Smart Vehicle Concepts Center (SVC)
National Science Foundation - Industry/University Cooperative Research Center

Annual Newsletter **December 2009 Issue**

Contents

Membership (Year 2)

Industrial Members (2008-09)

Members for the lead intuition (The Ohio State University):

- Advanced Numerical Solutions
- Army Research Laboratory
- The Boeing Company
- Edison Welding Institute
- Ford Motor Company
- Goodyear Tire and Rubber Co.
- Honda R&D Americas Inc. (2)
- Moog Inc.
- NASA Glenn Research Center
- Solidica
- Transportation Research Center, Inc.

Members for Texas A&M University:

- The Boeing Company
- NASA Glenn Research Center
- Space Engineering Institute

Mission

The mission of the Smart Vehicle Concepts Center (SVC) is as follows: (1) Conduct basic and applied research on the characterization of smart materials, and the development of adaptive sensors, actuators and devices (based on active materials and control methods) for application to vehicle sub-systems and components; (2) Build an unmatched base of research, engineering education, and technology transfer with emphasis on improved vehicle performance; and (3) Develop well-trained engineers and researchers (at the MS and PhD levels) with both experimental and theoretical viewpoints.

Third Semi-Annual Winter 2010 Meeting

A Meeting for SVC Members & Guests

February 23, 2010 8:00 AM to
February 24, 2010 12:00 PM
Texas A&M University
Annenberg Presidential Conference Center
George Bush Presidential Library and Museum
College Station, TX 77843-3141

Tentative Events:

- Overview of the Center (open to guests)
- Review of selected projects (open to guests)
- Reception (open to guests)
- Review of sponsored projects (Members Only)
- IAB Meeting

SVC Contacts including the Winter 2010 SVC meeting

Texas A&M University
Host: Prof. Jim Boyd
E-mail: jboyd@aero.tamu.edu
Tel: 979-458-0419

The Ohio State University
SVC Center Director: Prof. Rajendra Singh
E-mail: singh.3@osu.edu
Tel: 614-292-9044

Administrative Assistant: Caterina Runyon-Spears
E-mail: runyon-spears.1@osu.edu
Tel: 614-292-9044

Please visit www.smartvehicleconcepts.org often for updates!

Second Annual (Summer 2009) Meeting Report

The Second Annual Meeting was preceded by a two hour short course on "Shape Memory Alloys: Fundamentals, Analysis, and Engineering

Applications" presented by Profs. J. Boyd and I. Karaman. It was well attended.

The Smart Vehicle Concept Center held its Second Annual Summer Meeting at OSU on 12-13 August 2009. The open session on August 12 opened with a boxed lunch and an overview of the Center. Center sponsors were invited to give brief presentations about their organizations. A summary of recent research activities and accomplishments was presented. This was followed highlighted research projects from both The Ohio State University and Texas A&M University. Following these presentations, a poster session and a wine & cheese reception was held. Over 18 posters were displayed and manned by student researchers.

The closed session for SVC sponsors was held August 13, 2009, and technical sessions presented detailed reports on the sponsored projects. The Industrial Advisory Board met after the technical presentations. The Board reviewed the operations and evaluation forms, and then provided suggestions for future meetings. Members may view the project presentations and IAB meeting minutes on our website at www.smartvehiclecenter.org. Please note these items are password protected. Contact Prof. Raj Singh for the password.

New NSF Grant

The National Science Foundation has awarded the SVC a new research grant. Investigators Prof. M. Dapino from OSU and Z. Ounaies from TAMU are collaborating on a project titled "Electrospun Polymer-Based Materials as Next-Generation Flexible Sensors." This grant is worth $150K, and research will take place from July 2009 to June 2010.

Field Trip: Students Present SVC Research Posters at Honda R&D

The Smart Vehicle Concepts Center presented a poster session on September 18, 2009 at Honda in Raymond, Ohio. Three OSU faculty and twenty-two students attended. The day started with a tour of Honda facilities and discussion of technical issues before and during the lunch. Thanks to Honda for feeding our students! Nineteen posters were displayed and manned by graduate students. These included "Smart Mounts Design Tool," "PVDF Micro-pillar Sensors for Sound Measurements," "Interfacial Force Sensing," Torque Measurements," and "Active Noise and Vibration Control." Over 50 practicing engineers viewed the posters and interacted with students.

Lara Minor, a Honda R&D engineer (and Honda research coordinator at The Ohio State University) said that Honda was "excited and pleased" by the visit from SVC students. "The students showed a great deal of commitment and maturity." Honda R&D looks forward to the expansion of collaborative efforts with the SVC.

Shravan Bharadwaj, MS student, found the lab tour exciting, insightful and an inspiration to continue working to perform quality research and contribute to the engineering field. He stated that "the Honda poster session was an excellent opportunity to present academic research to engineers and simultaneously gain perspective from the industry's view point towards applicative research." Likewise, Osman Taha Sen, PhD student, believed the session to be beneficial due to the chance to explain research topics to individuals from different areas and with different backgrounds. The different responses will lead them to discover points that were missing.

Students from the SVC were able to network with other researchers and gather interest in the various projects being conducted at the SVC. "The poster session was a great chance to interact with automotive engineers and connect with them on the same research interests," said MS student Ben Barszcz. MS student Ryan Hahnlen found the Honda poster session to be an excellent opportunity to interact with Honda engineers and discuss the SVC's research. Said Hahnlen, "It was rewarding to see their interest and hear their input for the projects. It was very educational to hear about their modeling methods as well as their experimental methods and setups."

Finally, according to Jared Liette, a BS Honors student who recently had the opportunity to intern at Honda R&D, "Research often has a much different perspective on things than industry, and getting feedback on what industry wants out of our research is invaluable."

SVC Students Graduated in 2009

- Phillip Evans (PhD) - mini-project linked to projects #1 and #35
- Ryan Hahnlen (MS) - projects #7 and #36
- Arjun Mahadevan (MS) - project #35
- Shravan Bharadwaj (MS) - project #31

News Item: Texas A&M to lead $4 million NSF-Funded International Materials Institute

Texas A&M University is leading a $4 million, NSF-funded international effort that focuses on materials for energy conversion. The International Institute for Multifunctional Materials for Energy Conversion (IIMEC) is an NSF-funded International Materials Institute, recently established at Texas A&M University. Dimitris Lagoudas, PI of the Texas A&M University SVC, is the director of IIMEC. Key players include Ibrahim Karaman, Tahir Cagin, Dan Davis and Zoubeida Ounaies, Dwight Look College of Engineering; Mostafa El-Sayed and Ken Gall, Georgia Institute of Technology and Pradeep Sharma, University of Houston. The mission of IIMEC is to establish strong collaborations with international participants in North Africa, the Middle East and Mediterranean countries, focusing on transformative research on multifunctional materials exhibiting strong coupling among different fields, resulting in various forms of efficient energy conversion. By bringing high quality research and education programs on materials to the selected international regions, IIMEC will improve the utilization of natural resources and bring balance between renewable and non-renewable energy sources. Key international participants include the British University in Egypt, Science and Technology University in Algeria, Polytechnic School in Tunisia, Bilkent University in Turkey, University of Patras in Greece and Texas A&M University-Qatar. The international partnership also extends to Saudi Arabia, Kuwait, Morocco, France, and Cyprus.

For information contact Dr. Dimitris Lagoudas: lagoudas@tamu.edu

Undergraduates Participate in Sponsored Research Project: High Torque Shape Memory Alloy Motors

A team of students supervised by Professor James Boyd are developing High Torque Shape Memory Alloy Motors. The project was initiated by the Space Engineering Institute, which is affiliated with Texas A&M University and the Johnson Space Center. The team consists of one graduate student and six undergraduate students from aerospace, mechanical, industrial, and electrical engineering, ranging from first-year students to seniors.

The objective is to develop a rotary actuator, driven by shape memory alloys, that has a much higher torque density than conventional gear-motors. High-torque density motors will be useful in space and weight-constrained applications such as oil wells and satellites. The prototype consists of an SMA wire that pulls a rack connected to a pinion. Two ratchets control the direction of rotation. Simple spur gear ratios control the speed of the output shaft. When the SMA wire is heated by electrical resistance, the martensite transforms into austenite, thereby contracting the wire, pulling the pinion, and turning the gear. A bias spring orients the SMA martensite variants during cooling.

The prototype, using only one SMA wire, exhibited a torque density of 8.9 oz-in/in^3, and easy improvements could increase the torque density to 22 oz-in/in^3. By comparison, conventional gear-motors have torque densities of approximately 7oz-in/in^3. The torque density of the SMA motor can be increased by adding more SMA wires with little increase in the volume or mass.

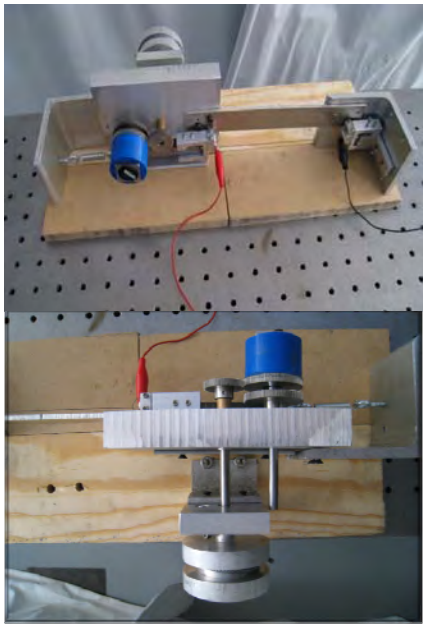

Figure 1. SMA Motor Prototype (blue object is ratchet, pulley is used to apply torque)

SVC in the News

An article on SVC project #31, "Adaptive Seat Belt System using Smart Material Technologies," appeared in the April 2009 issue of the Society of Automotive Engineers' publication *Automotive Engineering International*.

Professor Singh Interviewed by PBS's "NOVA"

The PBS science show NOVA producers conducted an on the record teleconference interview with Prof. Singh in the interest of planning a show about smart materials. Professor Singh provided guidance in terms of topics and devices that could be covered by the show. He has invited the SVC and NSF community to share videos and other interesting ideas with NOVA. We are looking forward to this show (to be telecast in 2010)!

Professor Singh is Elected a Fellow of Institute of Noise Control Engineering

Dr. Rajendra Singh, a Professor in the Mechanical Engineering Department, has been elected as a Fellow of the Institute of Noise Control Engineering of the USA (INCE/USA). The INCE Fellow rank honors (and recognizes publicly) any member who has rendered valuable service to the Institute and has made a "notable or distinguished contribution to the advancement of noise control engineering or notably promoted knowledge of noise control engineering." Dr. Singh is among the first of "outstanding members" to be elected. With this, Prof. Singh now holds the fellow grade in 4 professional societies; the other three include the American Society of Mechanical Engineers (ASME), Acoustical Society of America (ASA), and Society of Automotive Engineers (SAE).

Enclosure

**Smart Vehicle Concepts Center brochure appended after the newsletter.*

***Based on the Industrial Advisory Board request, we have prepared project descriptions in the form of quad-slide presentations. Samples are appended at the end of this document, and include Projects 1, 20, and 31 from The Ohio State University and Project 2.1 from Texas A&M. If you wish to receive slides on the rest of our projects, please contact Caterina Runyon-Spears.*

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February 23, 2010 8:00 AM to
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Texas A&M University
Annenberg Presidential Conference Center
George Bush Presidential Library and Museum
College Station, TX 77843-3141

Third Annual Summer 2010 Meeting

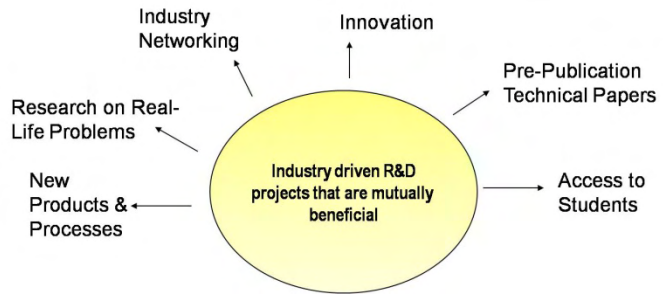
August 11, 2010, 12:00 pm to
August 12, 2010, 5:00pm
Ohio State University (Scott Laboratory)
Columbus, OH 43210

The Smart Vehicle Concepts Center would like to wish everyone
A Safe and Happy Holiday!

Smart Vehicle Concepts Center (SVC)

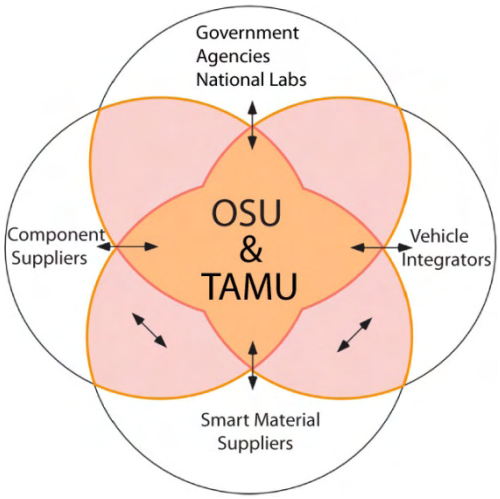
National Science Foundation - Industry/University Cooperative Research Center

Cooperative Center Concept - I/UCRC



The National Science Foundation (NSF) Industry/University Cooperative Research Center (I/UCRC) program provides industry, government, and other organizations the means to leverage research and development (R&D) investments with multi-university centers renowned for their innovative research capabilities.

- The NSF I/UCRC program encourages collaborative research
- Focuses on pre-competitive research
- Driven by Industry
- The NSF appoints an evaluator to ensure quality control



Smart Vehicle Concepts Center (SVC)

- Lead Institution – The Ohio State University (OSU)
- Academic Partner – Texas A&M University (TAMU)

Membership Fee Structure

The Ohio State University

- $40K/year - Full Membership (One vote per full membership)
- $10K/year - Affiliates (access to one ongoing project; no voting or intellectual property rights)

Texas A&M University

- $50K/year - Full Membership (One vote per full membership)
- $10K/year - Affiliates (access to one ongoing project; no voting or intellectual property rights)

Recent SVC Members

Advanced Numerical Solutions
Army Research Laboratory
The Boeing Company
Goodyear Tire and Rubber Co.
Moog Inc.
Solidica
Tokai Rubber, Inc.
Transportation Research Center, Inc.
American Axle & Mfg.
BorgWarner, Inc.
Edison Welding Institute
Honda R&D Americas Inc.
NASA Glenn Research Center
Space Engineering Institute

Industrial Advisory Board

- IAB will consist of one representative from each member company. The board is responsible for evaluating current research thrusts, suggesting new opportunities, evaluating center operations, and matching center capabilities with unfilled research needs.
- IAB holds two meetings throughout the year during the SVC review meetings.

SVC Mission

- Conduct basic and applied research
- Build an unmatched base of research, engineering education, and technology transfer with emphasis on improved vehicle performance;
- Develop well-trained engineers and researchers (at the undergraduate, MS, and PhD levels) with both experimental and theoretical viewpoints.

What Does the SVC Offer?

- Characterization of smart materials (using generic components)
- Comparative evaluation of existing materials or concepts
- Development of new sensors, actuators, and control algorithms
- New (revolutionary) design paradigms using smart materials
- Enhancement in functionality and performance
- Better understanding of vehicle constraints and environments
- New vehicle components and sub-systems
- Improved vehicle design and integration methods
- New or improved models for static, dynamic, or thermal responses
- Multi-domain/multi-physics modeling
- Tools to improve the vehicle developmental cycles
- Tools to understand the limits of existing components
- Explore technologies for new applications or markets
- Generation of scientific knowledge

Contact Information

Prof. Rajendra Singh — Center Director
Tel: 614-292-9044 <singh.3@osu.edu>
Prof. Dimitris Lagoudas — TAMU Site Director
Tel: 979-845-1604 <lagoudas@aeromail.tamu.edu>
Caterina Runyon-Spears — OSU Office Associate
Tel: 614-292-9044 <runyon-spears.1@osu.edu>

Research Thrusts at OSU and Some Sponsored Projects

Thrust A: Interfacial Mechanisms

- Electro-Hydrostatic Actuation and Sensing (E-HAS)
- Comparative Design Tool for Examining the Feasibility and Performance of Smart Engine Mounts
- Development of Interfacial Force Sensing Systems using Experimental and Computational Methods
- Adaptive Seat Belt System Using Smart Material Technologies
- Joining of Shape Memory Alloys and Structural Materials

Thrust B: Adaptive NVH

- Multifunctional Composites with Embedded Actuators, Sensors, and Stiffness Control
- Smart Material Database Compilation and Material Selection Tool Development (with Focus on Elastomers)
- Critical Assessment of Active Noise and Vibration Technology for Rotorcraft Gearboxes and Airframes
- Micro-Sensors for Sound Measurement

Thrust C: Safety

- New projects to be defined

Thrust D: Energy

- New projects to be defined

Research Thrusts at TAMU and Some Sponsored Projects

Thrust 1: Shape Memory Alloy Design and Processing

- Processing and Characterization of NiTiPd and NiTiPd-X Shape Memory Alloys for Aerospace and Space Exploration

Thrust 2: Shape Memory Alloy Material Characterization and Model Development

- Ni-rich Shape Memory Alloy Fatigue Testing and Modeling

Thrust 3: Engineering Application Design and Performance Evaluation of Shape Memory Alloys

- High Torque Shape Memory Alloy Motors

Pre-Competitive Research

- Overcomes basic obstacles that prevent a technology from being used in commercial applications
- Provides an understanding of the characteristics of new technologies or materials
- Is aimed at providing the tools, information, and data that enables others to develop future products and services
- Offers equal benefit to all competitors
- Develops industry standards and test procedures where no precedents exist

Benefits to Industry:

- Accomplish research at a fraction of the cost
- An avenue to investigate a topic of common interest
- Allow an industry to efficiently utilize the talents and resources of a university
- Platform for changing the university culture and inject ideas for relevant research
- Provide an excellent recruiting tool
- Leveraging: Nominal membership fee, when combined with cost-sharing and NSF money, gives members access to over ***$750K*** of research

Key Project Leaders

Raj Singh *singh.3@osu.edu*
(Donald D. Glower Chair in Engineering and Professor, Director of SVC)
Expertise: Noise & vibration control, geared systems, nonlinear dynamics, DSP

Marcelo Dapino *Dapino.1@osu.edu*
(Assoc. Professor, OSU)
Expertise: Smart materials, nonlinear coupled systems, design, control

Greg Washington *Washington.88@osu.edu*
(Interim Dean of Eng and Professor, OSU)
Expertise: Active material systems, vibration control, mechatronics

Dimitris Lagoudas *lagoudas@aeromail.tamu.edu*
(John and Bea Slattery Chair of Aerospace Engineering and Professor, TAMU Site Director)
Expertise: Micromechanics of active materials and smart structures; shape memory alloys (SMA)

Ibrahim Karaman *ikaraman@tamu.edu*
(Professor, TAMU)
Expertise: Micromechanical constitutive modeling; Twinning and martensitic phase transformation in metallic materials

Jim Boyd *jboyd@aero.tamu.edu*
(Assoc. Professor, TAMU)
Expertise: Structural applications of multi-functional materials; nano and microelectromechanical systems; micro and nano scale electro-mechanics

SVC History

- In October 2005, the National Science Foundation awarded a planning grant to The Ohio State University to develop the Smart Vehicle Concepts Center.
- The Ohio State University held a planning conference in October 2006, after which it prepared proposals and signed-up members.
- The Smart Vehicle Concepts Center was officially launched in July 2007 with support from National Science Foundation and industrial members.
- Texas A&M University submitted a successful proposal to the National Science Foundation in early 2008 and joined SVC as an academic partner in summer 2008.

SVC Website
Please visit us online:
http://smartvehiclecenter.org

NSF Fact Sheet on the SVC:
www.nsf.gov/eng/iip/iucrc/directory/svc.jsp

Electro-Hydrostatic Actuation and Sensing (E-HAS)
(SVC Project 1)

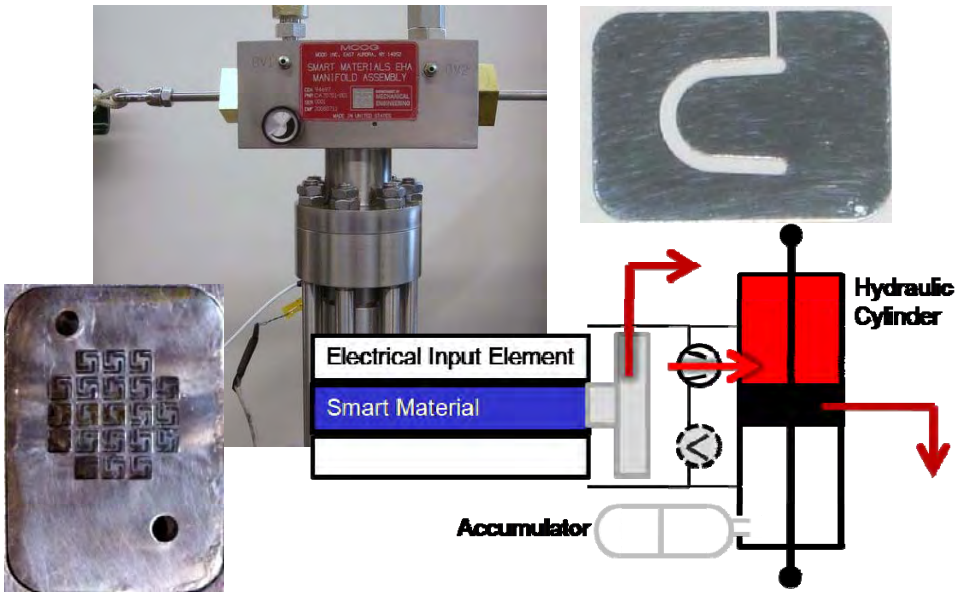
Technology Summary

- Smart materials produce high force, high frequency, low displacement motion
- Hydraulic fluid is used to rectify motion to create large displacement and high force
- Frequency response of existing mechanical one-way fluid valves is a limiting factor

Applications/Benefits

Advantages over traditional linear actuators:

- No need for separate pump/fluid lines
- Few moving parts
- Fast response
- High power-to-weight ratio



Plan

- Investigate valve designs to improve high frequency operation:
  - Reed-type mechanical valves
  - Micro-machined valve array
  - Active valve concepts
- Design, model, and test progressively miniaturized actuator designs to reduce system compliance and inertance

Project leader: Marcelo Dapino <dapino.1@osu.edu>

Project initiated by Moog Inc.

Development of Interfacial Force Sensing Systems

SVC Project 20 - Problem II: Preload and Stiffness Estimation in Rolling Element Bearings

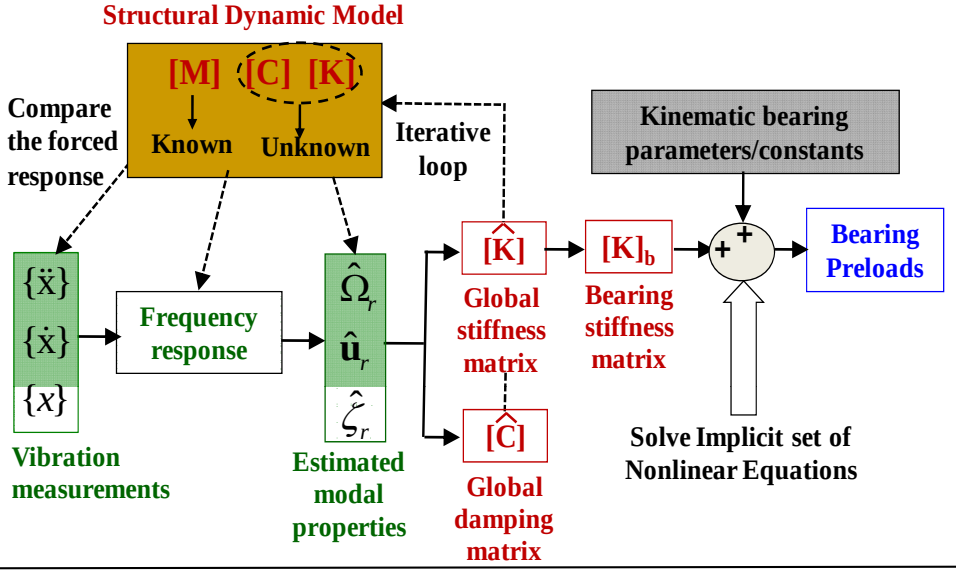
Goals

- Develop a vibration based method to estimate the bearing stiffness elements and bearing preloads
- Formulate a model and quantify shifts in stiffness-dependent resonances of a structure with preloaded bearings
- Develop experimental methods to estimate the preload and bearing stiffness

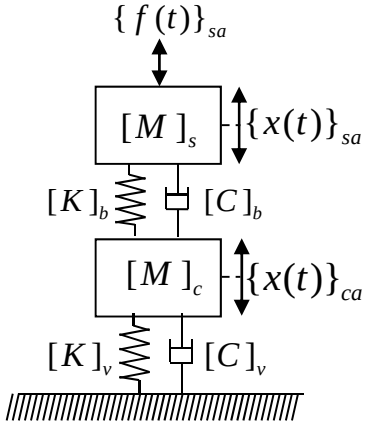
Ball bearing

Roller bearing

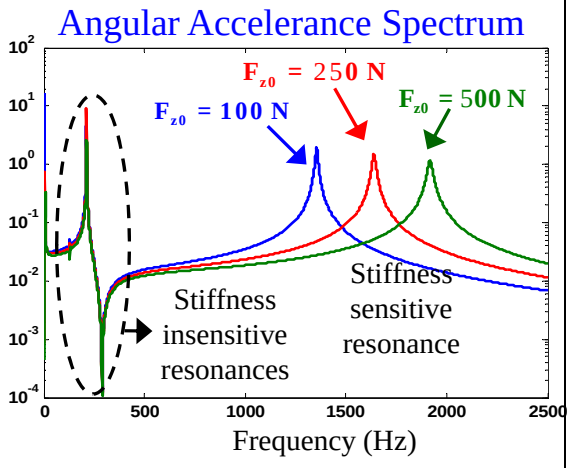
Methodology



Preliminary Simulation



12 DOF System Model



Research Plan

- Develop a lab experiment for vibration measurements
- Refine theory and estimate bearing stiffness matrix based on vibration measurements and model
- Estimate bearing preloads based on bearing stiffness and kinematic parameters
- Quantify shifts in the stiffness-dependent resonances
- Conduct experiments at different preloads
- Validate the method via experiments and analyses

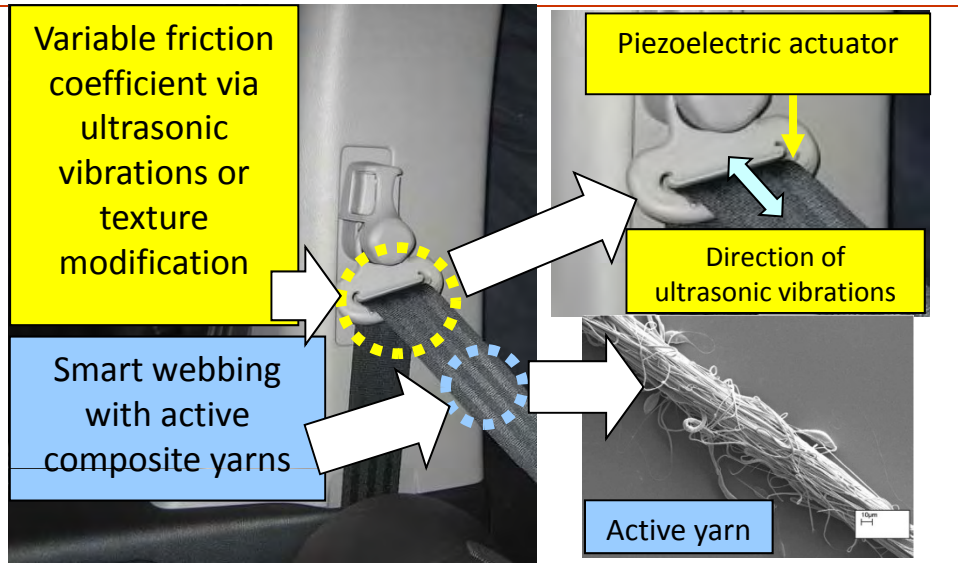
Project Leader: Raj Singh <singh.3@osu.edu>

Project Initiated by: Army Research Lab and Honda R & D

Adaptive Seat Belt System using Smart Material Technologies (SVC Project 31)

Technology Summary

- **Ultrasonic lubrication:** the coefficient of dynamic friction between two surfaces decreases when ultrasonic vibrations are superimposed to the sliding velocity
- This form of friction reduction is "solid state" and **requires no greases or oils**
- **Piezoelectric actuators** can be used to create ultrasonic vibrations
- The objective is to modulate the friction coefficient between "high friction" (**off state**) and "low friction" (**on state**) by driving the actuator at different voltages



Application/Benefits

- Adaptive seat belt system capable of providing **superior safety and comfort, reduced mass, simpler operation and more flexible design**
- Using smart materials to continuously measure and control the loading force can help design **active systems with feedback control**
- The friction control concept is applicable to a wide range of traditional problems **where lubricants are not feasible** and future applications with **active friction control as an enabling technology**

Plan

- Create a **proof-of-concept experiment** to fundamentally analyze and demonstrate ultrasonic lubrication at high speeds and high normal forces
- Demonstrate the principle of active friction control on a **tabletop seat belt system**
- Analyze and understand the dependence of friction on **system** parameters
- **Analytical modeling** of friction behavior in the presence of ultrasonic vibrations

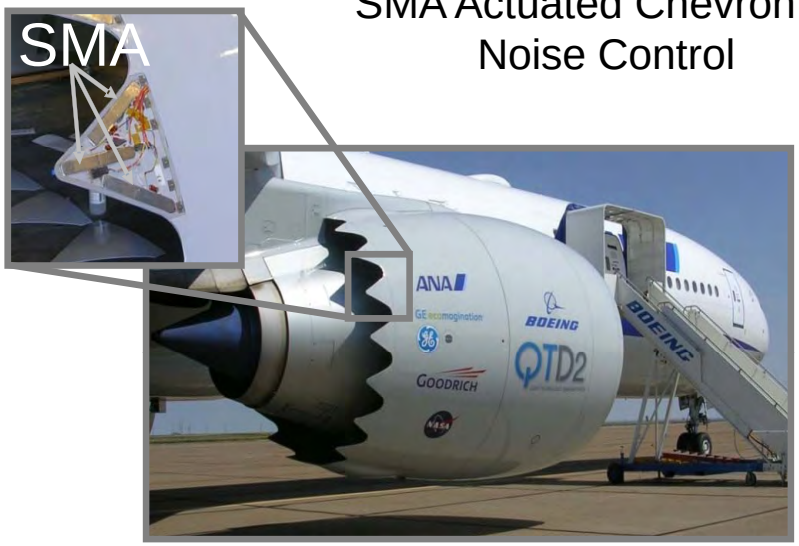
Project leader: Marcelo Dapino <dapino.1@osu.edu>
Project initiated by Honda R&D Americas

Ni-rich Shape Memory Alloy Fatigue Testing and Modeling (SVC Project 2.1)

Technology Summary

- Characterize the fatigue response of Ni60Ti40 shape memory alloy dogbones
- Constant stress fatigue testing
- Two environments: ethylene glycol (corrosive) and gaseous nitrogen (non-corrosive)
- Specimens cut by EDM
- Results:
- Fractography revealed that all specimens fail due to crack initiation at the Ni3Ti precipitates
- EDM recast layer lowers fatigue life
- Removing recast layer and polishing increases fatigue life by a factor of 2-4
- Fatigue testing in non-corrosive conditions increases fatigue life for polished specimens by a factor of 2

SMA Actuated Chevron for Noise Control



Application/Benefits

- Service life fatigue accounts for 80% of aircraft failures
- Commercial aircraft undergo 70k fight cycles
- Compact, thermally-actuated SMAs on chevrons allow for reduced noise on takeoff and landing
- A mechanistic understanding of fatigue initiation will help design alloys with improved fatigue life

Plan

- Increase specimen size to eliminate size effects 4th Qtr 2009
- Variable load testing to better simulate application on aircraft chevrons 4th Qtr 2009/1st Qtr 2010

Project Leader: Dimitris Lagoudas <lagoudas@aeromail.tamu.edu>
Project initiated by The Boeing Company