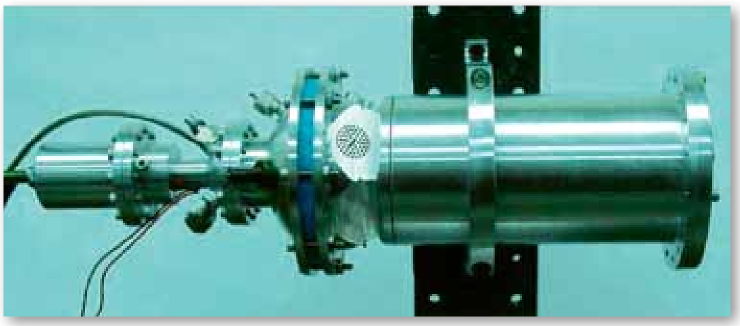
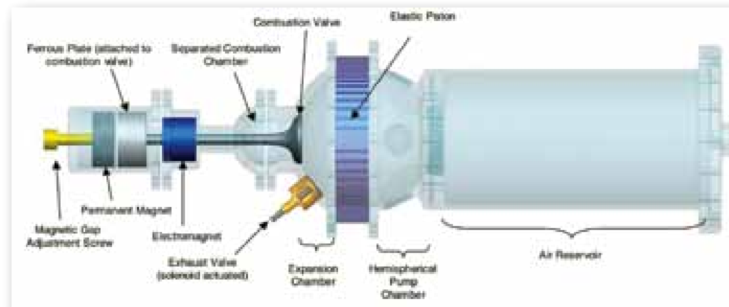
PROJECT 2B: FREE-PISTON ENGINE COMPRESSOR

An interview with Eric Barth, Professor, Vanderbilt University





Project Goal: Develop a compact high energy density pneumatic power supply applicable to untethered fluid-power applications that is an order of magnitude more power dense than existing technologies. This will be achieved by designing, building and testing a free-piston engine utilizing spark-ignited fuel that is specifically load matched to the task of compressing air.

What is the overall goal of this project?

The overall goal of this project is to provide a power source for small-scale, fluid-powered applications. Such applications include pneumatically actuated robots such as rescue robots, orthoses and portable powered hand tools, among others. Fluid-powered actuation offers the highest power density of any type of actuation. This project seeks to exploit this high power density on a scale not typical of most fluid power applications. It will provide an untethered source of pneumatic power so that the application can be mobile, compact, powerful and run without needing refueling for hours. We seek to achieve this goal using a free-piston engine compressor.

As the name implies, it is a combined internal combustion engine and compressor in one. What makes it different from a normal engine is that it utilizes an elastic free-piston and a separated combustion chamber. The elastic free-piston is a thick, high-temperature silicone diaphragm that acts as a piston. Combustion pressure pushes on one side of the piston, and pump work is done on the opposite side. This piston is compact and lightweight. It is also not subject to the same friction and blow-by losses as typical sliding pistons. The separated combustion chamber frees us from an intake and compression stroke, and results in an engine that does not need to idle and can be fired on demand. The engine runs on propane fuel.

How did this particular project come about?

This project came about within the larger context of a lack of power sources for untethered applications. If you look at untethered robots, they are typically powered by batteries and actuated by electric motors. The low energy density of the batteries results in a system that cannot operate for long before requiring a recharge. The low power density of the electric motors results in a heavy system not able to exert high forces on its environment. This shortfall is not limited to batteries and motors, but rather is the universal limitation for all small-scale untethered robotics. This problem is very much a challenge of scale; obviously larger scale untethered applications, such as automobiles and earthmoving equipment, have adequate solutions. The challenge comes when the systems need to be on the power scale of people. Half of the solution is a high power density form of actuation – fluid power. The other half of the solution is a high energy density source of power. This project fits naturally within the motivations of the Center for Compact and Efficient Fluid Power.

What direct application will this project have in the fluid power industry?

This concept will open up entirely new markets for the fluid power industry. Fluid power is mostly aimed at large-scale applications. By bringing fluid power to a smaller scale, one can imagine the vast number of new applications that become possible.

What work has been so far and what have been the results?

Thus far, we have designed, fabricated and experimentally evaluated a prototype device. Much of our work has centered on formulating a detailed model that not only helps us to further understand which energetic mechanisms to exploit to enhance compactness and efficiency, but it also leads to a general model-based design method that can be used to make such an engine/compressor with accurately designable specifications for any number of target applications. The experimental prototype successfully pumps air up to 94 PSIG, and its performance and efficiency is well predicted by the model.

Looking ahead, what is planned for this project in the future, and what is the timeframe?

Future plans include a second prototype designed specifically for the compact rescue crawler robot testbed and a third prototype designed for the orthosis testbed, both within the CCEFP. The timeframe for these goals is two years.

What is your role in the project? How and why did you get involved?

I am the PI on the project. I got involved based on previous work I had done in both accurate pneumatic control and high energy density compressible fluid power actuation. The CCEFP was a natural fit for my work.

What has the experience of working on this project been like for you? What have you learned by being a part of it?

The most rewarding part of this work is the research community of folks within the CCEFP. Many ideas and refinements have come from discussions with my colleagues and industrial partners within the Center.

Why do you feel the CCEFP is important?

The CCEFP will bring about a shift that is needed not only for the fluid power industry, but also for a host of applications both old and new that have challenges that fluid power, and in many cases arguably ONLY fluid power, can meet.