# Developmen ow-cost Wearable Servo Valve Using Buckled Tubes and Embedded Controller

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# NOTATION

$A_i$ : Sectional area of buckled tube [$m^2$]

$b_T$ : Damping coefficient of disc with buckled tubes [Nm/(rad/s)]

$D_Z$ : Duty ratio corresponding to the dead zone of the valve [%]

*duty (i)* : Input duty ratio to the RC servo motor [%]

*e(i)* : Deviation of the displacement from the desired position [mm]

$e_p(i)$ : Pressure deviation from the desired pressure [Pa]

$i$ : Motor current [A]

$J_M$ : Servo motor inertia moment [kg·$m^2$]

$k_e$ : Reverse electromotive force constant [Vs/rad]

$K_D$ : Differential gain for positioning control of rubber artificial muscle [%·s/mm]

$K_{DP}$ : Differential gain for pressure control [%·s/kPa]

$K_p$ : Proportional gain for positioning control of rubber artificial muscle [%/mm]

$K_{pp}$ : Proportional gain for pressure control [%/kPa]

$L$ : Dead time of servo motor [s]

$L_M$ : Internal inductance of servo motor [H]

$P_a$ : Atmosphere pressure [Pa]

$P_o$ : Output pressure of the valve [Pa]

$P_s$ : Supply pressure of the valve [Pa]

$Q_a$ : Exhaust flow rate of the valve [kg/s]

$Q_s$ : Supply flow rate of the valve [kg/s]

$R$ : Gas constant [J/(kg·K)]

$R_M$ : Internal resistance of servo motor [Ω]

$r_T$ : Distance from the central axis of the motor to the fixed point of the right/left tube [m]

$r_{Ti}$ : Distance from the tube buckling point to the tube holding point [m]

$T$ : Absolute temperature [K]

$u(i)$ : Control input [%]

$V_{cc}$ : Supply voltage to servo motor [V]

$V_M$ : Applied voltage to servo motor [V]

$V_o$ : Volume of the tank [$m^3$]

$W_T$ : Distance from the motor axis to the buckling point of left/right tube [m]

$\theta$ : Motor rotational angle [rad]

$\theta_{i0}$ : Initial angle of buckled tube from motor shaft [rad],

$\theta_r$ : Target angle of motor [rad]

$\theta_{Ti}$ : Buckling angle of buckled tube [rad]

$\kappa$ : Air specific heat ratio [-]

$\rho$ : Atmospheric density [$kg/m^3$]

$\tau_M$ : Generated torque of the motor [Nm]

$\tau_{Mi}$ : Restoration torque at motor shaft given by restoration torque of buckled tube [Nm]

$\tau_{MV}$ : Motor torque corresponding of $K_M \cdot V_M/R_M$ [Nm]

$\tau_{Ti}$ : Torque generated by the restoration force from the buckled tube [Nm]

$\Delta_T$ : Sampling period [s]

Here, suffix "$i$" in certain equations will indicate "$L$" and "$R$" that mean left and right, respectively. Then, 0 indicates the initial value.