ARC Collaborative Research Seminar Series
Winter 2011

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January 21	January 28	February 4
February 18	March 11	April 1
April 8	April 22	

January 21st, Friday (9:30-11:00am)
University of Michigan, Duderstadt Center, Room 1180

Vehicle and Crash Dummy Response to an Underbelly Blast Event
Risa Scherer, Team Leader, Blast Mitigation, Ground Systems Survivability
RDECOM-TARDEC

Abstract: Historically, the Department of Army has had difficulty educating industry and academia on the severity and speed of underbody blast events. Due to the sensitive nature of the work performed by the Department of Army and Department of Defense, data generated from testing military vehicles is CLASSIFIED, making it difficult to share the data. To alleviate this problem, Research, Development and Engineering COMmand-Tank Automotive Research, Development and Engineering Center (RDECOM-TARDEC) fabricated a generic vehicle hull and subjected it to an underbody live fire test. The intent is to evaluate blast mitigating technologies and to share the data publicly. This talk will present preliminary results from this test.

Birth of a Crash Dummy: How Injury Biomechanics Data are used to Design Anthropomorphic Test Devices
Matthew Reed, Research Associate Professor
Biosciences Group, University of Michigan Transportation Research Institute
Center for Ergonomics, Industrial and Operations Engineering

Abstract: Crash dummies are used routinely to evaluate the safety of vehicles and the performance of restraint systems. Dummies with a wide range of body size and complexity are available, most designed for a particular type of impact or restraint test. Many of the people who work with crash dummies, or computational models of them, are not familiar with the dummy design process and the consequent strengths and limitations of the dummies. Using examples from UMTRI's participation in various dummy design programs, this presentation will outline the key steps in developing a crash dummy, including accurate characterization of injury causation, gathering applicable data on human tolerance and response, designing the hardware, and developing appropriate procedures for calibrating and using the dummy. An understanding of this background is critical for anyone using crash dummies, or computational models of crash dummies, to make design decisions.

January 28th, Friday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, 3rd Floor, Johnson Rooms

Multi-scale simulations for developing light weight vehicles with increased survivability to loads from explosions and high velocity projectiles
Nickolas Vlahopoulos, University of Michigan

Abstract: Composite materials provide some of the most viable options for manufacturing lightweight vehicles provided that they can offer desirable level of protection against explosive threats. Multi-scale simulations can be engaged for designing such materials and

(Micromechanics Analysis code with Generalized Method of Cells) code which enables coupled multi-scale analysis of advanced composite structures. In this project the MAC/GMC code is combined with commercially available software for simulating the loads applied on a structure from explosion/fragmentations in order to develop a new multi-scale simulation method suitable for determining the response of Army vehicles with composite armor to loads from an explosion. This simulation capability will be employed within a multi-level optimization framework for determining desired material properties for increased blast resistance without any weight increase compared to metal structures. Novel mathematical developments for inverse material identification will be formulated in order to determine the micro-structure which offers the desired macro properties for increased survivability. The new simulation methodology will be used for designing light weight materials and vehicles with high resistance characteristics to combined loads from explosions and high velocity projectiles. Concepts of multifunctional composite materials will be pursued. Multifunctional materials can enhance the abilities of the composite to withstand simultaneous blast loads and resist penetration damage from projectiles. The progress towards these overall objectives will be discussed.

Quantification of the design relationship between ground vehicle weight and occupant safety under blast loading

Steven Hoffenson, Panos Papalambros (PI), University of Michigan

Abstract: Military ground vehicle design must consider the threat posed by underbody blasts to new vehicles and their occupants, while also accounting for weight reduction goals for improving fuel economy, mobility, and cost. A two-stage process is presented to model the blast event, using LS-DYNA for simulating the vehicle response and MADYMO for the occupant's response. Issues including computational expense, objective function formulation, and multi-objective seating system optimization are addressed in detail, and three different blastworthiness optimization formulations are presented and evaluated. The impact of interdisciplinary factors such as human behavior, biomechanical data and occupant comfort is discussed in the context of designing for ground vehicle occupant safety.

February 4th, Friday (9:30-10:30am)
University of Michigan, Lurie Engineering Center, 3rd Floor, Johnson Rooms

Qualification of Alternative Fuels for Use in DoD/Army Tactical Ground Systems

Patsy A. Muzzell, Team Leader, Alternative Fuels, RDECOM-TARDEC

Abstract: The US Army Tank Automotive Research Development and Engineering Center is conducting the program to qualify alternative fuels for use in DoD/Army tactical ground systems. Qualification and approval of alternative fuels paves the way for their acceptance and use in military equipment, and supports the Army Energy Security Implementation Strategy calling for increased use of renewable/alternative energy. Currently under investigation are second and third generation alternative fuels as replacement / drop-in fuels for jet propellant 8 (JP-8) comprised of either Fischer- Tropsch synthetic paraffinic kerosene (FT SPK) or hydroprocessed renewable jet (HRJ) blending stock in blends with petroleum JP-8. This presentation will focus on the these alternative fuels and will provide an overview of key regulations and policies shaping their emergence in the market, along with a more in-depth understanding of their physicochemical properties. Main topics include: the military's (specifically the Army) energy security goals and plans for use of alternative fuels; the current logistical fuel used in the military, JP-8, and it's properties; alternatives to JP-8 and how key physical and chemical properties compare to JP-8 and diesel fuel; a market and environmental analysis of alternatives fuels; the qualification and approval process; and a sampling of the RDTE conducted by TARDEC to understand the impacts to the performance, durability and operability of equipment when operating on synthetic/renewable fuel blends in order to qualify them for use in DoD/Army tactical ground systems.

February 18th, Friday (9:30-11:00am)
University of Michigan, Duderstadt Center, Room 1180

Neutron Imaging for In Situ Metrology of Lithium Ion Batteries

Jason Siegel, Anna Stefanopoulou (PI), University of Michigan

Abstract: Pulsed load, start-up, shut-down, and sudden load changes are characteristic and ubiquitous to all power producing devices and especially portable and mobile power-sources in real world applications. Accurate estimates of lithium-ion battery State of can help meet the high power demands of military applications, while controllers based on these models can maintain operation of battery system within dynamically evolving constraints and prevent thermal events and over charge/discharge conditions that precipitate degradation of battery performance and energy storage capacity.

Neutron radiography offers unique opportunity to measure in-situ the spatial distribution of lithium concentration across the electrode active material at the 10 µm length scale. These measurements can be used for the parameterization and validation of necessary physics based mathematical models of Li-ion cells. The measurements can also be used to observe the manufacturing defects and degradation of energy storage material, by the changes (or non-uniformity) in local lithium concentration distributions during normal operation of the battery. The movement of lithium ions between the anode and cathode active material has been successfully observed in the radiographic images and a methodology for quantifying the change in lithium concentration is presented. Swelling and contraction of the un-constrained active material during lithium intercalation (cycling of the battery) is also observed in the images. These observations point to internal stress in the battery which may contribute to degradation of the energy storage materials. Further research is ongoing to utilize these measurement for calibration of a physics based battery model.

Power Management Approaches for Fuel Efficient Propulsion and Safe Battery Operation in a Hybridized Military Truck

Zoran Filipi (PI), Tae-Kyung Lee, and Youngki Kim, University of Michigan

Abstract: Electrification and hybridization are critical for improving fuel economy of military trucks, while also addressing increased on-board power and export power requirements. However, the size of military trucks and the nature of their typical missions create particular challenges, such as very high peak currents experienced by the battery. This creates a risk for battery health and thermal management, and practical solutions often mitigate the risk by oversizing the battery. The undesirable consequence is of course the impact on cost and packaging. Therefore, the aim of this research is to pursue supervisory controller design for a series HEV capable of achieving fuel efficiency objectives, while eliminating or reducing the risk of battery failure due to extreme dynamic loads. Two approaches will be highlighted. The first proposes a model-based battery control strategy that relies on prediction of the battery electrochemical dynamics. This effort is pursued in collaboration with the ARC group working on LiION battery modeling and neutron imaging. The extended Kalman filter is constructed to estimate the Li-ion concentration information under an aggressive real-world military driving cycle and used for controller design. The second approach explores a blending strategy that splits the power request between two power sources depending on the signal frequency. The predictive models and a fully integrated hybrid system simulation provide detailed insight about interactions in the system, allow controller development and evaluation of the tradeoff between fuel economy and battery health considerations.

March 11th, Friday (9:30-11:00am)
University of Michigan, Duderstadt Center, Room 1180

Off-Road Soft Soil Tire Model Development, Validation, and Interface to Commercial Multibody Dynamics Software

Dr. Corina Sandu (PI), Eduardo Pinto, Scott Naranjo, Anake Umsrithong (Virginia Tech), Dr. Paramsothy Jayakumar (TARDEC), Dr. Archie Andonian, Dr. Dave Hubblle (Goodyear Tire & Rubber Company), Dr. Brant Ross (MotionPort)

To accurately predict the dynamic behavior of off-road vehicles on soft soil, we need to estimate the forces and moments that occur at the tire-terrain interface. Therefore, tire-terrain interaction models that accurately describe this dynamic behavior are needed for vehicle dynamic simulation. There is a significant number of studies in which tire models have been developed; however, most of the development in tire-terrain interaction has been limited to on-road conditions, or has treated the tire-soft soil interface in a simplified manner.

The final goal of this project is to develop an accurate and comprehensive, but in the same time efficient, off-road tire model for soft soil. The model will be structured to interface with commercial multibody dynamics software, and it will be validated against experimental data. The types of applications we target are handling, traction, ride, vehicle durability studies, as needed to support current army mobility goals.

The first step of this project has been to conduct an extensive literature research, and to identify the desired capabilities of the tire model to be developed. During the literature tire-soil interaction). We relied on technical publications that describe such models developed based on analytical, empirical, and finite element methods. The review focused on the features of the individual models, the strength of their theoretical formulation, and model accuracy, but we also looked at the ease of parameter collection and ease of interfacing with commercial software. Various methods to collect data needed as input into the model are currently being investigated. We are also working on available methods and equipment for the experimental testing in order to validate the tire model. The results from the state of the art review are summarized, and an outline of the features to be incorporated in the model is presented. Previous work at AVDL on tire modeling will serve as the foundation for the new tire model.

A Control Theoretic Perspective to Characterizing and Improving Transparency in Internet-Distributed Hardware-in-the-Loop Simulation

Tulga Ersal, Brent Gillespie, Zoran Filipi, Jeffrey L. Stein (PI) (University of Michigan), Mark Brudnak (TARDEC), Marcella Haghgooie (Applied Dynamics International)

As highlighted by our previous integration of TARDEC's ride motion simulator with UM's engine-in-the-loop simulator, the Internet-distributed hardware-in-the-loop simulation (ID-HILS) presents unique opportunities for geographically-dispersed concurrent systems engineering. By enabling the Internet-based integration of distributed HIL setups, ID-HILS can offer significantly higher fidelity experiments significantly earlier in the design stage. Thus, alternative designs can be evaluated with unprecedented speed, effectiveness, and with significantly less investment of resources than full physical hardware integration.

This talk will summarize our ongoing efforts to characterize and improve transparency in ID-HILS. Transparency is a crucial performance metric for ID-HILS: it is a measure of how much the system dynamics of interest are affected by distribution over the Internet. A high transparency means that the adverse effects of such distribution (e.g., the Internet's delay, jitter, and loss; sampling effects; etc.) are not significantly visible in the dynamics of interest and is hence desired, but may be difficult to achieve. Taking a control theoretic perspective, we will first introduce a frequency domain metric to characterize transparency, namely, distortion. In this framework, the ultimate goal of increasing transparency translates to attenuating distortion. We will then discuss the utility and fundamental limitations of three different tools to reduce distortion: coupling point selection (i.e., the point at which the system is divided and distributed over the Internet), feedback control, and iterative learning control. Simulation studies on a simple system will be used to illustrate the discussion. Finally, the key points of the discussion will be summarized to provide important guidelines for improving transparency in ID-HILS.

April 1st, Friday (9:30-11:00am)
University of Michigan, Duderstadt Center, Room 1180

Thermal Management of Vehicle Electronic Payloads Using Nanofluids and Thermoelectric Devices - Modeling and Analysis

David Ewing (Presenter), Joshua Finn, Dr. Lin Ma (Co-PI), and Dr. John Wagner (Co-PI), Clemson University

Abstract: Electronic payloads have become an integral part of modern military ground vehicles. These electronics often feature high thermal density that must be effectively managed, especially under demanding operating conditions, to maintain system reliability. This presentation describes the modeling and analysis of nanofluids and thermoelectric devices to address the cooling challenges posed by these thermal loads. A sensitivity analysis has been performed to investigate the suitability of a particular nanofluid model. Numerical results obtained show that the convective heat transfer coefficient can be enhanced up to 16.1% with the augmentation of nanoparticles into the base fluid (water). The simulation results also show that the peak computer chip temperature varies by only 0.4%, demonstrating that it is insensitive to the complexity of the selected nanofluid model. Furthermore, the proposed thermal management system provides cooling performance which would not be possible with traditional air-cooled heat sinks which remain limited to the ambient temperatures.

Vehicle Thermal Management System of Advanced Vehicles: Impact of VTMS on Series Hybrid Electric M-ATV

Presenters: Dohoy Jung (Assistant Professor, PI) and Sungjin Park (Research Fellow)
Contributors: Dennis Assanis and Zoran Filipi (UM)
Quad members: Pete Schihl (TARDEC), Bashar AbdulNour (GDLS), John Myers (Hyundai)

survivability of Army ground vehicles. In addition, climate control (Air Conditioning) system is also important for reduced fatigue of vehicle operators and thermal damage of on-board electronic equipments. In hybrid powertrain systems, the battery pack is cooled by the climate control system and both the powertrain cooling system and the climate control system are major parasitic power consumers. Thrust area IV at the University of Michigan has studied on the design and optimization of the vehicle thermal management system for better performance and fuel economy of advanced powertrains. This year we expanded our work scope to include the battery thermal management system (BTMS) as a subsystem for vehicle thermal management. A numerical model of BTMS has been developed to predict the battery temperature distribution in a battery module and the power consumption of the BTMS under transient vehicle operations. The model is used for the study of the design parameters of BTMS and the comparison of BTMS methods.

Developed VTMS model including the vehicle cooling system model, the climate control system model and the battery thermal management system model is integrated with vehicle powertrain model developed for M-ATV with series hybrid electric powertrain to simulate the interaction between the powertrain components and VTMS components and eventually to predict the fuel economy accurately. The integrated VTMS simulation results can supply guidelines for the development of powertrain control design of M-ATV performed by Dr. Filipi's team (hybrid propulsion system modeling) because additional power consumption by VTMS should be supplied by the powertrain. It can provide constraints for the battery packaging study because the power consumed by climate control system which removes the heat from battery pack is critical information for the battery packaging study performed by Dr. Fadel's team (thermal packaging design). We can improve the fidelity of the system model by integrating battery thermal model developed by Dr. Stefanopoulou's team (battery pack modeling) with the VTMS model.

April 8th, Friday (9:30-11:00am)
University of Michigan, Duderstadt Center, Room 1180

Refreshments will be provided. Please contact William Lim (choonhun@umich.edu) if you wish to attend remotely via teleconference/WebEx Conferencing.

An Importance Sampling Approach in Time-Dependent Reliability and Accelerated Testing of Vehicle Systems
Amandeep Singh (TARDEC), Zissimos Mourelatos (Oakland University), Igor Baseski (TARDEC & PhD Candidate, Oakland University)

Reliability is an important engineering requirement for consistently delivering acceptable product performance through time. The reliability usually degrades with time increasing the lifecycle cost due to potential warranty costs, repairs and loss of market share. Reliability is the probability that the system will perform its intended function successfully for a specified time. In this research, we consider the first-passage reliability which accounts for the first time failure of non-repairable systems. Methods are available to obtain an upper bound of the true reliability. The upper bound however, can grossly overestimate the true value. Using time-series modeling, we present an importance sampling methodology using the new concept of decorrelation length, to calculate the cumulative probability of failure (probability of first passage or up-crossing) of a random dynamic system driven by an input random process. The computational cost of the traditional Monte-Carlo simulation is reduced by concentrating the sample points in the region of most importance. Many failures are artificially induced using a sampling distribution with a larger variance than the original variance of the time-series residual process. The failure rate estimation is then corrected using weights which are proportional to the likelihood ratio between the actual and the sampling distributions. Because the decorrelation length affects the accuracy and variance of the failure rate estimate, a criterion was developed to choose the optimal decorrelation length. A representative example of a quarter car model on a stochastic road will be used to demonstrate the accuracy and efficiency of the presented importance sampling method over the traditional Monte-Carlo simulation.

We are currently developing an accelerated testing capability based on importance sampling, to estimate the actual failure rate of different vehicle components by artificially inducing high failure rates which are experimentally measured in a controlled environment. The accelerated testing capability will be institutionalized in the TARDEC Physical Simulation Laboratory.

Investigating the Impact of Assumptions in Bayesian Hypothesis Testing-Based

Hao Pan, Michael Kokkolaras and Greg Hulbert (University of Michigan)

Bayesian hypothesis testing is used widely to quantify model confidence based on comparisons of multivariate computational and test data because it is suited to consider multiple sources of errors and uncertainties, combine multiple sources of information and update validation assessments as new knowledge and/or information is acquired. To our knowledge all Bayesian-based approaches reported in the literature use a Gaussian error model. We investigate whether this assumption is reasonable for general purposes and assess its impact on quantifying model confidence by using normality tests and data transformation techniques. In addition, when feature extraction methods such as probabilistic principal component analysis (PPCA) are used to reduce data dimensionality and remove multivariate correlation we must decide how much information to use when applying the Bayesian methodology for model confidence quantification. We will report on the usefulness of available techniques for making such decisions.

April 22nd, Friday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, 3rd Floor, Johnson Rooms

This seminar has been cancelled due to conflicts in timing. Sorry for the inconvenience.

Combustion Behavior and Fuel Economy of Modern Heavy-Duty Diesel Engine Using JP-8
Dennis Assanis (PI), Mike Smith, Doohyun Kim, University of Michigan

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