MINIATURIZED PIEZOELECTRICALLY DRIVEN UNCONSTRAINED VALVES FOR ROBOTIC APPLICATIONS

JIEN SUMADI

Pneumatic actuators have many promising features that make them attractive for robotic use, including light in weight and having high compliance and force-to-weight ratio. The growing demand for an increased power-to-weight ratio in pneumatic robots drives trends in miniaturization in component production. These trends have been hindered by the lack of ultra-precision assembly and the limited availability of mini solenoid valves. An unconstrained valve driven by a piezoelectric actuator (PEA) is thus proposed for its simplicity and high miniaturization potential. In this thesis, the realization of miniaturized unconstrained valves is discussed, which covers valve design towards miniaturization and implementation in robotics. The miniaturization design of a pneumatic valve with unconstrained poppet - orifice mechanism was considered as an advantageous breakthrough to eliminate the assembling complexity and to avoid the effect of positioning distortion due to temperature changes. Firstly, we presented an analysis and simulation model of an unconstrained poppet valve, which includes the mechatronic part of a PEA, Hertzian model, dynamics of poppet motion, and airflow through an orifice. An overall valve model based on the dynamics of a bouncing poppet were built and verified experimentally for valves with different piezoelectric dimensions. Secondly, we studied individual design parameters in detail referencing experimental results. The simulation model can therefore be used to understand the behavior of unconstrained poppet valves. Flow generation drops together with valve miniaturization, illustrating the tradeoff between output flow and size limitations. The energy conversion inefficiency in PEA is improved by using a LC tuner with 400% increase over the conventional approaches. Thirdly, using unconstrained valves for pneumatic control has the advantage over solenoid on-off valves of compactness made possible by the unconstrained structure and PEA use, enabling inherent PCM-emulation. Application tests of pressure control for artificial muscle and speed control for pneumatic cylinder were verified by experiments.