Anchored in Tradition –
Soaring with Innovation:

Research in Manufacturing and
Engineering Design

at UW Mechanical Engineering

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Overview

• Research in manufacturing and engineering design
  – Emerging areas
    • Micro/Nano Manufacturing
    • Biomedical Manufacturing

• Summary
Superplastic Forming of Friction Stir Welded (FSW) Titanium Joints

Objective:
To develop a FSW/SPF process for Titanium Alloy.

Challenge:
- Controlling the geometry, optimizing FSW conditions
- Surface and sub-surface integrity
- Minimizing defect

Current Status:
- Titanium is weldable by FSW
- FSW joint Titanium was successfully superplastically formed

Funding: The Boeing Company
Dynamic Thermal Tensioning to Control Welding Induced Distortion

**Objective:** To control welding induced distortion caused by production variation.

**Challenges:**
- Large structure, tight tolerance
- Coupled thermal mechanical material behavior
- Long time-delay

**Results:**
- Scrap rate from 7% to 1%
- Millions of dollars saved

**Funding:** Genie Industries, Redmond, WA

Prof. Wei Li
A Unified Algorithm to Predict Vibration of Rotating Flexible Structures

Prof. I. Y. (Steve) Shen

Challenges:
- No algorithms are available to predict vibration of rotating machines with arbitrary geometry.
- Design simulations rely on special software based on specific geometry.
- Physics of rotating machines remains largely unclear.

Achievements:
- Developed algorithms to predict response for arbitrary geometry.
- Filed a patent to protect the algorithm.
- Transferring technology to software developers.

Funding: NSF, ARO
Manufacture of Polymer Photonic Crystal Fiber

Objectives:
- Incorporate non-linear organics.
- Tailor PCF for highly non-linear behavior.
- Hole size, pitch controlled to 1-2%.

Challenges:
- Low processing temperatures.
- Convection’s role.
- Steady/unsteady flow.
- Heat transfer effect on PCF dimensions.

Applications:
- Wavelength converters, high speed light modulation, super-continuum generation.

Funding: NSF, STC/MDITR
Objective:
To develop a continuous microcellular extrusion process for environmentally benign plastics: Recycled PET and corn-based PLA

Challenges:
• Short gas diffusion time
• Fast bubble nucleation
• Control of bubble growth

Funding:
to be funded by NSF
Emerging Area 1: Micro/Nano Manufacturing
Objective:
To fabricate mass-producible micro/nano structures such as gaps, pores, channels, and membranes
Objective:
To develop wafer scale assembly of nano/bio materials with an extremely high packing density (for example, 100 molecules/μm)

Applications:
- Sensing platform for bio/chemical species
- Nanoelectronic transistors
- DNA analysis

Nanomanufacturing Lab. Chung’s group
Emerging Area 2: Biomedical Manufacturing
Patient-Specific Manufacturing (PSM)

**Objective:**
To rapidly fabricate patient-specific parts

**Current Status:**
- Accurate models (CAD models and physical prototypes) for pre-operative planning created quickly/economically from medical scan data
- Provisional patent submitted; pursuing commercialization with Tech Transfer
- Clinical trials underway (TGIF funding)
- In the works: Bio-compatible custom implants

Funding: NSF-STTR, TGIF

Profs. Duane Storti, Mark Ganter
Randy Ching, Rhonda Anderson
Solvent-free Process for Tissue Engineering Scaffolds

Profs. Wei Li and Vipin Kumar

Objective:
To develop a solvent-free processing technique for fabrication of biodegradable porous polymers with interconnected pores

Approach:
Solid state foaming and ultrasonic cavitation

Results:
Original foam sample

(Diameter of the sample is 20 mm, pore size 200-300 μm)

Foam sample after ultrasonic processing

Top        Bottom        SEM

Funding: NSF
Selective Ultrasonic Foaming for Lab-on-a-Chip and Animal-on-a-Chip Devices

Objective:
To develop lab-on-a-chip and animal-on-a-chip devices using the selective ultrasonic foaming process.

Approach:
Creating open cell porous structure with controlled pore size at selected locations.

Example:
a passive micromixer

Funding: NSF
Other Research

- Machining of composites, *Mamidala Ramulu*, NSF and Boeing
- Water jet peening, *Mamidala Ramulu*, Flow International
- Fuel cell materials selection and design for recycling, *Joyce Cooper*, DOE and NSF
- Design of a Thermal Protection System, *Ashley Emery*, NSF
- Fabrication of Nanofoam, *Vipin Kumar* and *Wei Li*, NSF
- Rapid manufacturing for autonomous aerial vehicle propulsion, *Duane Storti* and *Mark Ganter*, Subcontract from Powerix DoD funding underway
- Microcellular coffee cups, *Vipin Kumar*, WTC and MicroGreen
- Cluster computing for fluids simulation and CAD, *Mark Ganter*, Intel
**Design of a Thermal Protection System**

**An Application of Global Sensitivity, Gaussian Processes, Markov Chain Monte Carlo, and Bayesian Inference to a highly Stochastic System**

**Questions:**
1) What is the metric of survival?
2) What is it sensitive to?
3) What does its probability look like as a function of the parameters?

**The Metrics**
1) Time for the reaction front to reach the component
2) Thickness of the reaction front

**The answer obtained by Gaussian Processes and Markov Chain Monte Carlo**

E1 and E2 affect the metrics in different ways and the usual sensitivity calculation completely misses the effect of E1.

**Estimate parameters from TGA Experiments using Bayesian Inference**

Prof. A F Emery
Life Cycle Assessment and Fuel Cells Design

• Active research topics includes:
  1) Emerging technology design for the environment (forecasting the energy/materials use and emissions of mass production design and manufacturing sequences)
  2) Fuel cell materials selection and design for recycling
Waterjet Peening Process

• **Objective:**
The goal of this research is to develop waterjet surface treatment processes at ultra high pressures to induce controlled surface characteristics.

• **Challenge:**
  • Controlling the droplet size, optimizing jet conditions
  • Inducing desired surface textures
  • Increasing the compressive layer depth to enhance fatigue strength

• **Current status**
  • A mathematical model was developed and verified.

**Funding:**
In-kind support from Flow International
Edge Trimming and Drilling Methods for Composite Materials

**Objective:**
Design and development of cutters for machining hard-to-cut materials, such as Polymer, Metal and Ceramic Composite Materials

**Challenges:**
- Cutter design
- Surface and edge finishing quality
- Process Modeling
- Identifying the Cutting Mechanisms

**Funding:** The Boeing Company and other multiple of local industries

**History:** Work initiated in 1985, 20 years of effort.

**Standing:** UW is one of the leading schools in composite machining research.
Microcellular Coffee-Cups

- Recycled PET
- Service Temperature, Cycle Time, and Product Stiffness Goals Met
- Startup company launched in 2003
PEI Nanofoam

Prof. V. Kumar

Cell Size ~ 50 – 150 nm

Foam Density Reduction ~ 50%

Cell Density ~ $1.4 \times 10^{14}$ cells/cm$^3$

(Unpublished Result from Kumar's Lab, May 2006)
Rapid/Additive Manufacturing
Profs. Rhonda Anderson, Randy Ching
Mark Ganter, and Duane Storti

• Active topics include:
  – Patient-specific manufacturing
  – Material systems for rapid manufacturing
  – Solid modeling systems to support new scanning/fabrication technologies
  – Autonomous vehicles
  – Cluster computing applications
Summary

• Strength
  – Anchored in tradition:
    • Strong research in manufacturing and engineering design
    • Broad expertise in materials and structures, thermal and fluids, dynamics and controls, and manufacturing and design
  – Soaring with innovation
    • Growing research in emerging areas, micro/nano manufacturing and biomedical manufacturing
    • Willing to break boundaries of traditional engineering discipline
Summary (cont’d)

• Opportunities
  – Demand for micro/nano manufacturing and biomedical manufacturing technologies
    • High performance materials, nano devices
    • Biomedical devices for drug discovery, diagnostics, and disease treatment
  – Funding agencies
    • NSF, NIH, DOD, etc.
  – Local environment
    • State initiative (Life Science Discovery Fund (SB 5581))
    • Local biotech industry
    • Potential collaboration on campus