Mesoscopic Pump Development

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FY 1997 Cost: $0K
FY 1998 Cost: $0K
Estimated FY 1999 Cost: $100K

Study Control Number: PNXXXXXX

Project Description

This research project undertook the development of a meso-scale pump/compressor. The prototype article was designed as a diaphragm pump to circulate saturated lithium bromide solution at 60 mL/min with a pressure rise of up to 1 bar (15psi) with input power of 1.5 watt, for a target efficiency of 7%. The pump, motor, and controller needed to be compact, lightweight, and efficient and the fluid side reliably sealed from the environment. No maintenance should be required because the components will be too small to handle under field conditions, and LiBr solution is somewhat hazardous. The unit should operate quietly, in any attitude, and tolerate overloading without failure.

The prototype device is a small diaphragm pump, as illustrated in Figure 1. The linear drive motor operates by alternating excitation of the drive coils, which pull the thrust plate in a reciprocating motion at a controlled frequency of 2 – 32 Hz. The thrust plate actuates a metallic diaphragm supported between soft gaskets. Stainless-steel reed check valves control the liquid flow through the working chamber, which was designed for fluid pumping with a flat upper valve plate opposite the diaphragm. For gas compression, the upper valve plate surface would need to closely match the profile of the diaphragm at full stroke.

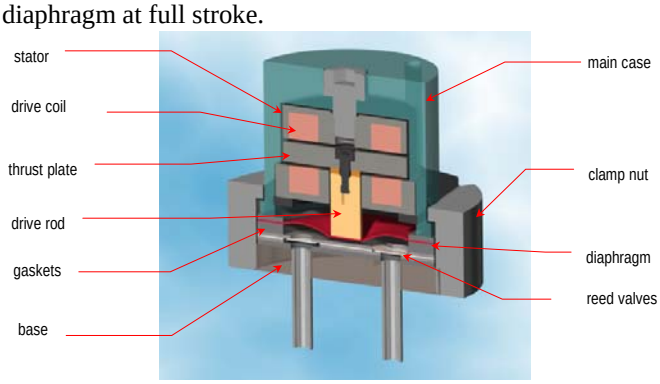

Figure 1. Section View of the Mesoscopic Pump.

Technical Accomplishments

Pump Development

Several of the program goals were accomplished. The performance of the pump at the end of this phase of development did not meet the target. The best measured efficiency was 0.13%. The fundamental problems with the pump design are insufficient power, a failure to match the motor power output to the pump power requirement over the duration of an entire cycle, and resistance and backflow losses in the check valves. Summary performance test results for several drive frequencies are presented in Figure 2.

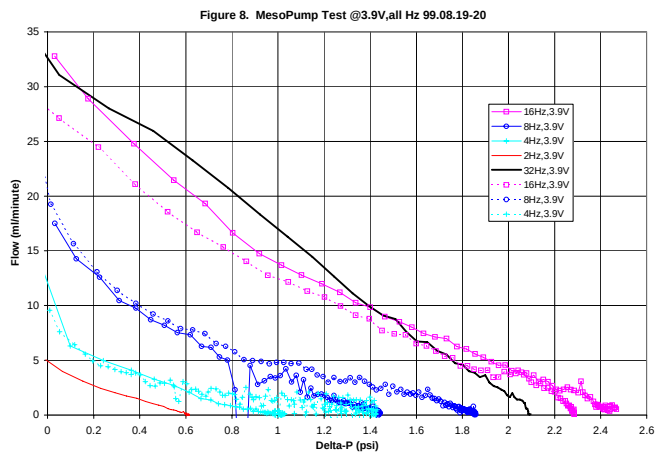

Figure 2: Performance Curve for the Mesoscopic Pump at 0 psig Static Suction Head.

Hydrostatic Forming of Small Diaphragms

An overall objective in this task was to develop technologies and in-house capabilities for forming parts at the millimeter scale. The metallic diaphragms (Figure 3) were successfully produced using hydrostatic forming against a single hard die, a technology not previously used at PNNL.

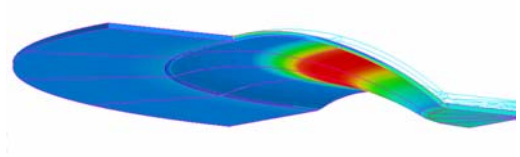

Figure 3. FEA Results for a Diaphragm Model. Note the offset of the center hub, which resulted in significant stress reduction overall and reduced stress concentrations.

An ultrasonic scanning system was developed and used for profile measurements of 1) the diaphragms in both rest and deformed states and 2) the dies. This was performed by the PNNL Applied Mechanics, Measurements, and Nondestructive Evaluation Group at minimal cost in the course of evaluating the scanning system. A representative scan section is shown in Figure 4.

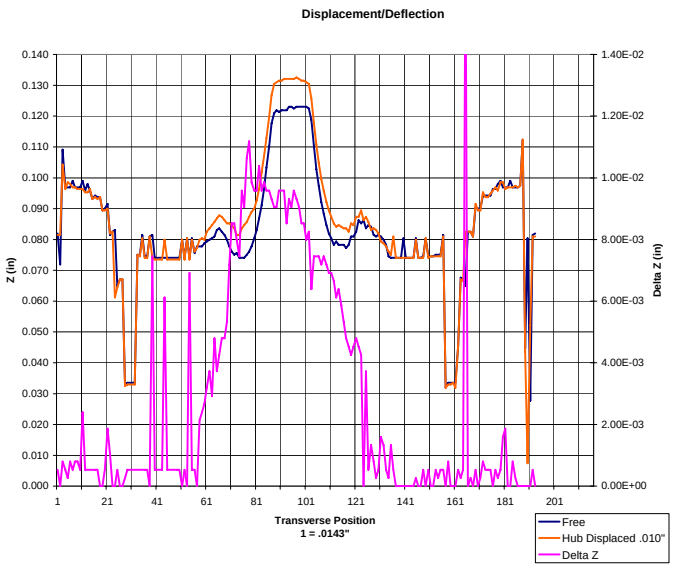

Figure 4. Profile Scan of a Diaphragm in Free and Displaced Positions. The difference between the two scans is presented as "delta Z" on a 10x scale.

Acknowledgments

Dr. Jerry Martin initiated this R&D project and performed the fundamental engineering of the pump and drive motor completed the electrochemical aspects of this work. Dennis Mullen designed the diaphragm, created the tooling, and managed the testing program. Kevin Gervais generated the design drawings for the pump. Peter Armstrong and David Hurn designed and conducted the performance tests. Dr. Morris Good and Justus Adamson performed ultrasonic diaphragm profile measurements.