Deformation Processing Equipment

**Advanced Deformation Simulator**
*MTS Model 311.31*
- Hot/warm/cold forming
- Multiple deformation sequences
- 110 Kip forging actuator
- 220 Kip indexing actuator
- Maximum loading rate: 120”/s
- “Large” samples (e.g. 5” diameter)
- Emulates industrial processes
- Large strain deformation

**Advanced Forming Apparatus**
*MTS Model 866.725*
- Forming limit diagrams
- 10” Punch stroke
- 11.8”/s Punch velocity
- Dynamic punch force: 105 Kip
- Static punch force: 150 Kip
- Clamp actuator: 157 Kip
- Various dies: 27” wide, 40” depth

**Fenn 14” Rolling Mill**

**Extrusion**
- Innovare, Inc. LES Explorer Series
  - Maximum temperature: 900°C
  - 100,000 lb force
  - Billet diameter: 0.5”
  - Extrusion dies: 1/4”, 5/16”, 3/8”
  - Extrusion rate: 0.5”/min-1.0”/min
- Advanced Metalworking System
  - 400,000 lb force apparatus

**Impact Testing: 240 ft-lb Capacity**
*Wiedemann-Baldwin; Tinius Olsen*
- Dynatup instrumentation package

The Center is capable of mechanically evaluating and deformation processing materials that range in size scale from the micrometer range up through bulk quantities. This unique facility enables mechanical characterization at loading rates as low as one micrometer/hour (i.e. rate of fingernail growth) up through impact (e.g. 3-4 meters/sec) at temperatures ranging from -196°C (i.e. liquid nitrogen) up to 1400°C. Monotonic as well as cyclic fatigue testing is possible via remote control and/or monitoring. In addition, evaluations of mechanical behavior and processing with superimposed pressures up to 2 GPa are possible. Deformation processing is conducted on novel forging, forming, and extrusion equipment. Materials systems that have been investigated span the range of organic and inorganic materials, including metals, ceramics, polymers, composites, electronic materials, and biomedical materials systems.

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About

The Advanced Manufacturing and Mechanical Reliability Center (AMMRC) was established in 1987 to provide advanced manufacturing (e.g., deformation processing, extrusion, forming, etc.) and mechanical characterization (e.g., mechanical testing, reliability testing, fatigue, etc.) expertise to the CWRU campus, medical, industrial, legal, outside university, and government laboratory communities.

The Center, housed in the Charles M. White Metallurgy building, currently maintains equipment valued in excess of $4.5M and has been accessed by the local, national, and international communities.

The CWRU campus community can access the facility via the use of a valid CWRU university account number that will be charged at an internal rate for machine time, including set up and any technician time involved. Long term testing can be provided at pro-rated charges in consultation with the Center Director. Equipment usage is charged at $24/hr including setup. Technician assistance is charged at $24/hr including set up time and any further analyses.

Arrangements can be made to train users on the equipment and reserve time for equipment use by contacting the Center co-director. Outside (i.e. non-CWRU) users can access the facility via a number of different mechanisms by contacting the Center Director. Remote access and/or monitoring of testing is possible.

Servo-Hydraulic Equipment

**Capabilities**
- Tension, compression, fatigue
- Load, stroke, or strain control
- Low T and high T testing
- DCPD – FTA software
- Fatigue crack growth
- Fracture toughness

**MTS Machines**
- 50 Kip (2): High alignment grips
  - Temperature: -125°C to 600°C
- 20 Kip
  - Temperature: -125°C to 225°C
- 10 Kip: Horizontal machine
- 3 Kip: Fully reversed bending

**Instron Machine**
- 5 Kip
- Temperature: -125°C to 600°C

Electro-Mechanical Equipment

**Instron/MTS Model 1361**
- Capable of 1 µm/hr test rate
- Temperature: 1500°C
- Load, stroke, or strain control

Universal Testing Machines

**Instru-Met/Instron Model 1125**
- Tension, compression, torsion
- Temperature: 25°C to 1600°C
- 100 kN capacity

**Instru-Met/Instron Model 1130**
- Tension, compression
- Temperature: -125°C to 200°C
- Pneumatic grips
- 5 kN capacity

Microscale Testing Equipment

**EnduraTEC**
- Tension, torsion, cyclic
- 5 lb, 25 lb, 50 lb, 500 lb load cells

**Nikon QM Hot Microhardness**
- Vickers or Knoop indenter
- 50 g – 1 kg
- T < 1000°C

**Universal Flex Bending Fatigue**
- R = -1
- Test frequency: 1 – 17 Hz
- Mandrel sizes: 1 – 24 mm
- Automatic break detection

**Rotating Bending Fatigue**
- R = -1
- Test frequency: 60 Hz
- Wire diameter: 0.05 – 1.0 mm
- Automatic break detection
- High cycle fatigue

**Positool Model 100**
- Bend radius: 2 – 127 mm
- Bend radius: 7.24 – 76.2 mm
- Accommodates wet testing

High Pressure Testing

**MTS Machine**
- Pressure up to 700 MPa, Ar gas
- Tension, compression
- 30 kN load cell

**Innovare LES Explorer**
- Tension testing, isopressing
- Pressure up to 2 GPa, oil
- Hydrostatic extrusion
- T < 300°C
Mechanical Characterization

Rotating Bending Fatigue

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

Additional Equipment

The Cleveland Clinic and NASA also house additional equipment associated with the Nitinol Commercialization Accelerator program including:

- Raydiance/Rofin Femtosecond Laser
- Techne FB-08 Precision Calibration Bath
- MTS Cryo-Chamber and Grips
- Aramis/Optrak Certus 3D Strain Mapping

Additional details of the facility at The Cleveland Clinic can be found at:

mds.clevelanlrdclinic.org/Services/Nitinol-Center.aspx.

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About
The Ohio Third Frontier Wright Projects Program has 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 high 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 laboratory housed at CWRU’s Materials Science and Engineering Department contains processing and characterization (thermal and mechanical) equipment that allows for the manufacture and analysis of nitinol products.

The CWRU campus community can access the facility via the use of a valid CWRU university account number that will be charged at an internal rate for machine time, including set up and any technician time involved. Long term testing can be provided at pro-rated charges in consultation with the Laboratory Director(s). Arrangements can be made to train users on the equipment and reserve time for equipment use. Outside (i.e. non-CWRU) users can access the facility via a number of different mechanisms by contacting the Laboratory Director(s).

Processing Equipment
- Vacuum Arc Melting
  - Maximum temperature: 2000°C
  - Hearth: Water-cooled Cu 9” OD
  - Bell jar: Stainless steel, water-jacketed 10” ID x 11.5” high
  - Casting: Typical sizes range from 0.5” – 3.0” diameter
  - Operating vacuum: 10^-2 torr
  - Ultimate vacuum: < 10^-5 torr

- Vacuum Heat Treatment
- Hot Extrusion
- Superelastic Nitinol in Tension

Characterization Equipment
- Differential Scanning Calorimetry
  - Temperature range: 25-1500°C
  - CP range: 25-1400°C
  - Heating rate: 0.1-50 K/min
  - Enthalpy range: 0-30000 J/g
  - Specific heat: 10-5000 J/kg K
  - Platinum furnace
  - Thermocouple: Type S
  - Protective gas: Argon

Mechanical Characterization
- Flex Bending Fatigue
  - R = -1
  - Test frequency: 1-17 Hz
  - Mandrel sizes: 1/24 mm
  - Automatic break detection
  - Constant strain amplitude
  - Low cycle, high cycle fatigue

- Universal Model 3DFV Fatigue Tester

Nitinol Commercialization Accelerator Laboratory (NCAL)
Case Western Reserve University
Charles M. White Metallurgy Building
Room 300