CONTACT INFORMATION

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RESEARCH INTERESTS

(1) Nondestructive Evaluation Methods:

- Advanced ultrasonic techniques with guided waves to quantitative information of structural integrity of plate/tube-like multilayered structures for aerospace, oil and gas, nuclear and shipping industries. Internal defects such as delaminations of solid rocket motors and material characterization (i.e. evaluate the aging state of solid propellants). Corrosion, pitting, stress corrosion cracking.
- Nonlinear ultrasonics to predict the remaining life of critical aircraft components, i.e. turbine blades, based on the fatigue damage precursors such as dislocation pile-ups, veins, and persistent slip bands.
- Eddy current techniques to quantify fatigue cracking in ferromagnetic tubes and level of sensitization in marine aluminum alloys.
- Electrochemical Impedance Spectroscopy to assess coating integrity and quantify the level of corrosion in marine steel structure such as ballast tanks for submarines.
- Assess the stress distribution in fastener holes and compressor and fan blades with acoustic birefringence and surface skimming longitudinal waves.
- Study the detection internal defects inside rubber-steel composites and develop a detection method and apparatus.
- Finite Element Modeling with application in ultrasonics, electromagnetics.

(2) Digital Signal Processing:

- Study the application of Artificial Neural Networks in real-time pattern recognition and inspection systems.
- Apply advanced time and frequency domain techniques for signal cleaning, feature extraction and accurate measurements.

(3) Bio-Inspired Robotics:

- Study the use of smart materials to design bio-inspired adaptive structures.

TEACHING INTERESTS

(1) Mechanical Vibrations and Control of Dynamic Systems, Theory and Applications:
• Mechanical Vibrations • Experimental Physical Acoustics • Ultrasonic Wave Propagation in Solids • Nondestructive Testing • Sound and Vibration Measurement and Control • Statics and Dynamics • Linear Feedback Control and Design of MIMO Systems • Nonlinear Systems and Control

(2) Robotics: Kinematics, Dynamics, Navigation Programming and Control, Mechatronic Control

(3) Smart Materials and Adaptive Structures

(4) Thermodynamics and Heat Transfer

EDUCATION & TRAINING

PostDoc. in Automotive Engineering — Jan. 2011 – June 2012
Clemson University
Advisor: Professor Thomas R. Kurfess
Field of Research: Mechatronics and Systems control

Ph.D. in Mechanical Engineering, minor in Electrical and Computer Engr. 2010
North Carolina State University
Advisor: Professor Stefan Seelecke
Dissertation: *BATMAV – A Biologically Inspired Micro-Air Vehicle for Flapping Flight*
Examination Fields: Control, Robotics and Mechatronics, Smart Materials and Adaptive Structures, Wing Theory GPA: 3.6

M.S. in Mechanical Engineering 2007
North Carolina State University
Advisor: Professor Stefan Seelecke
Thesis: *BATMAV – A Biologically Inspired Micro-Air Vehicle for Flapping Flight: Kinematic Modeling* GPA: 3.5

B.S. in Mechanical Engineering 1994
Polytechnic University of Bucharest, Romania, Europe GPA: 3.7

PROFESSIONAL APPOINTMENTS

Assistant Professor Aug 2015 - present
Murray State University,
Institute of Engineering
Teaching in Engineering Physics and research focused on nondestructive evaluations.

Senior Research Engineer July 2012 – July 2015
Intelligent Systems Group, Nondestructive evaluations
Luna Innovation
Research focused on developing advanced nondestructive evaluation techniques for aircraft, rockets and ship components mainly for Air Force, Navy, Army, and oil and gas industry. My activities include proposal writing, design of experimental setup, laboratory measurements, progress reporting, and prototype developing.

PostDoctoral Research Fellow Jan. 2011 – June 2012
Automotive Engineering Department
Clemson University
Research oriented on nondestructive detection of internal defects and delaminations in truck tires

Research Assistant 2009 – 2010
Mechanical and Aerospace Engineering Department
North Carolina State University
Research focused on modeling analysis, design and development of a bat-like robotic flyer using artificial muscles and membranes for actuation and control.

Course Instructor Sept. 2007 – Dec. 2008
Mechanical and Aerospace Engineering Department
- Fundamentals of Heat Transfer – taught undergraduate junior class and grade students
- Engineering Measurements Laboratory – instruct and grade students

Teaching Assistant 2006 – May 2007
Mechanical and Aerospace Engineering Department
North Carolina State University
Grading homeworks and exams, having office hours for 3 undergrad courses (statics, dynamics and mechanical vibrations).

Project and Design Engineer 1995 – 2003
Locomotive Factory – SC FAUR SA, Bucharest, Romania, Europe
Designed the technological planning of *manufacturing (machining) processes* for powertrains and cardanic shafts used in locomotives, trams and subway cars as well as middle size ships.

RESEARCH PROJECTS

Quantitative Propellant Diagnostics with Ultrasonic Guided Waves for AFRL, Edwards AFB, PI: G. Bunget

- The structural health and functionality of solid rocket motors (SRM) are critical to the success of many aerospace and military operations. Age related degradation in SRM is considered among the primary sources of failure or malfunction in their overall systems. Binder decomposition, particle mobility, cross-linking and outgassing in the propellant lead to variations in moduli, shrinkage cracks, and disbanding both in the propellant and at the propellant-liner interface.
- The objective of this Air Force program was to develop a practical application of ultrasonic guided waves as an evaluation technique of highly attenuating multilayer structures of solid rocket motors. Guided elastic waves were used to characterize the acoustoelastic properties of the aging propellant and to detect internal delaminations, kissing bonds and cracks.
- Lead PI during second phased of this program. Completed successful measurements on motors with aluminum, carbon fiber composites and steel casings. The ultrasonic measurements showed that the attenuation had a significant correlation with the propellant aging and the ultrasonic energy is a suitable indicator of internal defects. Designed and demonstrated an ultrasonic scanning prototype at the Edwards AFB.

Identification of Material Damage Precursors using Novel NDE and/or SHM Hardware for US Army Research Laboratory, Aberdeen Proving Ground, PI: G. Bunget

- Widespread damage in aging aircraft is becoming an increasing concern as both civil and military fleet operators are extending the service lifetime of their aircraft. During extended service, the probability for aircraft to develop fatigue cracking increases with time. Fatigue damage initiation occurs at micro-features called fatigue damage precursors (FDP).
- The objective is to develop advanced techniques to improve life prediction for aircraft structural and propulsion components by identifying the FDP early in the component life.
- As the lead PI, my proposal was awarded a SBIR Phase II after a successful Phase I, I presented convincing results that nonlinear ultrasonics with both longitudinal and Lamb waves are capable of FDP identification as early as 20% of the total life was spent.
- Conducted linear and nonlinear ultrasonic measurements on aluminum and Ni-based superalloys specimens both at Luna and ARL. Currently, I am preparing a provisional patent for a dual ultrasonic transducer for nonlinear measurements on hot section aircraft components.

RESEARCH PROJECTS

Quantitative Gun Barrel Diagnostics with Remote Field Eddy Currents and Artificial Intelligence
Air Force Sustainment Center, Warner Robins, PI: G. Bunget

- Gun barrels have a variety of failure modes that must be monitored over the life of a barrel. Fatigue cracking is one of the most critical failure modes and can result in catastrophic barrel rupture if not detected and addressed.
- Proposed to develop a portable diagnostic inspection system that integrates remote field eddy-current techniques with artificial intelligence to automatically and accurately assess fatigue cracking during gun barrel inspection directly on flight lines. The proof of concept was successful and during the mid of Phase I the Phase II was awarded. During the first quarter of Phase II our team was invited at Warner Robins AFB to perform multiple tests on medium range calibers using our first generation prototype.

Novel Autonomous Ultrasonic System for Monitoring the Remaining Effective Stabilizer in Aging Rocket Propellant for MDA, PI: G. Bunget

- Age related degradation in solid rocket motors is considered among the primary sources of failure or malfunction in their overall systems. For example, various chemical reactions and physical processes take place in rocket propellants over time. Chemical stabilizers are formulated to minimize these degradation reactions. However, as the stabilizer is consumed the auto-oxidative crosslinking reactions accelerate and the propellant may harden over time resulting in decreased performance and service life of solid propellants
- Based on my results from previous rocket project, I proposed to develop an ultrasonic to monitor the percentage of remaining stabilizer with acoustic attenuation as an effect of acoustoelastic changes inside the aging propellant.

Low Cost Autonomous Coating Condition Monitoring System
Navy, PI: Fritz Friedersdorf

- Carbon steel tanks and enclosures within Navy submarines and ships are protected by a combination of coatings and cathodic protection systems. Our team proposed to develop a reliable, long service life and low cost coating health monitoring system that can be easily installed, accessed outside the tank and that senses and stores cumulative measurements of coating degradation.
- The primary objective of our program was to design a network of sensor nodes for using electrochemical impedance spectroscopy (EIS) and artificial intelligence to characterize the properties of the coating, substrate, and to quantify the extension of corrosion defects and their location as well as the level of cathodic protection.
- My role in this program was to perform EIS measurements, identify the corrosion indicators and design an intelligent algorithm based and artificial neural networks.
- Successfully designed a robust neural system that predicted the presence, size, and location of corrosion defects in 3-dimensional tanks for various temperatures and water salinity conditions. A provisional patent is currently under preparation.

Embedded Long Service Life Monitoring System for Aluminum Alloy Sensitization for Naval Sea Systems Command, PI: Fritz Friedersdorf

- New Navy combatant and non-combatant vessels need to be faster, carry bigger payloads, travel longer distances and have reduced acquisition, manning and life cycle costs. These goals are being achieved in part by incorporating light weight alloys and composite

materials in advanced ship designs. In particular, 5XXX series aluminum alloys provide high strength-to-weight ratios, while maintaining good as-welded strength and excellent corrosion resistance. Although 5XXX series alloys have excellent marine corrosion resistance, sensitization can cause susceptibility to localized intergranular corrosion, exfoliation, and stress corrosion cracking.

- The primary objective of this program is to develop an effective and efficient autonomous Embedded Aluminum Sensitization Monitoring (EASM) system to provide accurate and reliable information about the degree of sensitization (DoS) of aluminum alloys.
- Conducted experimental work with eddy current techniques, analyzed data and developed a temperature compensation algorithm and an empirical model for the DoS. These efforts resulted in further funding of the program and a provisional patent for tooling and algorithms.

RESEARCH PROJECTS

Residual Stress Measurements at Fastener Holes, preliminary work for a project with Cessna and Tinker Air Force Base, PI: Fritz Friedersdorf

- The Air Force and commercial aviation perform many manufacturing processes with the aim of inducing residual stress in metals to prevent the onset of fatigue cracking. Cold working and shot peening create localized compressive residual stresses increasing fatigue life from two to ten times. Despite the known benefits of cold working there are limitations in the ability to nondestructively assess its quality.
- The objective of this preliminary research was to present Luna's capability in developing advanced ultrasonic techniques for stress distribution measurements around fastener holes with the potential of extending the application toward compressor and fan blades during a second phase program.
- Conducted experimental measurements and developed accurate birefringence measurements with bulk shear waves on Cessna specimens. A Phase I contract is impending.

Detection of Internal Voids and Separations in Used Truck Tires Casings, with Prof. T.R. Kurfess – Sponsored by Michelin Americas Research Company

- Recycling and retreading is the key for reducing costs and energy used for manufacturing of the tire casings, thus the cost per mile for operations. This is an environmentally friendly technology since it conserves approximately15 gallons of crude oil for each retread of a truck tire. An effective retread necessitates a tire casing with good structural integrity, without internal damages.
- The main objectives of this project were: (*i*) explore a non-destructive method of detection and identification of internal voids and separations in used tire casings, and (*ii*) design and build an automated apparatus to test 10 tires per hour.
- Managed a team of two PhD students and an undergraduate student involved in this project. Several sensors were tested, and acoustic and force measurements provided the most efficient results. A detection algorithm was developed and proved an increased prediction capability over the current technology. An automated prototype is currently under development and a patent application filled together with Michelin.

BATMAV – A Biologically Inspired Micro-Aerial Vehicle for Flapping Flight, with Prof. Stefan Seelecke – Sponsored by Parker Hannifin Corporation

- Advances in fabrication technologies, sensors, electronics and power storage have made

possible to design and fabricate small flying devices for applications where maneuverability in confined spaces in required.

- The overall objective of this research was to design and build a bat-like robotic flyer for flapping flight actuated with smart materials as shape memory alloys and electro-active polymers. The specific objectives were: (*i*) formulate a kinematic model that would mimic the maneuverable flapping motion of bat wing, (*ii*) design, fabricate (using rapid prototyping technologies) and assemble a flight platform based on the kinematic analysis, (*iii*) optimal design for actuation placement and (*iv*) sensing and controller development in order to power to the artificial muscles along the entire flapping cycle.
- During my graduate program, I was involved in all phases of this project. Laboratory tests showed suitable results and ongoing investigations focus on outdoor testing.

RESEARCH PROJECTS

Controller Design to Cancel the Operator-Induced Oscillations, with Prof. Gregory Buckner – Sponsored by Caterpillar

- The operator-induced oscillations are a main factor of instability for a skid steer vehicle and a serious injury cause. When the vehicle comes under a source of disturbance – road bump, its main body starts vibrating. This pitching oscillatory motion is conveyed to the operator who holds the joystick and so, the pitching angle is further added/subtracted to the command signal. These involuntary signals over a period of time may result in high frequency changes in vehicular speed which might exacerbate the oscillatory motion of the vehicle and force the operator to ultimately take his hands off the joystick.
- The main goal of this project was to design a controller that would cancel the effect of feed-forward vehicle dynamics which led to operator induced oscillations.
- Modeled and simulated the dynamics of the vehicle, as well as the human arm-joystick system. This analysis resulted in designing a notch filter to cancel the frequency range corresponding to human hand-joystick induced oscillations.

Noise Cancelling through Closed Loop Control of Hysteretic Materials, with Prof. Stefan Seelecke

- Smart materials have previously shown excellent damping capabilities due to the energy dissipated throughout the materials' hysteresis loops. Piezo-ceramic actuators have the ability to dampen and actuate as well as sense an oscillatory system.
- This was a proof of concept design in order to eliminate the wall vibrations of aircraft cabins using a stack of piezoelectric crystals.
- Designed a nonlinear-control algorithm to inhibit the induced oscillations of a composite cantilever beam. The algorithm, based on a single degree of freedom model (Euler-Bernoulli beam theory) has provided successful results during lab tests both in open and closed loop configurations.

Enhanced Evolutionary Robotics Platform – EVBOT, with Prof. Edward Grant

- The main objective of this project was to develop the next generation of autonomous mobile robots for distributed robot-colony research. The specific goal of its initial phase was to design and build a robust evolutionary mobile robotic platform in order to test various sensors and detection algorithms.
- One application was to detect explosives in public buildings and by remote control to defuse them.
- Worked both on the mechanical assembly and on writing an interface in C programming language to control the propulsion drive motors and the turret motor. Operated the robot

through an umbilical cord attached to a laptop. The project was continued by another graduate student.

Mechatronics Design of a Balancing Mobile Robot, with Prof. M.K. Ramasubramanian

- This research focused on the study the mechatronics design and control algorithm to balance an inverted-pendulum-type mobile robot using a PID controller. The algorithm would take readings from the sensors and maintain the rotation rate of the platform at minimum while the robot moves ahead with the desired speed.
- My part was to design and write the control algorithm in C programming language and interface it on the onboard microcontroller. The robot had been enhanced with infrared sensors and sonar for collision detection, a compass to determine its orientation and a two-axis accelerometer and gyroscope for balance control

RESEARCH PROPOSALS

1. Novel autonomous ultrasonic system for monitoring the remaining effective stabilizer in aging rocket propellants, STTR proposal for MDA, Oct. 2014 Phase I (**awarded Jan. 2015**)
2. Quantitative gun barrel diagnostics with remote field eddy currents and artificial intelligence, SBIR for Air Force – **Phase I (awarded April, 2014) and Phase II awarded (awarded Dec., 2014)** (Proposal No. F141-205-1364)
3. Identification of material damage precursors using novel NDE and/or SHM hardware, SBIR for Army –**Phase I (awarded May 2013) and Phase II (awarded Feb., 2014)** (Proposal No A131-016-0853)
4. Detection of internal voids and separations in used truck tire casings, for **Michelin - Awarded**:
    a. Phase I – Proof of Concept, 2010
    b. Phase II – Optimal detection algorithm and automated demonstrator design, 2011
5. Multimodal method to quantify the remaining strength of high-grade pipeline steels, SBIR proposal for PHMSA, Sept. 2014
6. Advanced ultrasonic techniques for residual stress measurements in cold worked aircraft components, SBIR proposal for Air Force, Jan. 2014
7. Novel approaches to bond quality NDE with emphasis on kissing bond detection and bond line assessment, SBIR for Navy, May 2013
8. Robust methods for the measurement of bulk residual stress, SBIR proposal for Air Force, Jan. 2013

TECHNICAL REPORTS

Quantitative Propellant Diagnostics with Ultrasonic Guided Waves

- Four progress quarterly reports No. FA9300-11-C-3008
- Final report Phase II

Identification of Material Damage Precursors using Novel NDE and/or SHM Hardware

- Ten progress monthly reports No. W911QX-13-C-0162
- Final report Phase I

Quantitative Gun Barrel Diagnostics with RFEC and AI

- Eight monthly reports No FA8501-14P-0041
- Final report Phase I

Detection of Internal Voids and Separation in Used Truck Tire Casings Phase I

- Final Report Phase I No. CUICAR/Michelin-2011-01

TECHNICAL PUBLICATIONS

Non-Destructive Evaluation Methods and Apparatus:

1. G. Bunget, A. Ghoshal, M. Pepi, Y. Liu, A. Chattopadhyay, A. Goff, F. Friedersdorf – "Identification of material damage precursors using nonlinear ultrasound" – 51st *AIAA/SAE/ASEE Joint Propulsion Conference*, Propulsion and Energy Forum, AIAA, July 2015
2. G. Bunget, Q. Shen, F. Gramling, D. Judd, and T. Kurfess – "Impact-acoustic evaluation method for rubber-steel composites: Part I. Relevant diagnostic concepts", *Applied Acoustics Journal*, Vol. 90 p. 74 – 80, 2015
3. G. Bunget, J.K. Na, F. Friedersdorf – "Quantitative propellant diagnostics with ultrasonic guided waves", *AIP Journal*, Vol. 1650, 2015
4. C. Andrews, G. Bunget, K.M. Farinholt, F.J. Friedersdorf – "Low Cost Autonomous Condition Monitoring System for Tank Coatings" *Proc. of NACE Conf. on Corrosion*, Dallas, March 15-19, 2015
5. G. Bunget, T. Kurfess, Q. Shen, F. Gramling, D. Judd – "Method and apparatus for nondestructive detection of tire anomalies" *patent* WO2015069218, May 14 2015
6. P.L. Takunju, S. Agnew, G. Bunget, M. Shedd – "Nondestructive characterization of sensitization of aluminum alloy AA5083 using eddy current probes" , *Proc. of ASNT 23rd Research Symposium*, Minneapolis, 24-27 March 2014
7. G. Bunget, Q. Shen, F. Gramling, D. Judd, and T. Kurfess – "Impact-acoustic evaluation method for rubber-steel composites: Part II. Comparative assessment on a diverse test set", *Applied Acoustics Journal*, manuscript submitted, under revision, 2014
8. Siegel, J., Brown, N.K., Bunget, G., Muskopf, P., Putic, M. – "Nonintrusive Load Monitoring of Rotating Machinery", *Proc. of MFPT & ISA's 59th Int. Instrum. Symp.*, Cleveland, May 13-17, 2013

Manuscripts in preparation:

9. G. Bunget, J.K. Na, M. McMullan, N. Brown, F. Friedersdorf – "Advanced eddy current testing of ferromagnetic tubes" manuscript based on the Phase I results of gun barrel testing
10. G. Bunget, Q. Shen, F. Gramling, D. Judd, and T. Kurfess – "Nondestructive evaluation of truck tires – Spectral Analysis", manuscript based on the Michelin project results
11. G. Bunget, Q. Shen, F. Gramling, D. Judd, and T. Kurfess – "Impact-acoustic method as a quantitative imaging tool for steel-rubber composites", manuscript explaining the acoustic B-scan imaging of truck tires
12. G. Bunget, Q. Shen, F. Gramling, D. Judd, and T. Kurfess – "Artificial Intelligence applied to Impact-Acoustic Evaluation Method", neural network optimization and results obtained for multiple tire structures and aging conditions.

Micro-Aerial Vehicle:

1. Furst, S.J., Bunget, G. and S. Seelecke – "Design and fabrication of a bat-inspired flapping-flight platform using shape memory alloy muscles and joints" in *Smart Materials and Structures*, Vol. 22, 2013
2. G. Bunget and S. Seelecke – "BATMAV: A biologically-inspired micro-air vehicle for flapping flight - Kinematic modeling," in *Proceedings of the 15th International Symposium on Smart Structures and Materials (SPIE)*, San Diego, California, USA, 2008
3. G. Bunget, T. J. Place and S. Seelecke – "Design and fabrication of a bio-inspired flapping flight micro-air vehicle," in *Proceedings of ASME Conference on Smart Materials, Adaptive Structures and Intellingent Systems (SMASIS08)*, Ellicot City, Maryland, USA, 2008

4. G. Bunget and S. Seelecke – "Actuator placement for a bio-inspired bone-joint system based on SMA," in *Proceedings of the 16th International Symposium on Smart Structures and Materials (SPIE),* San Diego, California, USA, 2009
5. G. Bunget and S. Seelecke – "BATMAV: A 2-DOF bio-inspired flapping flight platform" SPIE Conference *SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring*, San Diego, California, USA, 2010

BOOKS

G Bunget: "BATMAV: a bio-inspired micro-air vehicle for flapping flight", ISBN 978-3-8364-5972-3, VDM, 2008

COMPUTER SKILLS

- **MATLAB & SIMULINK** – broad experience in programming for data analysis for nondestructive evaluations, robotics, and control analysis;
- **C Programming** – 3 years of experience in software for DSP and embedded systems programming;
- **FORTRAN** – studied flow over airplane wing using LLT and Weissinger methods;
- **LabVIEW** – proficient in designing data acquisition systems for more than 5 years;
- **SolidWorks** – 5 years of experience in designing parts with intricate nature-like shapes;
- **ANSYS, COMSOL –** structural and modal analysis as well as simulations of the elastic membrane to be implemented on the bat wing.

HONORS & AWARDS

- First place at Annual Graduate Poster Competition, MAE Dept., NCSU in 2007, 2008, 2009, and 2010
- Second place at the Fourth Annual Graduate Research Symposium of NCSU in 2009

PERSONAL INFORMATION

Visa Status: **Permanent Resident (Green Card)**