless steel, water-jacketed 10 in (24.4 cm) diameter x 11.5 in (29.2 cm) high
- Casting: Typical size 0.5 in - 3 in diameter
- Operating Vacuum: 10^{-2} low vacuum
- Ultimate Vacuum: 10^{-5} torr or better

Vacuum Heat Treatment System:
Centorr/Vacuum Industries Series 2110 Super VII

Vacuum Heat Treatment

- Stainless Steel (Type 304) inner chamber, double wall stainless steel jacket and flanges, fully water baffled, 20 in I.D. x 30 in long
- Tungsten rod elements, molybdenum radiation shields and molybdenum hearth plate
- Maximum temperature: 1600ºC
- Ultimate vacuum: 10^{-6} torr range

Hot Extrusion:
Innovare, Inc. LES Explorer Series

Hot Extrusion

Phase I

- Maximum temperature: 900ºC
- 100,000 lb force
- Billet diameter: 0.5 in max
- Extrusion dies: 1/4 in, 5/16 in, 3/8 in
- Rate of extrusion: 0.5 in/min - 1.0 in/min

Phase II

- Advanced Metalworking System (AMS)
- 400,000 lb force apparatus

CHARACTERIZATION EQUIPMENT

Differential Scanning Calorimeter:
Netzsch 404 F3 Pegasus High Temperature DSC

Differential Scanning Calorimetry

- Temperature range: 25ºC - 1500ºC
- CP temperature range: 25ºC - 1400ºC
- Heating rate: 0.1 K/min - 50 K/min
- Enthalpy range: 0 J/g - 30000 J/g
- Specific heat range: 10 J/kg*K - 5000 J/kg*K
- Platinum furnace
- Thermocouple: Type S
- Protective gas: Argon

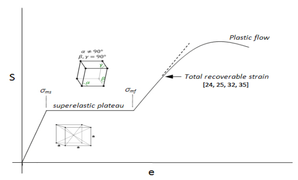
MECHANICAL CHARACTERIZATION

Fatigue Ductility Flex Tester:
Universal Model 3FDF Fatigue Tester

Flex Bending Fatigue

- R = -1
- Test frequency: 1 Hz - 17 Hz
- Mandrel sizes: 1 mm - 24 mm
- Automatic break detection
- Constant strain amplitude
- Low cycle and high cycle fatigue

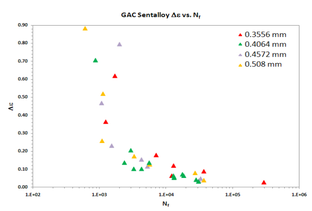
NITINOL TEST DATA



Superelastic Nitinol in Tension

Tension

- Strain rate: 1 x 10^{-3}/s
- Wire diameter: 0.3556 mm - 0.508 mm
- Superelastic
  - Recoverable strain < 8%
  - Ductile failure



Flex Bending Fatigue of Nitinol

Flex Bending Fatigue

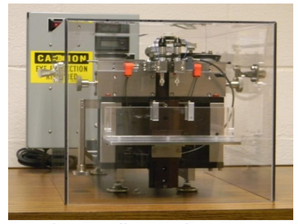
- Test frequency: 1 Hz
- Mandrel radii: 1 mm - 24 mm
- Wire diameters: 0.3556 mm - 0.508 mm
- $\Delta\varepsilon = d/\rho$
  - d = Wire diameter
  - ρ = Mandrel radius

MECHANICAL CHARACTERIZATION

Rotating Bending Dry Tester:
Positool Model 100

Rotating Bending Fatigue

- R = -1
- Test frequency: 60 Hz
- Bend radius: 2 mm – 127 mm
- Wire diameter: 0.05 mm – 1.0 mm
- Automatic break detection
- High cycle fatigue



Rotating Bending Wet/Dry Tester:
Positool Model 401

Rotating Bending Fatigue

- R = -1
- Test frequency: 60 Hz
- Bend radius: 7.24 mm – 76.2 mm
- Wire diameter: 0.05 mm – 1.0 mm
- Automatic break detection
- Accommodates wet and dry testing
- High cycle fatigue

ADDITIONAL EQUIPMENT

Raydiance-Rofin Femtosecond Laser (CCF)	Techne FB-08 Precision Calibration Bath (CCF)
MTS Cryo-Chamber and Grips (CWRU/NASA)	Aramis/Optotrak Certus 3D Strain Mapping (NASA)

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