Objective
- become a focal point for developing critical or novel technologies in laser-based manufacturing
- help industrial companies in implementing new laser applications

Current Areas
- Laser-assisted machining
- Laser hardening and alloying
- Laser cladding and direct deposition
- Laser shock peening
- Laser-assisted micromachining

Current Status
- Funded by the Indiana 21st Century R&T, NSF, DoD and over 10 industrial companies
- 9 faculty, 15 graduate students, 1 staff, 1 technician

[Links]
- http://tools.ecn.purdue.edu/~clm/
- PI: Yung C. Shin, Professor
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Purdue University - School of Mechanical Engineering
Laser-assisted Machining
Yung C. Shin, Professor of ME

Objective
• To develop a cost-effective precision fabrication technology for difficult-to-machine materials such as ceramics and high temperature alloys

Method
• Laser heating + conventional tool:
  • controllable heat source
  • heats workpiece prior to material removal
  • Traditional cutting tool removes material

Significant Result
• successfully machining of various ceramics and high temperature alloys (silicon nitride, PSZ, mullite, Inconel 718, Waspaloy, CGI, P550, MP35, MMC, CBN wheels)
• significantly higher productivity
• scientific tools for modeling and monitoring

Current and Future Work
• We are currently developing an integrated processing capability to perform laser-assisted milling, heat treating and cladding.
• We plan to expand the application domain of LAM to other materials.
• Laser-assisted micromachining set-up has also been developed.

Sponsors: National Science Foundation, Indiana 21st Century R&T Fund, Schlumberger, Caterpillar, Rolls Royce, Army

http://meweb.ecn.purdue.edu/~lampl/
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Purdue University - School of Mechanical Engineering
Objective
• develop high throughput laser-based micromachining capabilities applicable to a wide range of materials
• enhance the understanding of ultrashort (and very high power density) laser and material interaction

Current Areas
• Ps second laser micro hole drilling
• Laser micromachining
• Modeling of laser-matter interaction during ultrashort pulsed laser ablation

System
• 10 ps laser
• optical scanner
• high precision xyz system

Significant Results
• sample machined parts
• predictive modeling of ablation depth

http://tools.ecn.purdue.edu/~clm/
Laser Direct Deposition
Yung C. Shin, Professor

Objective
• To develop a cost-effective direct laser deposition and freeform fabrication processes

Current Approach
• Laser freeform fabrication
• Laser deposition + machining

Significant Result
• 3 different deposition systems
• powder flow characterization
• successful experimental studies
• scientific tools for modeling and monitoring

Modeling Strategy
• Laser Shape/Profile
• Laser Traverse Speed
• Powder Feedrate
• Material Properties (deposition, substrate, liquid melt)
• Incoming Powder Momentum/Thermal Energy
• Gas Velocity/Convection Boundary

Sample parts fabricated by the direct laser deposition process

Three layers of deposition of stellite 6

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Sponsors: Indiana 21st Century R&T Fund
NSF, ARL, Caterpillar

Purdue University - School of Mechanical Engineering
Objective
• To develop a cost-effective novel direct material deposition processes for surface enhancement and remanufacturing using lasers

Current Areas
• Laser cladding
• Functionally graded coating

Significant Result
• successful cladding using preplaced and blown powder deliver
• scientific tools for modeling and monitoring

Laser cladding examples (single and overlapping tracks)

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Sponsors: Indiana 21st Century R&T Fund
NSF, ARL, Cummins, Caterpillar

Purdue University - School of Mechanical Engineering
Objective
- develop a comprehensive and accurate predictive modeling tool for laser shock peening for process design optimization

Current Status
- Developed predictive models for 2D axi-symmetric plasma model and 3D finite element stress model
- Most of the important relevant physical processes for laser ablation and plasma formation and expansion have been considered
- The only real predictive model available in literature

Result

Modeling Approach

Incoming laser pulse

Breakdown Plasma model

Laser pulse transmitted through the breakdown plasma.

Confined Plasma model

Plasma recoil pressure exerted on workpiece surface

Finite element mechanics model

Residual stress

http://tools.ecn.purdue.edu/~clm/
Purdue University - School of Mechanical Engineering
Laser Hardening and Alloying
Yung C. Shin, Professor

Objective
• To develop a cost-effective laser hardening process and predictive models for process design and optimization

Modeling Approach

Input
Operating Parameters:
P, v, rb, Dw f, overlap

Thermal Model

T(r,z,t)

Thermal History

CCT Diagram

Kinetic Model
Pearlite to Austenite Transformation

Homogenization of Austenite

Output
Phase & Hardness Plots

Significant Result
• successful hardening of various steel alloys
• transformation hardening and nitriding of Ti-6Al-4V alloys
• near maximum hardness achievable
• prediction of hardness, stresses & deformation

Predicted vs. measured hardness profile

Sponsors: Indiana 21st Century R&T Fund International, Rolls Royce, NSF

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**Objective**
To develop a systematic method for intelligently optimizing, monitoring, and controlling complex manufacturing processes and other mechanical systems.

**System Overview**

- Sensing & Monitoring
- Control
- Modeling (Neuro-fuzzy Network)
- Intelligent Supervisory Controller
- Optimization Database
- Diagnosis

**Significant Result**
- Developed the Generalized Intelligent Grinding Advisory System (GIGAS), which automatically recommends optimal grinding conditions.
- Developed an autonomous learning scheme for complex nonlinear processes.
- Developed an intelligent sensor fusion strategy.

**Current and Future Work**
- Intelligent optimization of time-variant systems.
- Application to real world problems.
- Intelligent monitoring and diagnostics.

**Sponsor:** NIST ATP

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http://widget.ecn.purdue.edu/~simlink/
Intelligent Control
Yung C. Shin, Professor

Objective
To develop an intelligent control system that does not require mathematical models or does not require the measurement of conditions to be controlled

Significant Result
• Developed an data-driven intelligent control scheme that does not require mathematical model
• Extended the intelligent control system to multi-variable systems
• Successful application of intelligent control schemes to many systems

Current and Future Work
• Intelligent multivariable control schemes
• Intelligent observer-based control schemes

Application Example: force control

http://widget.ecn.purdue.edu/~simlink/

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**High Speed Machining**  
Yung C. Shin, Professor

**Research Objectives**  
To develop the enabling technologies for high speed machining and machining systems

**Approaches**
- **Process simulation**  
  - Prediction of chatter, force and vibration for various aerospace materials  
  - Milling, turning, boring, grinding processes
- **Digital machining system**  
  - Process design and optimization via virtual system  
  - Virtual machining system
- **Spindle and Tooling Design**  
  - Integrated predictive models for high speed spindles and tools
- **High speed Machining**  
  - Investigation of tool life, residual stress, surface finish, etc. in the high speed machining regime  
  - Titanium, Aluminum 7075-T6, Inconel and other high temperature alloys

**Sponsor**: National Science Foundation, NIST/ATP, Precise
Virtual Machining System
Yung C. Shin, Professor

Objective
To develop a virtual machining system that can be used for process design and optimization

Overall Approach
- Mechanistic models that can predict various process conditions have been developed.
- A predictive thermo-dynamic spindle analysis program has been developed.

Results
- Mechanistic models that can predict various process conditions have been developed.
- A predictive thermo-dynamic spindle analysis program has been developed.

Output
- Visualization (virtual reality, or other computer graphics)
- Solid modeling of machine tool and workpiece (CAD)
- Tool path generation (CAM)
- NC code generation and verification (CAM post-processor)
- Workpiece geometry
- Machine tool/workpiece geometry and material
- Verified or optimized machining parameters

Digital Machining System
- Thermo-dynamic model of machine tools/workpiece
- Machining process model
- Machining process model
- Machine tool constraints
- Process attributes
- Forces
- Responses

Sponsor
NSF, Caterpillar, Rolls Royce, GM

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