Annual Report

Project Title: Hybrid Actuators for Enhanced Automation in D&D Remote Systems Tasks
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Lead Principal Investigator:
Dr. John F. Jansen
Oak Ridge National Laboratory
Building 7601
P.O. Box 2008
Oak Ridge, Tennessee 37831-6305
Ph. (865) 574-8154; Fax. (865) 574-4624
Email: jansenjf@ornl.gov

Research Objectives

Revolutionary changes in both the design and control of manipulation systems are required to enable autonomous operations in unstructured environments, as those defined for decommissioning and decontamination (D&D) tasks. Many researchers are exploring issues associated with the control of existing manipulation systems, but there is very little research effort directed towards enabling technologies that will provide significant improvement in the mechanical performance of these systems. Neither advanced controls or improved mechanical performance alone will enable a revolutionary new class of manipulation systems. The best control algorithms will not expand the performance of an actuated system beyond its physical limitations. The focus of this research is to explore advanced actuation methodologies that have the performance and capacity required for a revolutionary new class of manipulation systems that will enable autonomous operations in D&D environments. There are three fundamental goals associated with achieving the required breakthroughs in actuation technology.

1) To understand the basic science associated with a new type of piezoelectric ceramic material and understand the engineering science associated with utilizing this smart material for a new type of actuator. Our analysis shows that the power density of these materials increases with frequency. Unfortunately, robotic applications require actuation systems that operate at lower frequencies. The primary problem addressed with this research is the transmission of high frequency/low displacement actuation to low frequency/large displacement actuation. While the focus of this project is on piezoelectric ceramic materials, the foundation that is being developed could also benefit research into magnetostrictive materials and actuators.

2) To study design issues associated with a hybrid actuator that has the power density of hydraulics but functions like a conventional electric motor.

3) To provide the enabling technology to allow remote systems to automate many of the subtasks associated with D&D applications and to facilitate tetherless operations.

Research Progress and Implications

This section summarizes work after three years. During the first year, the general models of the piezoelectric crystal and the mechanical pump have been completed. The dominant nonlinearities, such as the mechanical load model of the piezoelectric\hydraulic pump, have been developed in detail. Simulink models (Simulink is a commercial simulation package from MathWorks, Inc.) have been constructed. Understanding these models is critical to the research goals of this proposal. A conventional piezoelectric stack was used in an experimental setup and data was collected for various operating conditions. Variations in the electrical elements as a function of voltage and frequency have been taken and the results have been included in the computer models. One major observation has already been made concerning the effective capacitance of the piezoelectric stack. We observed significant variations in the material capacitance as a function of the applied voltage. The linear models of the piezoelectric stack fail to account for this phenomenon.

During the second year, small distributive valves, which possess the property of being very responsive (over 1 kHz), have been designed, modeled, and tested. An experimental setup was designed to verify the fluid dynamic forces on these valves. An actual pumping chamber with small distributive valves was constructed and assembled.

During the third year, testing of the valves and the comparison to the computer models were conducted and the results were very positive. Tests indicate that small distributive passive valves (see Fig. 1) were capable of achieving rapid pumping action. These valves are critical to the development of the proposed hybrid actuator. Our understanding of multi-physical problem (i.e., fluid forces, smart materials, and mechanical interaction) has increased significantly and has allowed us to model and predict these complex interactions. An optimized hybrid actuator (see Fig. 2) has been designed and compared with the computer simulation. Careful measurements and comparisons to the mathematical modeled were made and has been documented in references 1 and 2. We were able to achieve over 1,000 psi of deadhead pressure and over 70 Watts of fluid power out.

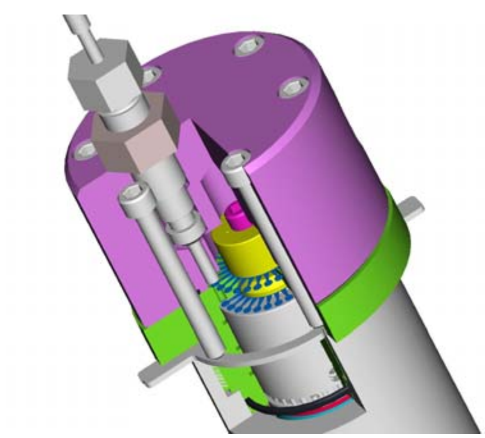

Fig. 1 – Distributive valves.

Fig. 2 – Piezoelectric pump.

Information Access

1. J. Jansen et al., *Design, Analysis, Fabrication, and Testing of a Novel Piezoelectric Pump*, ORNL/TM-2003/188, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 2003.

2. J. Jansen et al., "Modeling and Testing of a Novel Piezoelectric Pump," presented at the IEEE International Robotics and Automation Conference, New Orleans, Louisiana, 2004.