Center for Lightweighting Automotive Materials and Processing (CLAMP)

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Project ID No. TI010

www.engin.umd.umich.edu/research/gate/

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Overview

- **Timeline**
  - Project Start Date: September 2005
  - Project Finish Date: August 2012
  - 75% Complete
- **Budget**
  - Total Project Funding
    - DOE: $706,190
    - University Cost Share: $180,800
  - Funding Received in FY2011
    - $144,788
- **Barriers**
  - Not having PhD programs until 2009 (PhD program in Automotive Systems Engineering was started in 2009)
- Partners
  - PNNL
  - Chrysler
  - Ford
  - USAMP™
  - AISI

Objectives

- Overall Objectives
  - Provide graduate education in advanced materials used for lightweighting automobiles
  - Conduct research on lightweight automotive materials and processing
- FY2010 Objectives
  - Develop a new graduate level course in automotive materials and processing
  - Continue on research and research publications
  - Offer two research assistantships
  - Organize and hold one technical workshop/symposium

Participating Faculty

Prof. P.K. Mallick	Material Properties, Processing, Joining, Polymers and Composites
Prof. G. T. Kridli	Metal Forming
Prof. E. Orady	Casting, Machining
Prof. P. Mohanty	Additive Manufacturing, Nanomaterials, Laser Processing, Solidification, Casting
Prof. H. T. Kang	Fatigue, Finite Element Analysis
Prof. G. Reyes	Thermoplastic Matrix Composites, Ballistic Impact

Activities

- Graduate Education
- Materials Database
- Seminars and Symposia
- Research
- Collaborations

Graduate Education

- Graduate Courses taught in FY 2010
  - Advanced Steels for Automotive Applications
  - Analysis and Design for Vehicle Crashworthiness
  - Automotive Composites
  - Manufacturing Processes for Automobiles
  - Advanced Topics in Mechanics of Composite Materials
- Course developed in FY2010
  - Automotive Assembly Systems

Automotive Materials Database

- Contains archival and encyclopedic information on structural automotive materials
- Database on properties, processing, test methods and application examples
- Internet access to industry, universities and individuals @ idpsun.engin.umd.umich.edu:8080/

Seminars and Symposia

Seminars organized by CLAMP

- First Industry/University Gate Forum in March 2001
- Lightweight Automotive Materials Symposium in May 2003
- Canada-China-US Workshop on Magnesium in October 2005
- 21st Annual Technical Conference of the American Society for Composites in September 2006
- 12th US-Japan Conference on Composite Materials in September 2006.
- Workshop on Fuel Cell Materials and Manufacturing in June 2007
- Symposium on Materials for Lightweight Vehicles in December 2009

Research Facilities

- Materials Testing Laboratory
- Materials Characterization Laboratory
- Corrosion Laboratory
- Plastics and Composites Processing Laboratory
- Metal Forming Laboratory

Sponsored Research

- G.T. Kridli, “Investigating the Superplastic Behavior of Twin-roll Cast Magnesium Alloys for Effective Use in Automotive Applications”, Qatar National Research Fund.
- H.T. Kang, “Investigation of Weld Fatigue of AHSS and Conventional Steel Joints,” Auto-Steel Partnership.
- H.T. Kang, “Investigation of Thermo-Mechanical Fatigue Characteristics of Cast Aluminum (AL319-T7),” Chrysler.
- P. K. Mallick, “Evaluation of Titanium for Vehicle Fuel Economy and Performance Improvement,” Pacific Northwest National Laboratory.
- G. Reyes, “Development of a New Low-Cost Environmentally Friendly Lightweight Thermoplastic-based Composite/Metal Hybrid System,” UM Rackham Fellowship and Grant Program.
- G. Reyes, “A Novel Dynamic Joining Method to Improve the Recyclability of Aluminum Alloys,” UM-D Faculty Research Initiation and Seed Grants.

Research Funded by CLAMP

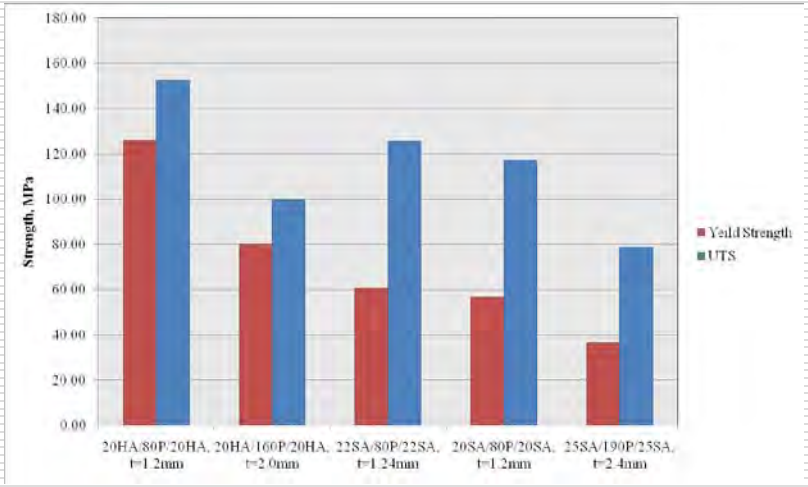
- Development of Corrugated Sandwich Composite for Lightweight Closure Panels
- Fatigue of Metal/Composite/Metal Laminates
- Fatigue of Injection Molded SFT with PA-6,6
- Tensile, Fatigue and Forming Properties of Self-Reinforced Composites
- Development of Thermally Conductive Composites for Lightweight Heat Exchangers

Investigating the Superplastic Behavior of Twin-Roll Cast Magnesium Alloys for Effective Use in Automotive Applications

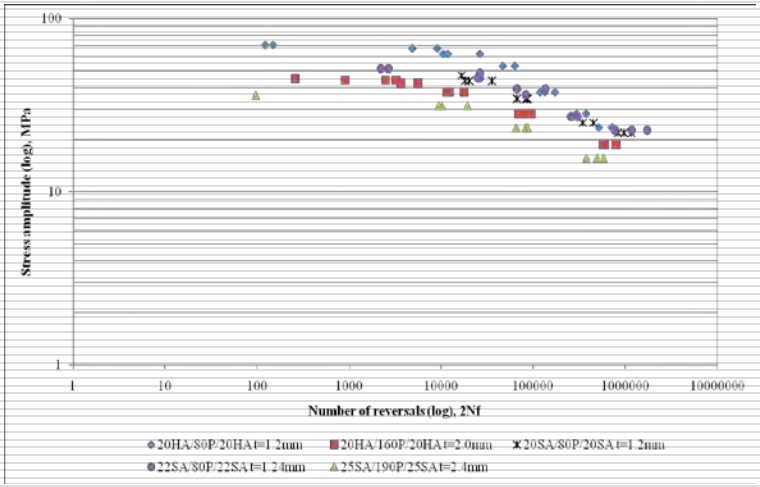
- **Research Team**
  - Prof. Ghassan Kridli
  - Hussein Zbib and David Field, Washington State University
- **Collaborators**
  - Texas A&M at Qatar, PNNL, Masdar Institute (Abu Dhabi)
- **Work Plan**
  - Analyze microstructure and evolution of the mechanical properties during thermo-mechanical treatment.
  - Develop physically-based evolution laws for the microstructure that can predict mechanical properties
  - Develop a constitutive model coupling microstructural features and their evolution to macroscopic behavior
  - Implement the model into a numerical tool for large scale applications.
  - Optimize the thermo-mechanical treatment parameters

Fatigue Characteristics of Al-PP-Al Sandwich Sheets

- Investigators: Prof. P. K. Mallick and R. Mandapati (GSRA)
- Objectives: Study the effects of sheet/core thickness and bonding on the fatigue strength of Al-PP-Al sandwich used for automotive body panels



Yield and Tensile Strengths of Al-PP-Al Sandwich



Fatigue S-N Curves of Al-PP-Al Sandwich

Development of Coupled Thermo-Mechanical Finite Element Analysis Tools for Simulating Warm Forming Processes

Investigators

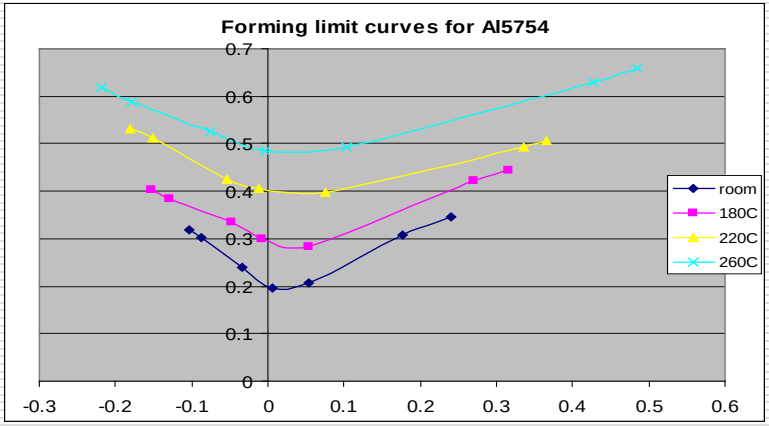
- Ghassan Kridli and Tigran Abovyan (GSRA)

Collaborator

- Ford Motor Company

Results

- Developed criteria that allow for numerical prediction of the forming limit curves for aluminum alloys.

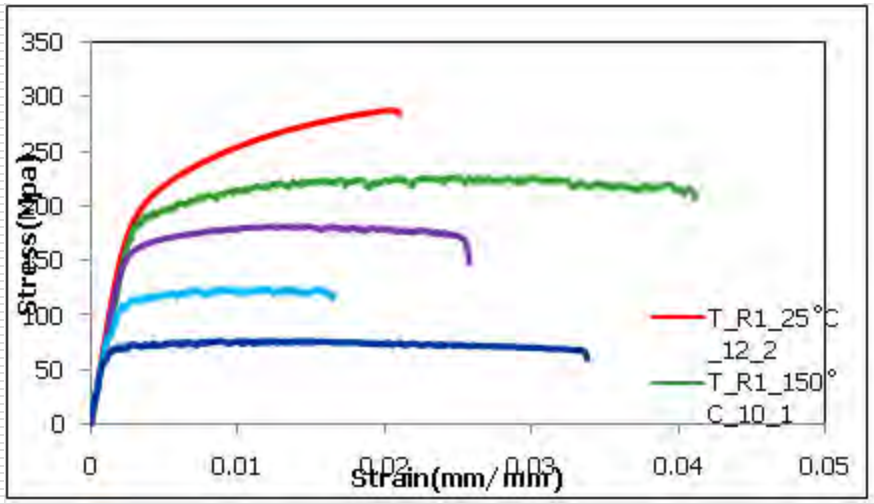


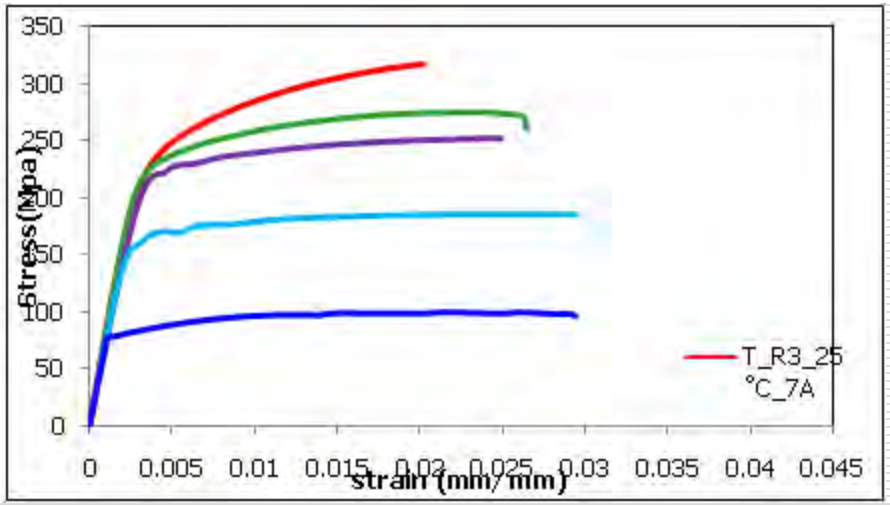
Forming limit curves for AA5754 at different temperatures

Investigation of Thermo-Mechanical Fatigue Characteristics for Cast Aluminum (AL319-T7)

Investigator: Prof. Hongtae Kang

Objective: Determine the tensile and fatigue characteristics of cast aluminum alloy (AL319-T7) at high temperatures

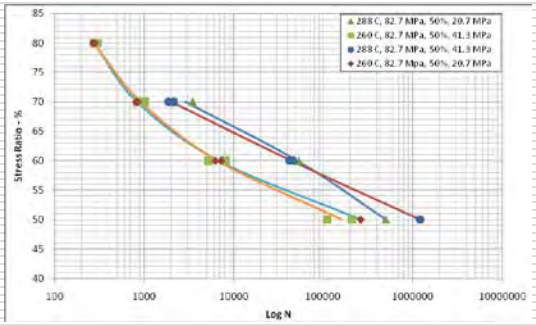




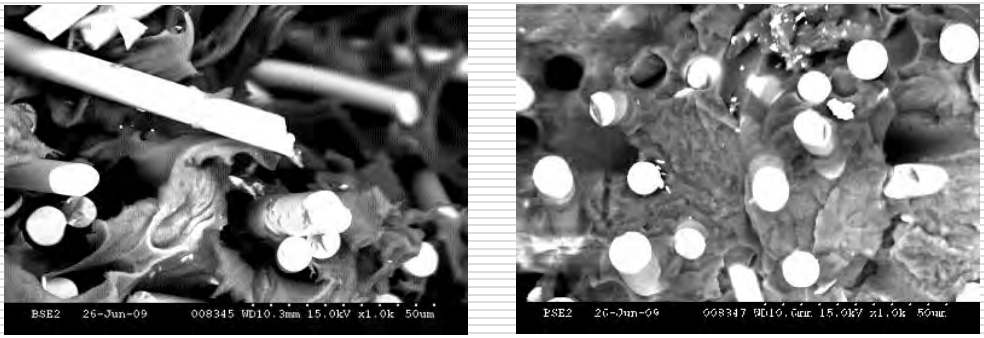
Tensile characteristics of AL319-T7 at different temperatures and strain rates

Fatigue of Injection Molded Short Fiber Reinforced Nylon 6,6

- Investigators
  - Prof. P.K. Mallick and S. Sankaran (GSRA)
- Objectives
  - Study the effects of injection molding parameters on the fatigue performance of short glass fiber reinforced nylon 6,6
  - Study the effects of injection molding parameters on fiber orientation and relate it to fatigue performance



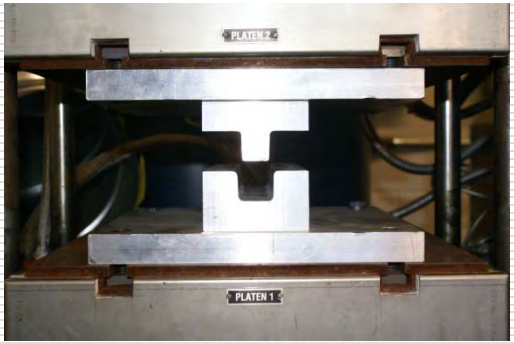
Effect of Melt Temperature on Fatigue S-N Diagram



Fracture Surfaces of Specimens after Fatigue Tests

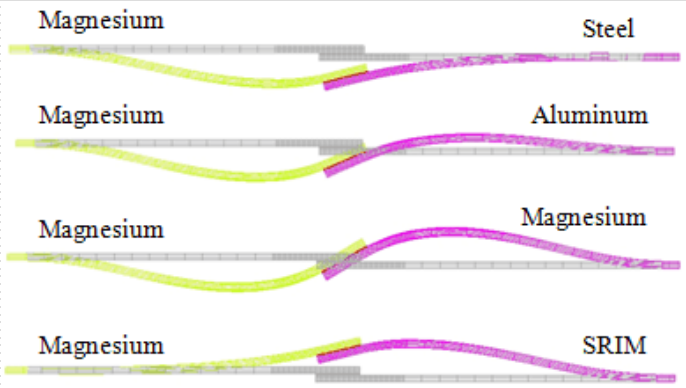
Mechanical and Processing Characteristics of a Self-Reinforced Polypropylene

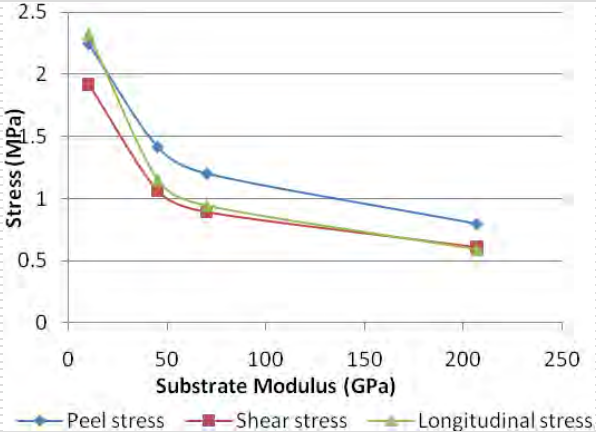
- Investigators:
  - Prof. P. K. Mallick and S. Valluri (GSRA)
- Objectives:
  - Determine the effect of temperature on the tensile and fatigue characteristics of Tegris, a commercially available self-reinforced polypropylene
  - Determine the effect of processing conditions on the springback of self-reinforced polypropylene



Failure Prediction of Adhesive Joints in Magnesium Alloys

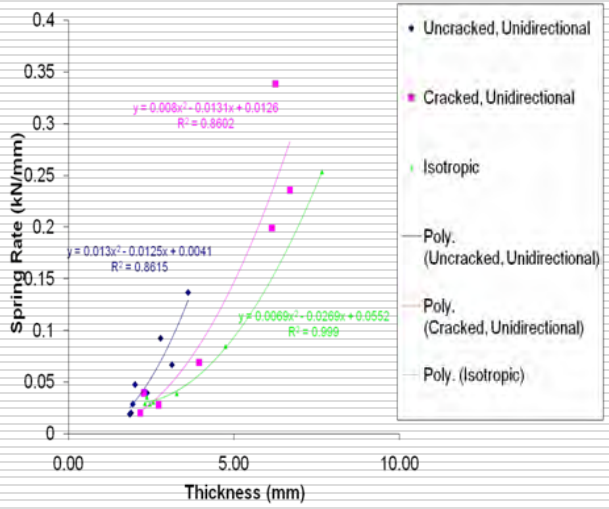
- Investigators:
  - Prof. P.K. Mallick and S. Bhambure (GSRA)
- Objective
  - Develop an energy-based approach to predict the failure load of adhesive joints in magnesium alloys



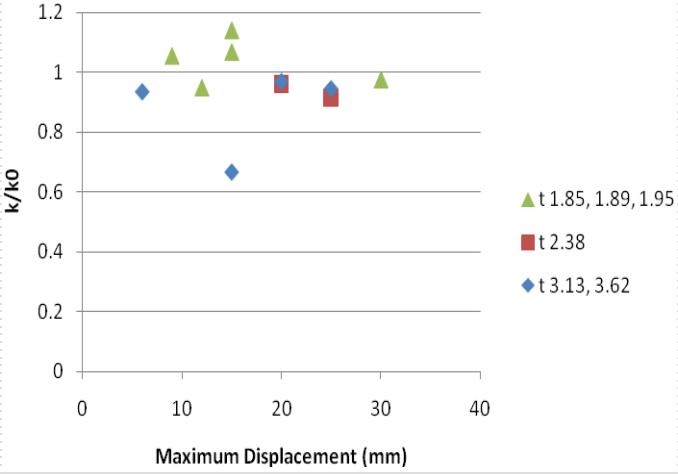


Development of Composite Elliptic Springs for Automotive Suspensions

- Investigators:
  - Prof. P. K. Mallick and B. Fell (GSRA)
- Objective:
  - Study the static and fatigue behavior of lightweight composite elliptic springs that may be used replace coil springs



Spring Rate vs. Thickness



Spring Rate Change Due to Fatigue Loading

Modeling and Damage Repair of Woven Thermoplastic Composites subjected to Low Velocity Impact

- Investigators
  - Prof. G. Reyes and U. Sharma (GSRA)
- Key Results
  - A one step compression molding process was successfully used to repair the impact damaged laminates.
  - Repaired samples showed a significant recovery of stiffness and flexural strength.
  - The maximum recovery of the flexural strength was limited by the fiber breakage damage present after low velocity impact

Fracture Properties of High Performance Carbon Foam Sandwich Structures

- Investigators
  - Prof. G. Reyes and S. Rangaraj (GSRA)
- Key Results
  - A new range of lightweight, multifunctional hybrid structures based on a carbon foam core and carbon fiber-reinforced PEEK skins have been manufactured and tested.
  - Single cantilever beam tests have shown that an excellent level of adhesion can be achieved between the skin and core materials using a simple one step manufacturing procedure.
  - Finally, three-point bend test results have shown that these systems exhibited stable failure by localized foam densification and cohesive bi-material crack propagation

Proposed Future Work

- Develop a graduate course on “Modeling of Thermo-Mechanical Automotive Manufacturing Processes”
- Develop new areas of research in Metal-Composite Hybrid Front-End Structure to address the following issues:
  - Optimum design and material selection for Stiffness and Crashworthiness
  - Joining of Metals and Composites
  - Durability and Vibration Characteristics
- Offer a one-day seminar on Modeling of Mechanical Properties and Processing of Automotive Materials

Collaborations

- Partnership with CLAMP for Research and Development Projects
  - Ford Motor Co.
  - Chrysler
  - USAMP
  - AISI
  - PNNL
  - Washington State University
  - Texas A&M at Qatar
  - Masdar Institute (Abu Dhabi)
  - Ulsan National Institute of Science and Technology, S. Korea (an MOU is under consideration)

Summary

- Graduate courses on automotive materials and processes are continued to be offered. Three new graduate courses were developed and taught in FY2010.
- Research on a variety of topics related to lightweight automotive materials and processing are being continued.
- Many collaborative research has been initiated and will be continued in FY2011.
- Interaction with automotive OEMs and suppliers has been maintained through seminars, collaborations and industry visits.

Publications

Book Title:
"Materials, design and manufacturing for lightweight vehicles"

Editor:
Prof. P. K. Mallick

Publisher:
Woodhead Publishing/CRC Press

Published in 2010