and (3) Develop well-trained engineers and researchers (at the MS and PhD levels) with an experimental viewpoint to complement theoretical understanding.

Many vehicle integrators and top tier suppliers have identified smart materials as a future technological and strategic thrust. Nonetheless, three major roadblocks continue to stifle the incorporation of these devices in future automotive designs. First, the typical development cycles of automotive products are inconsistent with the development time frame needed to move smart material technologies from laboratory concepts to next generation automotive products. Second, in contrast to conventional technologies, the commercial smart materials market lacks a technical and supplier infrastructure solely dedicated to transportation applications. Finally, since many of these materials are not being manufactured in large quantities, the cost of production can in some cases be relatively high. In spite of these issues, several smart material based subsystems are currently being offered in production automobiles. Two examples are Delphi's MagneRide system, which consists of a MR fluid based tunable vehicle body damper, and Belkin's piezoelectric based yaw rate sensor. In order to facilitate the incorporation of smart material technologies into the broader automotive framework, SVC lies at the knowledge intersection of academia, vehicle integrators and component and subsystem manufacturers. The Center's faculty and student researchers generate new scientific knowledge, identify and develop novel smart material-based components, subsystems and systems, and advance the associated dynamic models and constitutive relationships. Inherent in these responsibilities are the development of mechanisms for the dissemination of knowledge to practicing engineers who will utilize and incorporate these technologies.

A Planning Conference/Workshop jointly took place on October 19 & 20, 2006 in Columbus, Ohio with an attendance of about 25 company representatives and about 15 faculty and students. As a result of this Conference and subsequent meetings, visits and tele-conferences, with the feedback from the prospective company members, we identified the fundamental research needs and defined the underlying pre-competitive issues in the area of smart vehicle components and sub-systems. The Center and its research program have received overwhelming responses from companies and research organizations. In order to achieve its objectives, the Center cooperates with its industrial partners to conduct R&D and education in 4 thrust areas: (1) Interfacial mechanisms, (2) Adaptive NVH, (3) Safety, and (4) Energy. The Center focuses on active material based composites, piezoelectric and magnetostrictive materials, ferromagnetic shape memory alloys, and MR fluid based devices to achieve force, motion, noise & vibration control performance goals including superior spectral bandwidth, reduced mass, and reduced complexity. We are investigating some aspects of environmental requirements, safety, and comfort and performance, and are developing technologies aimed at reduction in cost, improved reliability, and enhanced functionality. In addition to conducting relevant research, the Center will provide advanced industrial education (short courses, web based tutorials, and conceptual demonstrations) to improve the knowledge and skill base of practicing engineers.

6930-07, Session 2

Model-based design of fluid rectification valves for smart material electro-hydrostatic actuator (EHA)

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Smart Vehicles Workshop

A smart material-based EHA consists of a smart material driver and rectification valves which convert high frequency fluid displacement into pseudo-continuous, low-frequency fluid displacement. These systems reduce complexity and mass compared with distributed hydraulic systems and are particularly well suited for automotive and aerospace applications. The EHA must run in the several thousand kHz range to meet performance specifications while current rectification valves are limited to several hundred Hz. This paper focuses on increasing the rectification speed over the state-of-the-art through model-based design of reed-type rectification valves and needle-type active valves. Several techniques are investigated including inertia, vibration, and pressure based models to quantify the overall EHA. Finite element modeling of fluid-structure interactions and in-situ valve testing are used to validate the valve models. This model-based design for high bandwidth rectification valves will be used along with a second iteration system model to design a next generation smart material EHA with improved performance and larger bandwidth.

6930-08, Session 2

Drop tests of a magnetorheological energy absorber

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Magnetorheological (MR) fluids (MRFs) are smart fluids that have field dependent rheological properties that can rapidly (5 - 10 ms time constant) be changed from a free flowing fluid into a semi-solid when exposing to a magnetic field. The rapid, reversible, and continuous field dependent variation in rheological properties can be exploited in a MRF-based damper or energy absorber to provide adaptive vibration and shock mitigation capabilities. The magnetorheological (MR) effect can be used to adapt the resistive force to varying payloads, vibration spectra, and shock pulses, as well as other environmental factors. Electro-magnetic coils are typically used to activate the MR effect, and these electromagnetic coils can be controlled electronically, so that feedback control implementation is practical. MR devices have been investigated for a variety of applications including: seismic mitigation, crashworthy vertical stroking helicopter seats, gun recoil alleviation, helicopter stability augmentation.

The focus of this study is the design, fabrication, testing and analysis of a magnetorheological energy absorber (MREA) for nominal impact speeds of up to 6.75 m/s. A key issue in this project, is the accurate analysis of MR flows in the MREA across this speed range. Generally, analyses fall into two categories: quasi-static models and dynamic models. Quasi-static models are usually based on Bingham plastic or Hershel-Bulkley constitutive laws and serve well in sizing analyses for MR device design and for excitations that induce low shear rate flows in the MR valve. Quasi-static models do not adequately represent MREA behavior under impact or shock loads. Therefore, there is a need to develop dynamic models that can capture built-up damper effects such as friction effects due to seals, compressibility, as well as force response due to shock or impact. The focus of this project is to develop experimentally validated design and dynamic response analyses as these are especially needed to improve understanding of MREAs under shock or impact loads.

A key consideration in damper performance is the ratio of the force at maximum field to the force in the absence of field, that is, dynamic range, D. As the piston velocity increases, viscous forces grow stronger than the yield forces, and this dynamic range tends to decrease as piston velocity increases. In the context of shock or impact, the dynamic range is typically defined as the ratio of the average MREA force at maximum field to that in the absence of field. Ahmadian's group examined the controllability of a double-ended MREA subject to impact velocities of up to 6.6 m/s. At 2.2 m/s (86 in/s) a dynamic range of D=2.75 was achieved. However, at a speed of 6.6 m/s (260 in/s), the dynamic range had reduced to nominally D=1, indicating no controllable damper force was achieved. They hypothesized that the transition from uncontrollable to controllable is related to the transition of fluid flow from turbulent to laminar, which is supported by the analysis in Ref. 3. Browne and coworkers (GM) conducted impact tests of an MR damper at stroking velocities ranging from 1.0 to 10 m/s and showed that the MR damper force could be tuned by adjusting magnetic field. However, it was noted that similar trend was found in these two studies-the dynamic range of the MR damper significantly degraded for high velocities.

The key goals of this study are to improve understanding of MREA behavior and to enable design of MR devices so as to avoid loss of dynamic range at high speeds (herein defined as nominal speed up to 6.75 m/s). To achieve these goals for valve mode MREAs, a nonlinear hydromechanical analysis, considering both laminar and turbulent flow, was derived and an effective design strategy was established. The key conclusion from this analysis was that the flow through the MR valve must be laminar to have sufficient dynamic range (e.g., D=2) and the Reynold's number must be kept sufficiently low to ensure this (Re=850). To validate the effectiveness of the design strategy at high speeds, a high force bifold valve MREA was designed keeping the Reynolds number was kept below 850. The MREA was then fabricated and tested at UMCP under low sinusoidal velocities using a damper dynamometer. The MREA was also tested at the GM R&D