Mechanical Engineering Department Seminar

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1130 Mechanical Engineering

Model-Guided Design of Compact Power

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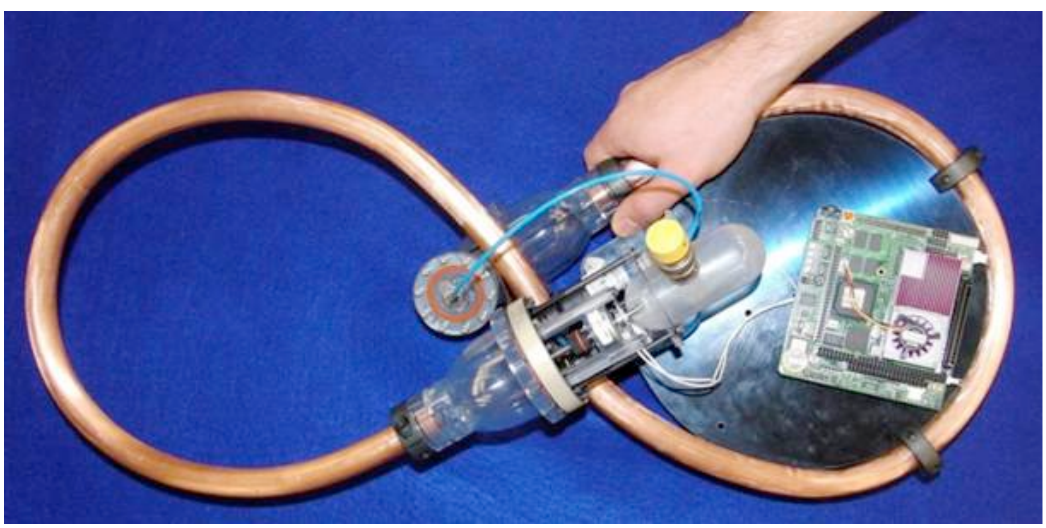
A high energy-density power supply system is in many ways the "long pole in the tent" for untethered robotic systems in the range of 100 W to 10 kW. The inadequate energy density of batteries coupled with the low power density of typical electromagnetic actuators leaves small scale untethered robotic systems grossly underpowered and with short run-times. A solution that makes use of a higher energy density energy carrier and higher power density actuators, all while adhering to the challenging constraints of a small-scale system, is required. A compressible fluid power solution driven by energy dense fuel is proposed. This seminar will present a system dynamics and controls perspective on the design of two different power supplies for such untethered and mobile systems: (1) a free-piston engine compressor, and (2) a controlled Stirling thermocompressor.

A free-piston engine is an engine with a piston that is not rigidly connected to a crankshaft. As such, the motion of the "free" piston is dictated by dynamic forces. This dynamically dominant character is a break from kinematically dominated crank engines. Traditional design and control of crank engines are highly dependent on the kinematically constrained relationships of and between the piston position (including the fact that the stroke length is known and fixed), the valve positions (typically governed by a cam that is kinematically linked to the crankshaft), and kinematically determined fuel injection and ignition timing. Some dynamic effects such as lift duration and timing advance are common features of kinematic engines, but largely represent fine-tuning. The modeling, design and control of free-piston engines require an approach that is more intimately linked to the system dynamics of the engine and load. The model-based design of a novel free piston engine compressor that incorporates a liquid piston will be presented. The second power supply system, a Stirling thermocompressor, is also a free-piston device. The Stirling thermocompressor is related to a Stirling engine, except that the Stirling cycle is utilized to compress and pump gas as opposed to deliver shaft work. The design and dynamic modeling of this concept will also be presented in the context of an energy dense power supply system.



Bio: Eric J. Barth received the B. S. degree in engineering physics from the University of California at Berkeley, and the M. S. and Ph. D. degrees from the Georgia Institute of Technology in mechanical engineering in 1994, 1996, and 2000 respectively. He is currently an associate professor of mechanical engineering at Vanderbilt University, Nashville, TN and director of the Laboratory for the Design and Control of Energetic Systems. His research interests include the design, modeling and control of mechatronic and fluid power systems, energy storage, energy harvesting, power supply and actuation for autonomous robots, and MRI compatible robots.