Abstracts

Group C: Pneumatics

C1 Modeling and simulation of pneumatic systems with focus on tubes

J. Kefer, S. V. Krichel, O. Sawodny

The design and dimensioning of pneumatic applications is currently done at Festo AG & Co. KG with simulation programs such as CACOS® requiring dynamic models for each component that represent both its steady-state and transient behaviour. The effects of pneumatic tubes connecting system components have been neglected so far to increase computational speed and reduce model size. In process automation, one of the novel application fields at Festo, long pneumatic tubes are used to cover the distance between distributed drive units and centrally arranged valve clusters. The influence of these tubes on the overall system dynamics is relevant and worth to be studied. Therefore, a dynamic tube model with a good trade-off between model complexity and accuracy is derived. It is designed to be compatible with signal-flow simulation programs, increasing its usability in large-scale industrial settings. The model is validated against experimental results for pressurizing and exhaust processes for tubes between 2 and 200m.

C2 Parallel Manipulator driven by Pneumatic Muscles

E. Bideaux, S. S. Mena, S. Sesmat

Pneumatic muscles show severe parametric uncertainties and non linearities in the dynamic modeling. These uncertainties come mainly from air compressibility that cannot be neglected but also from the rubber stiffness of the muscle itself. Here FESTO™ pneumatic actuator muscles (PAM) are used for controlling the attitude of a platform with 2 degrees of freedom (DOF). This type of actuators has widely been used in robotic applications but usually the full operating range of the muscle is not used and the control is restricted to the part where the actuator characteristics are mostly linear. In this paper, we propose a complete dynamic model of this actuator, which consists in an extension of the usually used model determined by Daerden /3, 6/. It includes static as well as dynamic characteristics of the PAM, which have been validated experimentally. It shows that the mathematical model used in many papers in the literature are far from the real behavior of this type of component.

C3 Nonlinear model-based control architecture for antagonistic pairs of fluidic muscles in manipulator motion control

F. Schreiber, Y. Sklyarenko, M. Calabria, W. Schumacher, et al.

In this paper a control structure and joint trajectory planning algorithm are presented for a type of kinematically redundant manipulator actuated by joints with pairwise antagonistic pneumatic muscles. The used muscles and the resulting behavior of a single manipulator joint featuring antagonistic muscles in a symmetric configuration are characterized.
The joint limits resulting from the limited deflection of the pneumatic muscles can present a problem for the planning of the reference joint trajectories. An algorithm is presented to ensure the joint limit avoidance in the redundancy resolution of the presented manipulator.
Beside the distinct limits, the pneumatic joint actuation also results in a hysteretic behavior, it is shown that in this case the hysteresis can be described by a Preisach hysteresis model. The resulting hysteresis model allows the construction of a model-reference following controller, with a model control loop, designed for good tracking performance and a disturbance rejection loop optimized for suppression of disturbances. Experiments confirm the improvement in tracking control as compared to the system solely controlled by a feedback regulator.

C4 Development of an Arbitrary Pressure Pulsation Generator for Testing Gas Flow Meters

T. Kato, T. Oowaku, H. Sakuma

The purpose of this study is to develop a novel and compact pneumatic pressure pulsation generator that can generate arbitrary pressure pulsations in a pipe system in order to evaluate the characteristics of flow meters and flow sensors. Gas flow meters and sensors (used in industrial processes and in homes) are exposed to unsteady pressure pulsations generated by the operation of other equipment and piping. In this paper, in order to establish a compact (laboratory-size) testing device to characterize gas flow meters and sensors (particularly around their zero point) at various pressure pulsations, a compact arbitrary pressure pulsation generator is developed and tested. First, using ordinary 15 m length piping and a T-tube, pressure pulsations are generated and supplied to two flow meters (a laminar flow sensor and an ultrasonic flow meter). Then, the pulsations are duplicated using the newly developed compact pressure pulsation generator and supplied to the flow meters. The experimental results indicate that the developed pulsation generator can accurately duplicate the pulsations generated by the ordinary piping. These results indicate that our system can potentially be used to reduce the cost of flow meter evaluation.

C5 Viscoelastic Properties of Artificial Pneumatic Muscle

Z. Varga, P. Keski-Honkola

An artificial pneumatic muscle is a hollow airproof actuator that is made out of fiberreinforced rubber tube attached to metal fittings at each end. Muscle can produce pulling force as a function of contraction and pressure. This kind of actuator can be used to generate changes in displacement, generate vibration or damp external forces. Behavior of artificial muscles can be described using the knowledge that muscle tends to find a position with lowest energy during the loading process. Modeling of this kind of muscle system is difficult because it has built-in nonlinearities from pneumatic medium and muscle material. The material viscoelasticity that can be described as force hysteresis, causes energy loss during loading and relaxing of the muscle. Muscle composite material elasticity also affects muscle volume and makes it a function of both pressure and contraction. The aim of this paper is to describe the behavior of the muscle fiber composite material. The measurements in this paper show muscle material viscoelastic behavior in different stretching angles in relation to fiber directions and the dissipation of energy during the measurement cycle. These measurements were made with different frequencies in a room temperature.