Dr. Xia Lu
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Objectives: Research & development position in material design, material characterizations and simulations, structural dynamics, acoustics, vibration control, smart structures, health monitoring.

Education

- 2002 Ph.D. in Aerospace Engineering, Georgia Institute of Technology, GPA: 4.0/4.0
- 1993 M.S. in Solid Mechanics, Peking University
- 1990 B.S. in Mechanics, Peking University

Experience

Postdoctoral Fellow: School of Aerospace Engineering, Georgia Institute of Technology
2/2003 – Present
Project:

- ONR MURI project (5/2004 – 5/2007): *Mechanisms of Nozzle Erosion and Design of Materials to Minimize Nozzle Erosion*
Research experiences: Design of rocket model for testing, fabrication of nozzle, nozzle erosion testing, and ab initio studies of nozzle erosion mechanisms.
- Air Force Office of Scientific Research (AFOSR) Multiple University Research Institute (MURI) 2002 Project (7/2002 – 7/2007): *Design of Multifunctionl Energetic Structural Materials (MESM).* "This MURI project is to develop tools for the optimal design of multifunctional reactive materials that are made of metal/oxide powder mixtures. As known, traditional organic high explosives have no structural strength, while traditional structural materials like metals have no explosive power at all. The MESMs are engineered as novel nanostructured systems to simultaneously attain structural strength and enhanced explosive power (much higher than organic explosives), so that they can be used as a dual-functioned material to replace structural materials and high explosives. This new generation of materials has many potential DoD applications like in the design of penetrating warheads for future weapons such as missiles and design of high-performance solid rocket propellants. Therefore, these research topics are of tremendous interest to the Air Force and of considerable national importance."
I am on the key personnel panel for design, modeling and characterization of difunctional energetic structural materials, which are using nanotechnology to increase energy release rate of a high-energy-content metal and metal oxide composite and using the multiscale reinforcement concept including carbon nanotubes to provide the required strength. The concept of multiscale modeling is applied, in which my contribution is on the continuum modeling by using nonequilibrium thermodynamics, also on material characterizations by ab initio methods (or quantum mechanics). This MESM can provide both strength and energy-content requirements. The potential applications are on new shank materials of target penetrating missiles and on debris-free rockets.
- NASA Project (1/2004 – 12/2006): *Instrumentation, automation and diagnostics of Autonomous drilling system.* "Exploration of the Martian subsurface will be essential in the search for life and water, given the desiccated and highly oxidized conditions on the surface. subsurface access will be critical for both future in-situ science and Mars sample return. Technologies for subsurface exploration must

support a variety of planned missions over the next two decades. The Smart Lander is scheduled for 2009, and will focus on in-situ science and technology demonstrations for later missions. One of those later missions that will include subsurface exploration will be the Mars Sample Return (MSR) mission, currently slated for the 2011-2014 timeframe. Simple subsurface devices (moles, scrapers, etc.) may also be carried by smaller missions as soon as the Beagle-2 mission in 2003, and the search for water on Mars could intensify after the MSL mission, with long-term plans that include drilling hundreds of meters into hard rock or into the polar ice caps. *This project* is to develop enabling astrobiology technologies for planetary subsurface exploration, specifically through the iterative implementation and field testing of drilling automation."

My participation is on the design of drill structural dynamic instrumentation, the development of monitoring and diagnostics techniques based on model based diagnosis with uncertainty models. The fuzzy neural network techniques are to be developed to direct the model based identification techniques to specific sub-categories like whirl mode identification or stick-slip mode identification or hard-target identification.

Graduate Research Assistant: School of Aerospace Engineering, Georgia Institute of Technology 3/1998–12/2002. All of the projects are extended to my postdoctoral research.

Projects

- Air Force Office of Scientific Research (AFOSR) Project (5/2001-): *Thermomechanics of Target Penetration*. "Many kinetic energy missiles are designed to penetrate through concrete targets before the initiation of reaction of energetic materials housed in the missile. Critical loading conditions for the design of such missiles are not the aerodynamic forces but the loading environment during penetration through concrete. To effectively defeat hard and deeply buried targets, technologies of employing very high striking velocities are explored. However, with an increase in the striking velocity, a measurable mass loss and nose erosion of the projectile are observed. The observed erosion is at a very high rate and is highly localized to the nose region of the penetrator and has the effect of changing the shape of the nose of the projectile. The shape of the nose is known to be critical in governing the intended penetration trajectory. Therefore, nose erosion results in a deviation of the penetrator from its desired path in the target materials. In some cases, this deviation is many times the diameter of the penetrator. This project is to develop theoretical models that are currently unavailable to predict penetrator nose erosion and resulting shape change that contributes to the observed trajectory deviations under very high impact velocities in the range of 850 – 2600 m/sec, and to develop methods to engineer the design of materials and structural characteristics of a new class of penetrators with superior impact and penetration performance while meeting or enhancing other specific objectives of penetrators."

  I have been responsible for the fundamental study on irreversible thermodynamics modeling of metallic penetrators with dislocation based plasticity and stress-thermal-induced phase transitions and the development of simulations of penetration events. I am also involved in exploring the new and available techniques for real time stress and temperature measurement and material design.
- Air Force Research Laboratory (AFRL) Project (1/2001-): *Active control on F/A-18 vertical tail buffet at high angles of attack by using smart structure concepts*. "This project is to efficiently alleviate the fin buffeting of all-weather F/A-18 aircraft, to

provide technique that be applied to other similar military, and also to provide knowledge to help design new high-performance, highly maneuver fighter and attack aircrafts."

I have been responsible for modeling and design of an active control system, partially contributed to building a $1/12^{th}$ scale F/A-18 model and will conduct wind tunnel tests to validate the developed active control system.

- Smart Musical Instrument Project: *boosting violin's IQs.* Design, simulation and implement of active vibration control and musical instrument quality improvement (e.g. violin) by using piezoelectric actuators and DSP. The IQs of violin was improved by designing a smart sound post.
- Research in *thermoeletromechanics of piezoelectric*. The study is to characterize the 'smart' materials used as active component in the design of smart structure. I have modeled the complicated thermo-electro-mechanic behavior of ferroelectric materials by bridging the characterization of microstructural evolution into a nonequilibrium thermodynamics framework.
- Research in *nonlinear dynamics, analysis of delaminated structure, analysis of adaptive structure*. The study is the basis for nondestructive health monitoring techniques (NHMT).
- Research in *damage detection and health monitoring*. Health monitoring technique reports the onsite structure response in a nondestructive way. It gives a precaution of possible failure and therefore extends the sevice life or promise safety of the monitored structure systems. The applications can be on aerospace, automotive, civil structures, machine tools, medical instruments and biomechanical systems. I have developed a NHMT by using the nonlinear structural dynamic characteristics.

Graduate Research Assistant: Department of Mechanical Engineering, Washington State University, 9/1997–1/1998. Simulation of crystal growth under magnetic field and microgravity environment.

Graduate Research Assistant: Department of Mechanical Engineering, Louisiana State University, 1/1997–8/1997. Simulation of crystal growth under magnetic field and microgravity environment.

Software Development Engineer: Peking University Founder Group Corporation, Beijing, China, 7/1993–12/1996. Developed barcode layout system, nonlinear chart layout system, advertisement system (team work), test system for college English (on Windows 95/98 or Window NT)

Graduate Teaching Assistant: Department of Mechanics, Peking University, 1991 – 1992: Grading and tutor for class "Probability & Statistics"

Skills

- **Research:** Solid mathematics and theoretical foundation, equipped with knowledge and research insight in the areas of aerospace, mechanical and electric engineering, and mechanics of materials. Experimental design and integration, familiar with various vibration and noise measurement instruments and facilities.
- **Computer:** Matlab, ABAQUS, IDEAS, Microsoft Offices, Mathematica, Maple, C/C++, Fortran, PowerBuilder, PhotoShop.

Honors/Activities

- Award for academic distinction, Peking University, 1988
- Guanghua Prize, Peking University, 1989

- Student member of AIAA since 1999, member of AIAA[1] since 2003, senior member
- Student member of ASME since 2002, member of ASME[2] since 2003

Publications

1. X. Lu and S. Hanagud, "A Domain Evolution Model for Hysteresis in Piezoceramic Materials", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 2005, accepted.
2. X. Lu and S. Hanagud, "Structural phase transitions and equation of state of aluminum from first-principles", submitted to Phys. Rev. B.
3. X. Lu and S. Hanagud, "Carbon-Nanotube-Reinforced Energetic Nanocomposites: CNT Alignment Technique and Simulation", submitted to Acta Materiallia.
4. X. Lu and S. Hanagud, "A Nonequilibrium Irreversible Thermodynamics Model for Material Damping", submitted to Int. J. Solids and Struct.
5. X. Lu and S. Hanagud, "First-principles Equation of State for intermetallic energetic structural materials", to be submitted to Physical Review B.
6. X. Lu and S. Hanagud, "First-principles Equation of State for hematite", to be submitted to Phys. Rev. Letts.
7. X. Lu and S. Hanagud, "Extended irreversible thermodynamics modeling for self-heating & dissipation in piezoelectric ceramics", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, v. 51, n. 12, 2004, pp. 1582 – 1592.
8. A. Gogulapati, X. Lu and S. Hanagud, Equation of state from first principle. International Conference on New Models and Hydrocodes for Shock Wave Processes, May 16 – 20, 2004.
9. X. Lu and S. Hanagud. Nonequilibrium Thermodynamics Model of Shock-Induced Chemical Reactions in Energetic Nanocomposite. International Conference on New Models and Hydrocodes for Shock Wave Processes, May 16 – 20, 2004.
10. X. Lu and S. Hanagud, "Phase Transitions and Dislocation-Based Plasticity at High-Strain-Rates in Solids", 45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference AIAA-2004-1920.
11. X. Lu and S. Hanagud, "Carbon-Nanotube-Reinforced Energetic Nanocomposites: CNT Alignment Technique and Simulations", 45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference AIAA-2004-1610.
12. X Lu and S Hanagud, First principle equation of state for an energetic intermetallic mixture, Editors: R Armstrong, N Thadhani, W Wilson, J Gilman, and R Simpson, 2003 MRS Fall Meeting: Symposium AA Synthesis, Characterization, and Properties of Energetic/Reactive Nanomaterials, Dec. 1-5, Boston, MA.
13. X. Lu, V. Narayanan and S. Hanagud, "Nonequilibrium thermodynamic model of shock-induced chemical reaction in multifunctional energetic metal-metal oxide nanocomposites," IMECE2003-42768, 2003 ASME Internal Mechanical Engineering Congress, Nov. 15 – 21, Washington, D.C..
14. X. Lu, and S. Hanagud, "Thermomechanics of impact and penetration of metallic projectile into concretes: Formation of shear bands," IMECE2003-42793, 2003 ASME Internal Mechanical Engineering Congress, Nov. 15 – 21, Washington, D.C..
15. X. Lu, V. Narayanan and S. Hanagud, "A Domain Evolution Model for the Ferroelastic Hysteresis of Piezoceramic Materials," IMECE2003-42764, 2003 ASME Internal Mechanical Engineering Congress, Nov. 15 – 21, Washington, D.C..

[1] The American Institute of Aeronautics and Astronautics (AIAA)
[2] The American Society of Mechanical Engineers (ASME)

16. Lu, X., Naranyanan, V., and Hanagud, S., "Shock-induced chemical reactions in energetic structural materials," Shock Compression of Condensed Matter, 13^{th} American Physical Society Topical Conference, June 20 -25, 2003, Portland, Oregon.
17. V. Narayanan, X. Lu and S. Hanagud, "A Domain Evolution Model for the Ferroelectric Hysteresis of Piezoceramic Materials," 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, AIAA 2003-1439.
18. Lu, X. and S. Hanagud, "Carbon-Nanotube-Reinforced Structural Materials and Nonequilibrium Thermodynamic Models," 44th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, AIAA Paper 2003-1538.
19. Lu, X., and Hanagud, S., "An irreversible thermodynamic model of nonlinearities and hysteresis in piezoceramics," Collect Tech Pap AIAA ASME ASCE AHS Struct Struct Dyn Mater, v. 4, 2002, pp. 2756-2765, AIAA 2002-1551.
20. Hanagud, S. and Lu, X., "Irreversible thermodynamic modeling of phase transition in ferroelectric ceramics under large mechanic or electric loadings," 14^{th} US National Congress of Theoretical and Applied Mechanics, June 23 – 28, 2002, Blacksburg, VA, pp. 477 – 478.
21. S. Hanagud, et al. "Smart structures." McGraw Hill Year Book of Science and Technology 2002, pp. 306-308.
22. S. Hanagud, X. Lu and R. Roglin, "Smart Structure technology & control of buffet induced helicopter vibrations," 27th European Rotorcraft Forum, Moscow, Russia, September 11-14, 2001.
23. S. Hanagud, X. Lu, P. Roberts and D. Henderson, "Model Based Simulation of Buffet-Induced Vibration Control of a F/A-18 Vertical Stabilizer", 42nd AIAA/ASME/ASCE/ AHS/ASC Structures, Structural Dynamics, and Materials Conference, 16-19 April 2001, Seattle. AIAA-2001-1352.
24. X. Lu and S. Hanagud, "Extended Thermodynamic Model for Piezoelectric Ceramics", 42nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 16-19 April 2001, Seattle. AIAA-2001-1356.
25. X. Lu, W. Lestari and S. Hanagud, "Nonlinear Vibrations of a Delaminated Beam", Journal of Vibration and Control, v 7, n 6, 2001, pp. 803-831.
26. S. Hanagud, X. Lu, M. Bayon deNoyer, and R. Roglin, "Smart Structure Technology & Control of Buffet Induced Helicopter Vibrations", 26^{th} European Rotorcraft Forum, September 2000, Netherlands.
27. S. V. Hanagud and X. Lu, "Boosting violin IQs," Acoustical Society of America 141st Meeting, Melville, New York, May 3, 2001
28. X. Lu and S. Hanagud, "Irreversible Thermodynamic Models for Damping", ICTAM2000, Chicago, 2000.
29. W. Lestari, X. Lu and S. Hanagud, "Dynamics of a Delaminated Beam: effects of nonlinearity", Collect Tech Pap AIAA ASME ASCE AHS Struct Struct Dyn Mater, 2000. AIAA-2000-1505.
30. X. Lu and S. V. Hanagud, "Modified Extended Thermodynamic Model for Material Damping", Adaptive Structures and Material Systems, ASME, AD, Vol. 59, 1999, pp. 403-410.
31. X. Lu and S. V. Hanagud, "Health monitoring of structures: multiple delamination dynamics in composite beams with axial load", Collect Tech Pap AIAA ASME ASCE AHS Struct Struct Dyn Mater, v 3 1999, p 2348-2357. AIAA-1999-1484.