RESEARCH FOCUS:

Research to Increase Fluid Power Energy Storage Density

By Perry Li, Co-Deputy Director

It is well known that fluid power has unsurpassed actuation power density compared to other approaches such as electric motors. In the area of energy storage, hydraulic accumulators can also accommodate much higher storage and regeneration powers than electric batteries. These advantages make hydraulic hybrid vehicles attractive since power dense actuators and storage with high power capability translate to high-performance vehicles and the ability to capture braking energy during fast braking events. Unfortunately, the energy storage densities of hydraulic accumulators, i.e. the amount of energy one can store per unit volume (volumetric energy density) or per unit mass (gravimetric energy density), are two orders of magnitude lower than electric batteries. The energy storage capacity affects how much braking energy can be captured, how much engine can be downsized, and the effectiveness of engine/energy management strategy to improve fuel economy and to limit undesirable emissions due to transient engine operation. For small passenger vehicles with little available space, limitation in energy storage density is even a more significant issue.

While energy densities of conventional accumulators can be improved to a small degree by increasing pressure and by introducing isothermalizing elements, CCEFP is investigating two revolutionary approaches to address this issue. Project 2C.1 is investigating an open accumulator concept that has the potential of increasing energy storage density by an order of magnitude, whereas in Project 2C.2, an elastomeric strain energy storage approach, has the potential of increasing it by two to three times.

The "open accumulator" approach being investigated in Project 2C.1 (led by Prof. Perry Li at University of Minnesota) overcomes the expansion ratio limitation by existing accumulators by compressing and exhausting air from and to the atmosphere when storing and releasing energy. This allows for a significant increase in expansion ratio (350 when Pmax = 35MPa), without the volume penalty (since the expanded air is exhausted and is no longer in the system!). In fact, only the compressed gas volume needs to be accounted for. Thus, a potential 20-fold increase in energy storage density is available (Fig 1). The main challenges in realizing the open accumulator concepts are (1) maintaining safety in compressing and expanding atmospheric air; (2) maintaining power density; (3) providing efficient input and extraction of energy; and (4) controlling heat transfer and temperature variation associated with the large compression and expansion ratios. These challenges are being addressed by utilizing a safe choice of materials, proposing a system architecture that maintains constant pressure, developing a specialized compressor/motor design, and optimizing heat transfer in the heat transfer and using thermal storage materials.

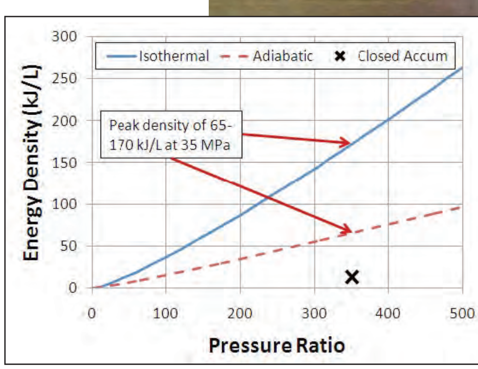

Fig 1: (Left) Energy density of open accumulator relative to closed accumulators
Fig 2: (Top) Bench top demonstration of strain energy storage concept using a surgical tubing.

In the "elastomer strain energy accumulator" concept being proposed and investigated in Project 2C.2 (led by Prof. Eric Barth at Vanderbilt University and started in Fall 2008), elastomers (such as polyurethane rubbers), instead of compressed gas, are being used as the storage medium. By storing energy in molecular springs of elastomers rather than agitation in compressed gas molecules, potential thermal losses can be significantly reduced without sacrificing power capability. The issue of gas diffusion through rubber diaphragms can also be eliminated. In addition, by using a thick-walled elastomeric balloon configuration, energy storage and release take place at nearly constant pressure through a large portion of its operating range. With this concept, an energy storage density that is 2 to 3 times that of conventional gas charged accumulator is expected at 35MPa.

Patent applications have been made for both the open accumulator and the strain energy storage concepts.

Faculty and students from the CCEFP visit Sauer Danfoss

CCEFP Visits Sauer-Danfoss

Fifteen CCEFP students and faculty from the University of Minnesota visited the Sauer-Danfoss facility in Ames, Iowa, on July 16 and 17. More than 50 employees from the company attended the event. The purpose of the event was to get to know one another better, present updates on CCEFP research projects, and to learn from industry experts. Because many of the students are affiliated with the hydro-mechanical passenger car test bed, a plant tour that highlighted their HMT manufacturing cells was viewed as a highlight. Another big hit was to witness actual engineering development and testing.

New Collaboration with Ford Motor Co.

CCEFP is collaborating with Ford Motor Co. and Folsom Technologies International on the Generation 2 platform for the hydraulic hybrid vehicle test bed. In this new platform, a Ford F-150 vehicle will be modified with a hydraulic hybrid power-train by incorporating hydraulic accumulators with a compact, integrated hydraulic continuously variable transmission (CVT). Although there are differences from the Generation I design, the new platform will remain a Hydro-mechanical transmission (HMT) power-split design. The Generation 2 platform offers a rugged test vehicle with integrated design for developing and testing control and optimization algorithms.

The Generation I platform, which is based on a Polaris Range utility vehicle chassis and discrete off-the-shelf components, will continue to be used for testing and integrating CCEFP concepts and project results.

IAB Elections Update

Joe Kovach of Parker Hannifin's Hydraulic Group was recently elected vice chairman for the CCEFP Industrial Advisory Board. He joins the Chairman, Dwight Stephenson of HUSCO International, as leaders of the organization tasked with providing strategic industry input and guidance into the CCEFP. He joins past IAB industry leaders including Ed Howe of Enfield Technologies, Jeff Herrin of Sauer Danfoss, and Dennis Szulczewski of Eaton Corp. who have all moved on to serve on the CCEFP Executive Committee.

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