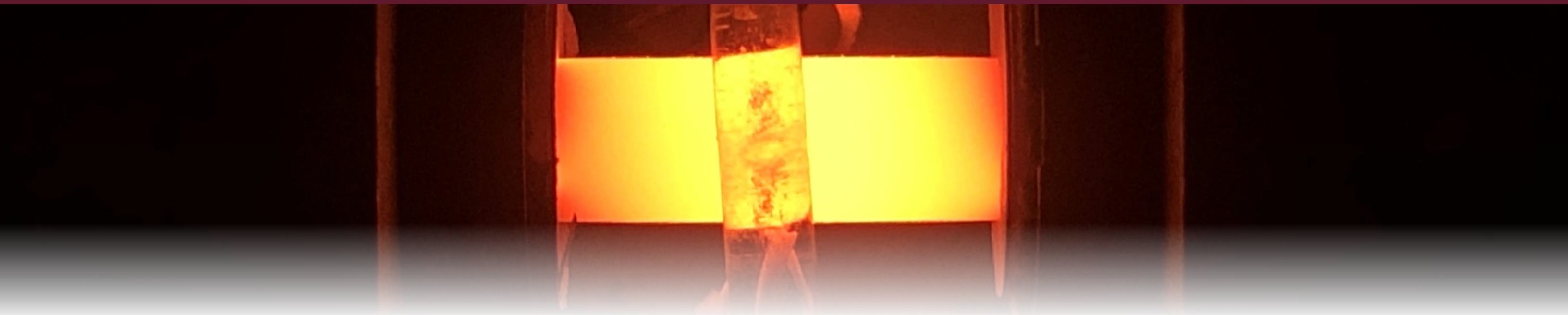
MISSISSIPPI STATE UNIVERSITY™
CENTER FOR ADVANCED VEHICULAR SYSTEMS



GLEEBLE THERMAL-MECHANICAL SIMULATION AT CAVS

Driven by the rising demand for high-performing materials, physical simulation has become a critical tool in materials development and testing. In a laboratory context, "physical simulation" involves precise replication of real-world processes such that lab results directly reflect full-scale material behavior. Here, the interplay between processing, structure, and properties can be explored to establish relationships between different aspects of a material's lifecycle.

At MSU's Center for Advanced Vehicular Systems, researchers use the Gleeble Thermal-Mechanical Simulator, a dedicated system developed to meet this need in the field of materials research. With independent control of atmosphere, temperature, strain, and strain rate, the Gleeble system allows parameters of interest to be isolated and their effects on material structure and properties to be studied.

THE GLEEBLE SYSTEM ENABLES THERMAL, MECHANICAL, AND COUPLED THERMAL-MECHANICAL EXPERIMENTS, INCLUDING:

THERMAL-MECHANICAL EXPERIMENTS

- Tension *(ambient & elevated temperatures)*
- Compression – uniaxial, plane strain *(ambient & elevated temperatures)*
- Strain-Induced Crack Opening
- Melting and solidification
- Nil-strength testing
- Hot ductility testing
- Thermal cycling & heat treatment
- Dilatometry
- Stress relaxation
- Creep/stress rupture
- Fatigue (thermal and thermal-mechanical)

PROCESS PHYSICAL SIMULATION

- Hot rolling
- Forging
- Continuous casting
- Mushy zone processing
- Welding + heat affected zone thermal cycling
- Continuous strip annealing
- Diffusion bonding
- Heat treatment
- Quenching
- Extrusion
- Sintering
- Self-propagating High-temperature Synthesis
- Additive manufacturing

SOURCE:
https://gleeble.com/products/gleeble-systems/gleeble-3500.html

CAVS' GLEEBLE 3500 HAS POWERED STUDIES OF A WIDE RANGE OF MATERIALS AND PROCESSES. EQUIPPED WITH THREE MOBILE CONVERSION UNIT (MCU) MODULES, THE GLEEBLE SYSTEM IS CAPABLE OF:

- User-defined programming of time-temperature-deformation profiles
- Feedback control with sampling rates up to 50,000 Hz
- Thermocouple-controlled direct resistance heating up to 1700°C (~3000°F) of electrically conductive materials
- Heating and cooling rates up to 10,000°C/s (depending on sample dimensions)
- Controlled test atmosphere: air, vacuum (as low as 10^{-8} Torr), inert gas, or custom gas mix
- Quenching using air, custom gas mix, water, or mist

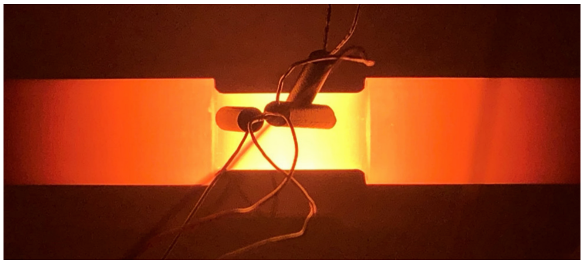
GENERAL PURPOSE MCU

The most versatile module, compatible with existing (and custom) fixturing for a variety of applications, including:

- Axial deformation (tension and compression) up to 110 kN
- Heat treatment design for material and process development
- Melting and casting simulation
- Phase transformation measurements
- Microstructure development

EXAMPLE USE CASES:

- Replicate industrial thermal histories to produce mechanical test samples
- Design processes and develop heat treatments
- Measure liquidus temperature for testing new alloy castability
- Analyze temperature and strain-rate effects for material model calibration
- Simulate thermal cycling during additive manufacturing (fusion & non-fusion)
- Dilatometry for heating and cooling phase transformations, continuous cooling transformation (CCT) diagrams, and time-dependent isothermal transformation
- Study steel recrystallization kinetics as functions of temperature & deformation



Hot Torsion Specimen (actual size)

MATERIAL SYSTEMS TESTED

- Ferrous Alloys (Steels, Ductile Iron)
- Titanium
- Molybdenum-Tungsten
- High-Entropy Alloys
- Aluminum
- Magnesium
- Bismuth

HOT TORSION MCU

Combines rotational and axial deformation capabilities with precise atmospheric and closed-loop thermal control

- Torque up to 100 N-m
- Axial load up to 900 kgf (8.8 kN)
- Rotational speeds up to 600 rpm sustained, 1500 rpm transient (≤ 60 rotations)
- Torsion with free or constrained axial length
- Coupled hot torsion and axial deformation (torsion + tension or torsion + compression)

EXAMPLE USE CASES:

- Replication of hot-rolled microstructures with high reduction ratio by recreating effective strain rates per pass
- Single and double twist analyses for full and nil recrystallization temperatures
- Physical simulation of thermal-mechanical conditions during additive friction stir deposition (AFSD) processes

HYDRAWEDGE MCU

Valuable in applications where deformation rate effects are crucial, thanks to the ability to produce single and multiple hits with minimal strain overshoot and deceleration effects

- 110 kN load capacity
- Can program exact rolling schedules:
  - Soak time and temperature
  - Number of passes
  - Temperature, and reduction rate (strain rate) at each stand
  - Interpass time
  - Controlled cooling time-temperature profile

EXAMPLE USE CASES:

- Obtaining rheological data
- Measuring recrystallization temperature based on hot-deformation history
- Testing overall (or individual parts of) rolling profiles
- Simulating effects of hot forging

LOOKING TO GAIN NEW INSIGHTS INTO YOUR MATERIAL PROCESSING, STRUCTURE, AND PROPERTIES?
CONTACT DR. HONGJOO RHEE, ASSOCIATE DIRECTOR FOR ENGINEERING MECHANICS AND MATERIALS SCIENCE.

hrhee@cavs.msstate.edu 662.325.5431

Clay Walden
Executive Director • CAVS
walden@cavs.msstate.edu

Hongjoo Rhee
Associate Director • Engineering Mechanics & Materials Science
hrhee@me.msstate.edu

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