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3rd International Conference and Exhibition on Mechanical & Aerospace Engineering
October 05-07, 2015 San Francisco, USA

Simulation Research of Driving Schemes for a Dynamic Calibration System of Fuel Turbine Flowmeters

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October 7, 2015

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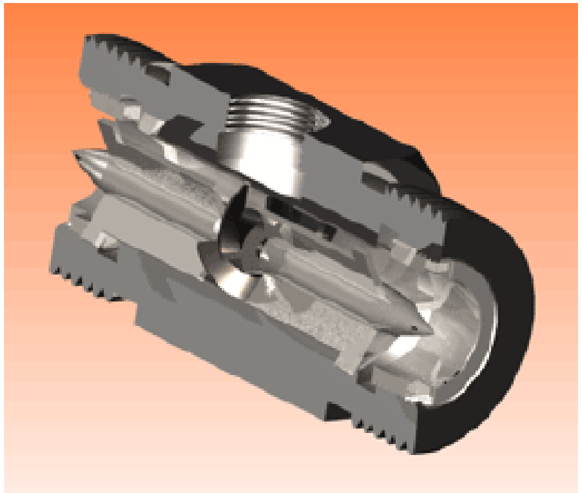
Introduction



long-term usage → performance degradation

→ fluctuation of meter coefficient → calibration needed

Introduction

Theoretical basis

$$K_s Q^2 - Q\omega = K_d \dot{\omega}$$

Review of research

Static

1、 mass method

2、 volume method

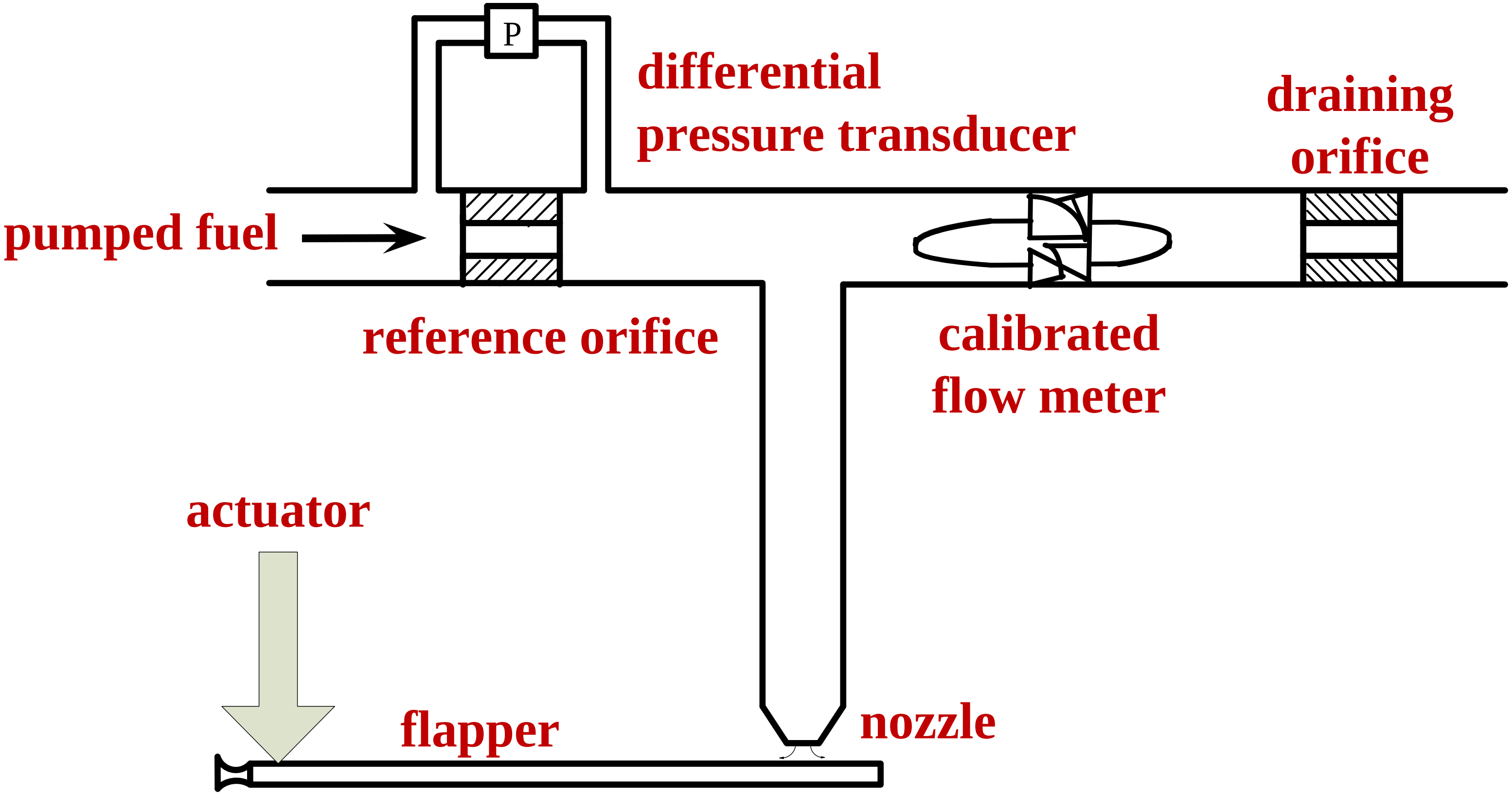
Dynamic

1、 thimble method

2、 ……

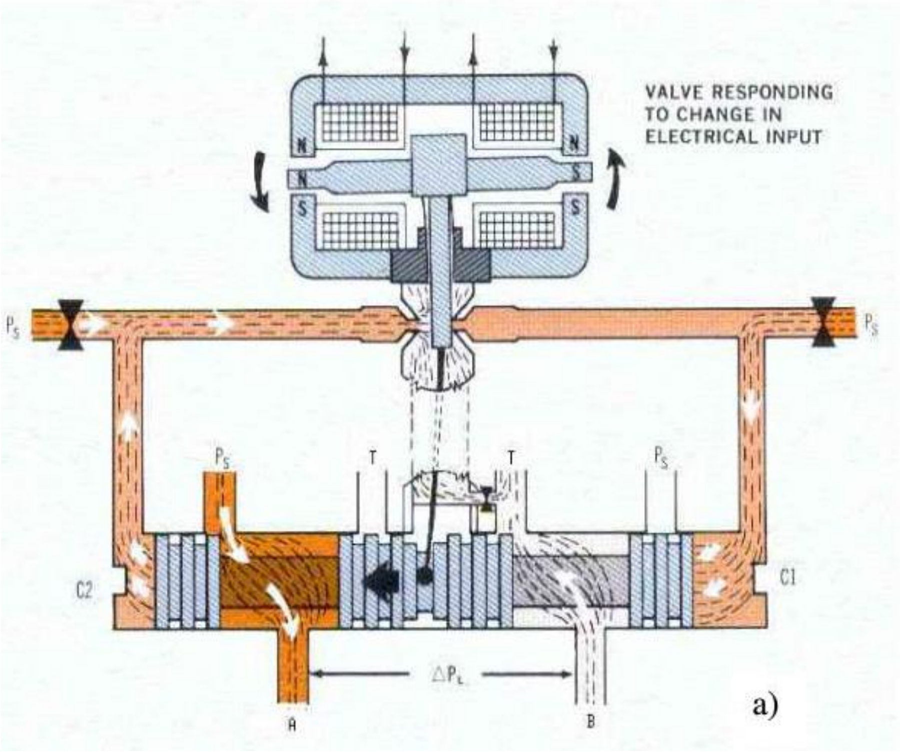
Introduction

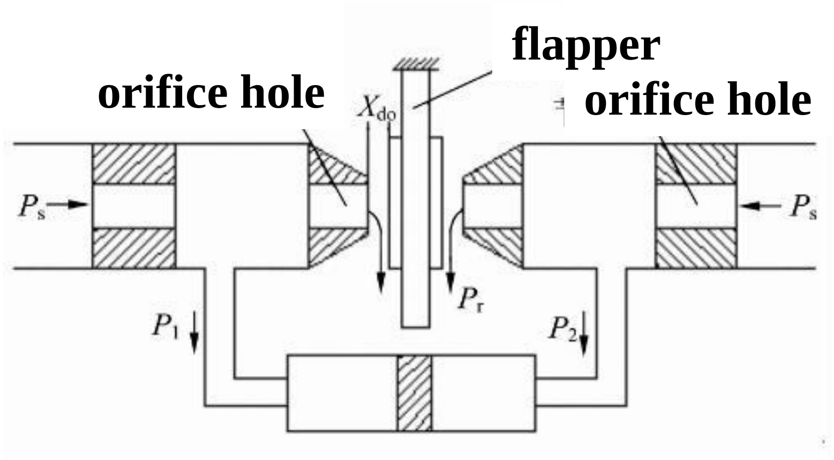
Principle and method presented by our research



Modeling and Simulation

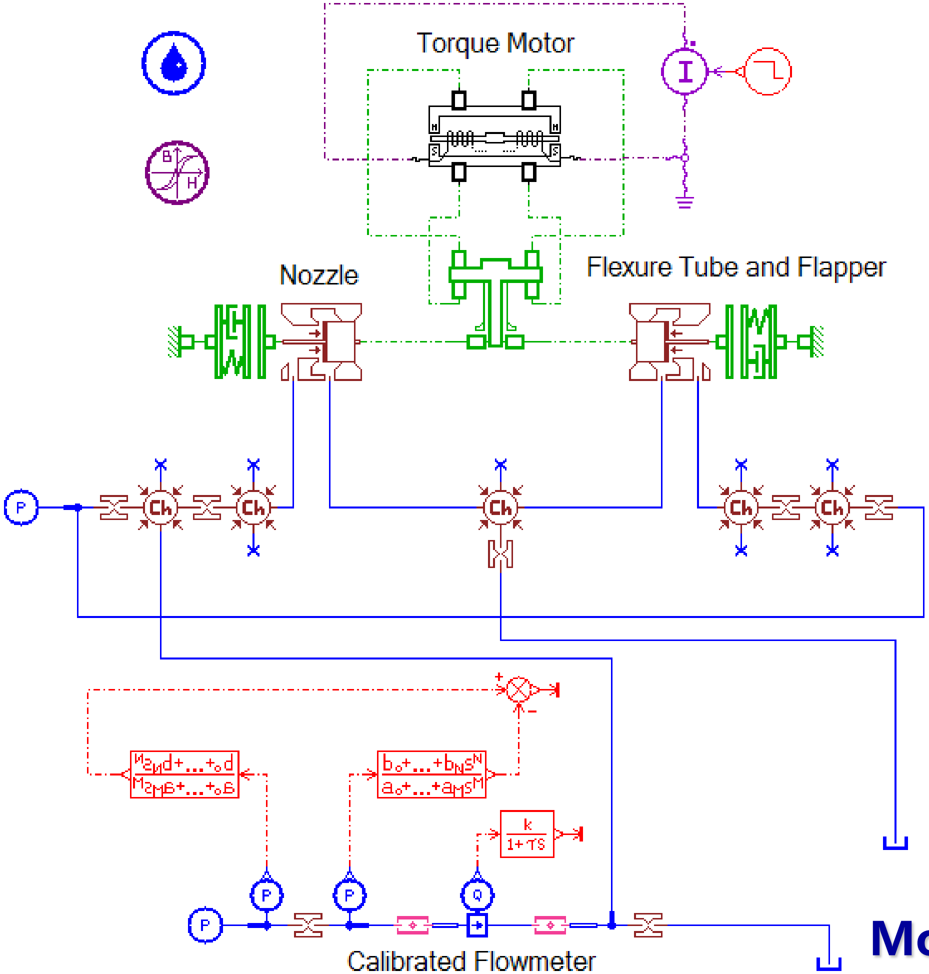
Alternative actuating solutions:

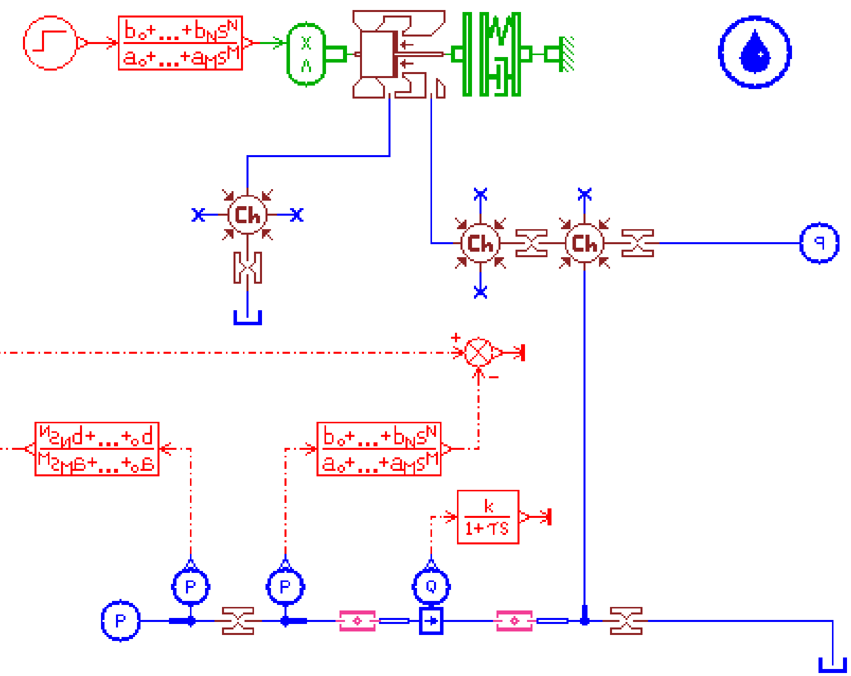




Torque motor driving NFV. **Piezoelectric actuator driving NFV.**

Modeling and Simulation

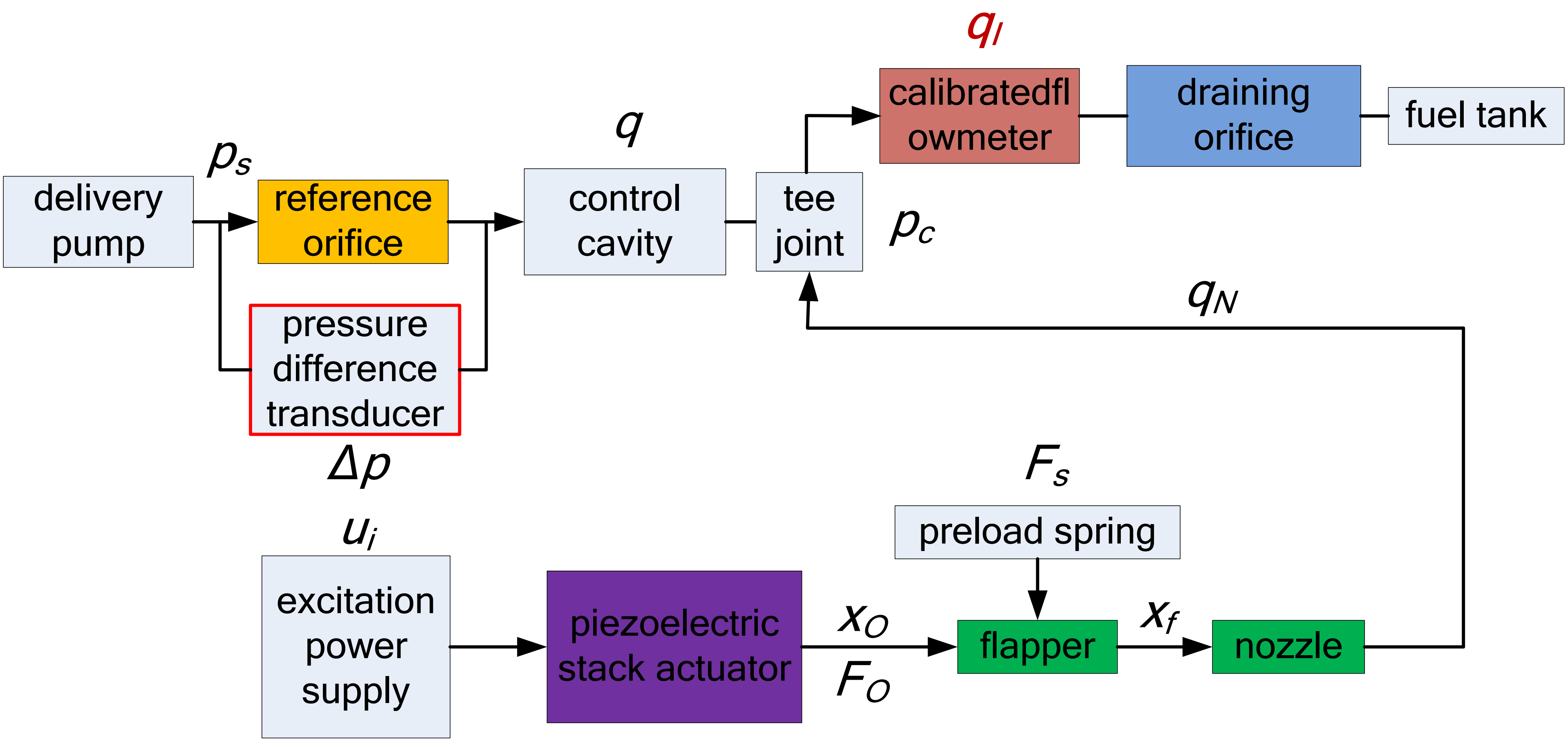




Model of piezoelectric stack driving scheme

Model of torque motor driving scheme

Modeling and Simulation



Structure of nozzle-flapper stimulating system

Modeling and Simulation

Piezoelectric stack actuator

$$x_0 = n x_n = n\left(\frac{t_n s_{33}^E F_s}{A_s} + d_{33} U\right)$$

$$x_o = x_0 \frac{K_p}{K_p + K_f} \quad F_o = \frac{K_p K_f}{K_p + K_f} x_0$$

Control cavity

$$q_L = q_g - q_k = C_{dg} A_g \sqrt{\frac{2}{\rho}\left(p_s - p_c\right)} - C_{dk} A_N \sqrt{\frac{2}{\rho} p_c}$$

$$A_g = \frac{\pi}{4} D_g^2 \quad A_N = \pi D_N \left(x_{f0} + x_f\right)$$

Flowmeter and pressure difference transducer

$$K_s Q^2 - Q\omega = K_d \dot{\omega}$$

$$G(s) = \frac{A_2 s^2 + A_1 s + A_0}{s^2 + B_1 s + B_0}$$

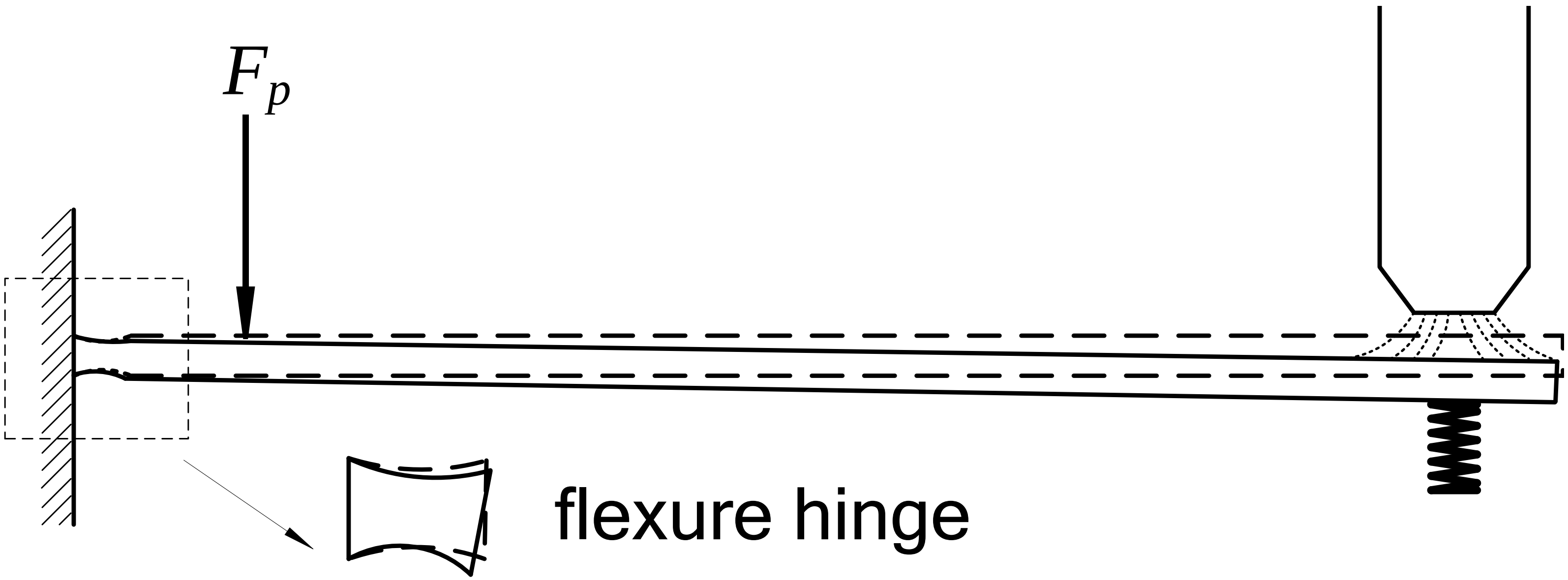
Equations of nozzle-flapper stimulating system

Modeling and Simulation

Parameters

Elements	Parameters	Value	Units	Origin
Piezoelectric stack actuator	excitation voltage U_e	0~150	V	datasheet
	electrostatic capacity Ce	1.6e-6	F	datasheet
	stiffness Kp	1.2e7	N/m	datasheet
	number of stack n	420	-	datasheet
	piezoelectric constant d_{33}	4.4e-10	pC/N	datasheet
Flapper	amplification factor n_a	10	-	designed
	length of flapper L	0.12	m	designed
	moment of inertia J	1.63e-4	$kg \cdot m^2$	calculated
	elasticity modulus E	2e11	Pa	datasheet
	stiffness K_f	5e6	N/m	calculated
Nozzle	inner diameter d_i	2.5	mm	designed
	external diameter d_e	5	mm	designed
Flowmeter	time constant τ	0.02	s	estimate
	fuel density ρ	800	kg/m^3	datasheet
Control cavity	reference orifice D_0	1.1	mm	designed
	draining orifice D_d	2	mm	designed

Modeling and Simulation



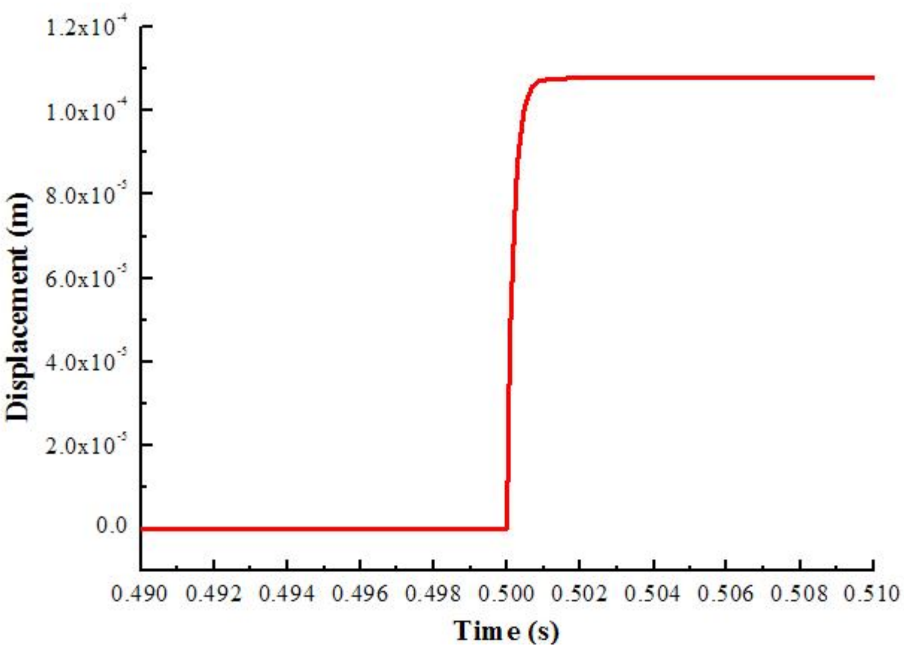
$$F_s = kx$$

$$F_l = p_c A_N \left[1 + \frac{16 C_{dk}^2 \left(x_{f0} - x_f \right)}{D_N^2} \right]$$

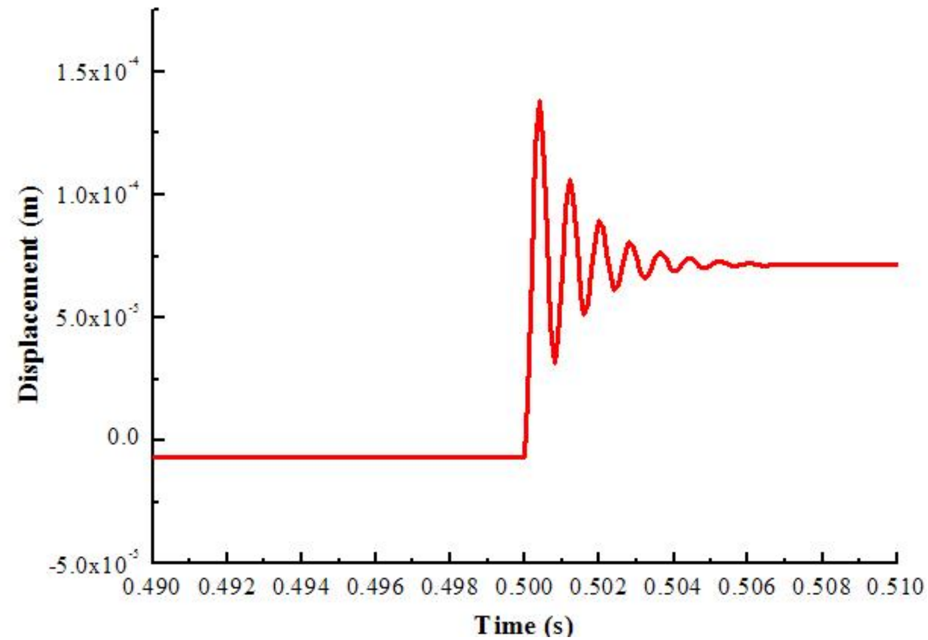
$$J\beta = F_p x_p + \left(F_l - F_s \right) l$$

Load analysis of the flapper

Results and Discussion



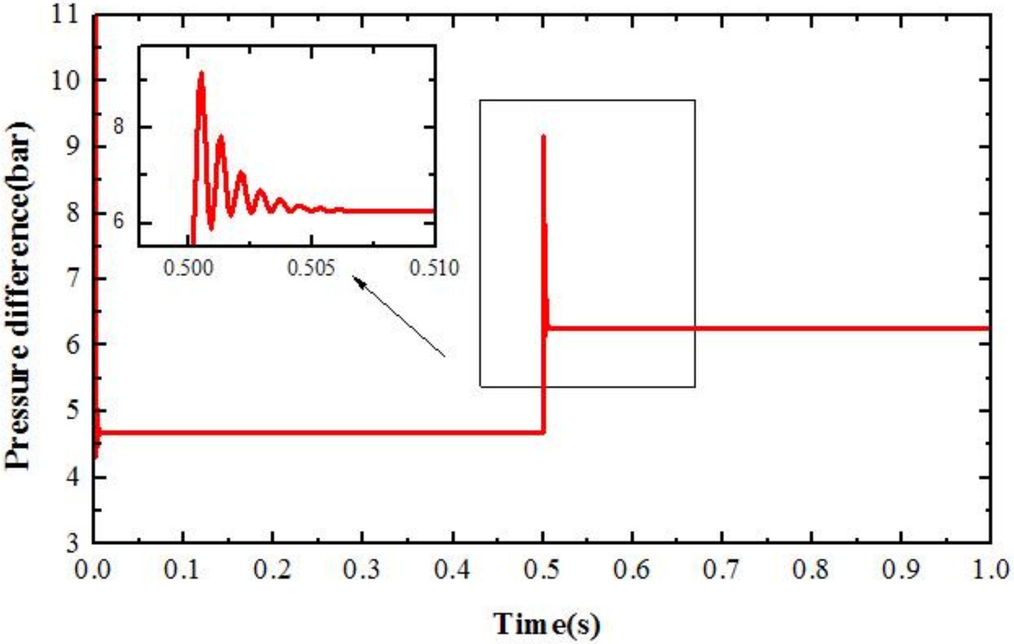
Disp. of piezoelectric stack system



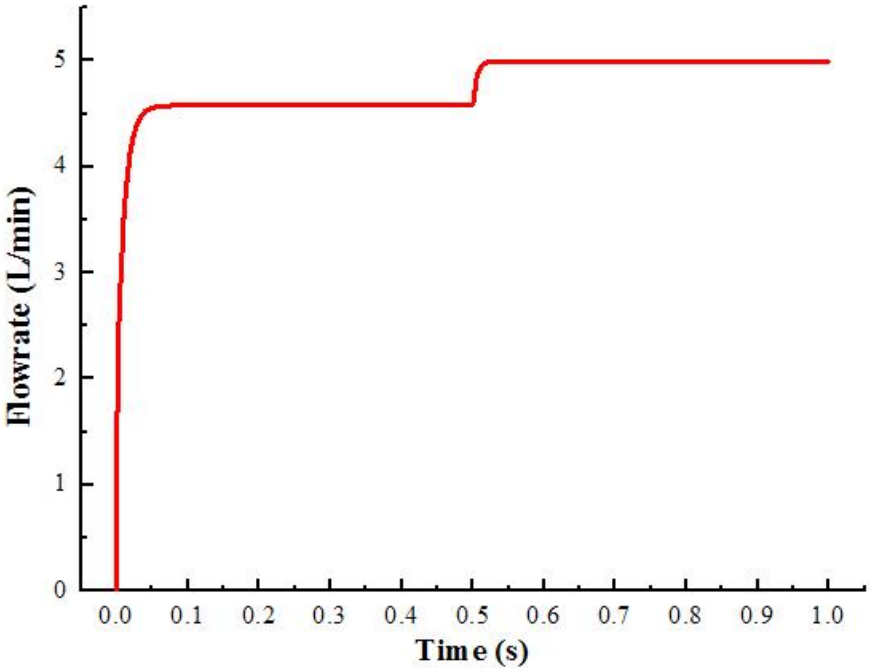
Disp. of torque motor system

Comparison between these two solutions

Results and Discussion

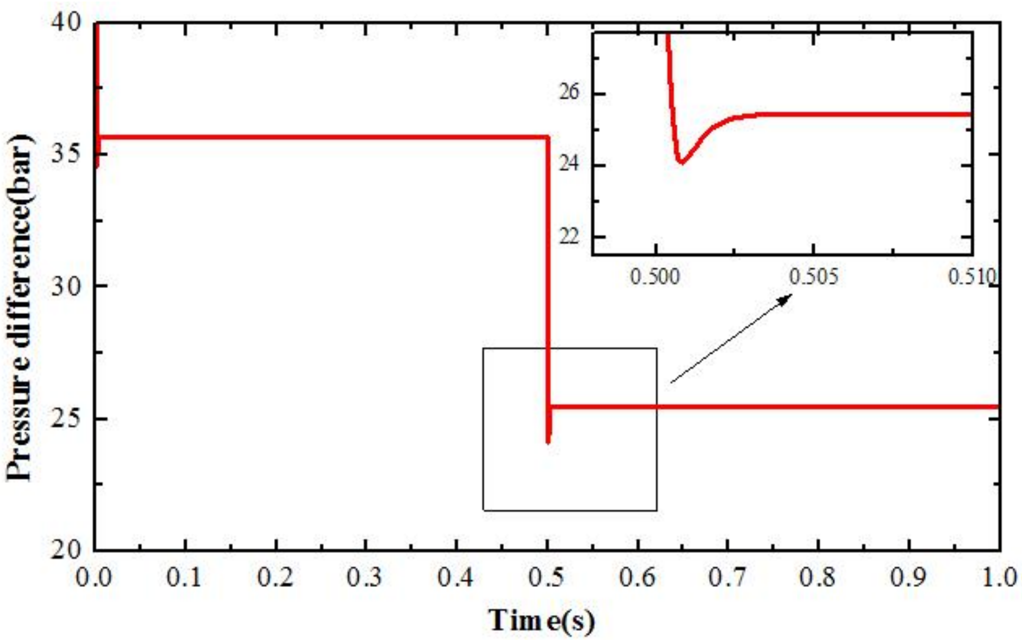


a. Pressure difference

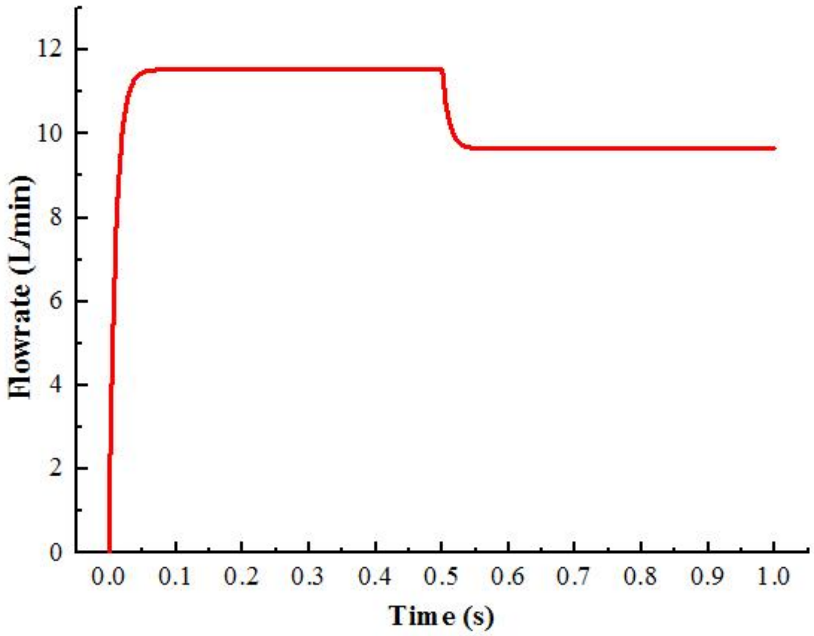


b. Flowrate

Performance of torque motor stimulating system



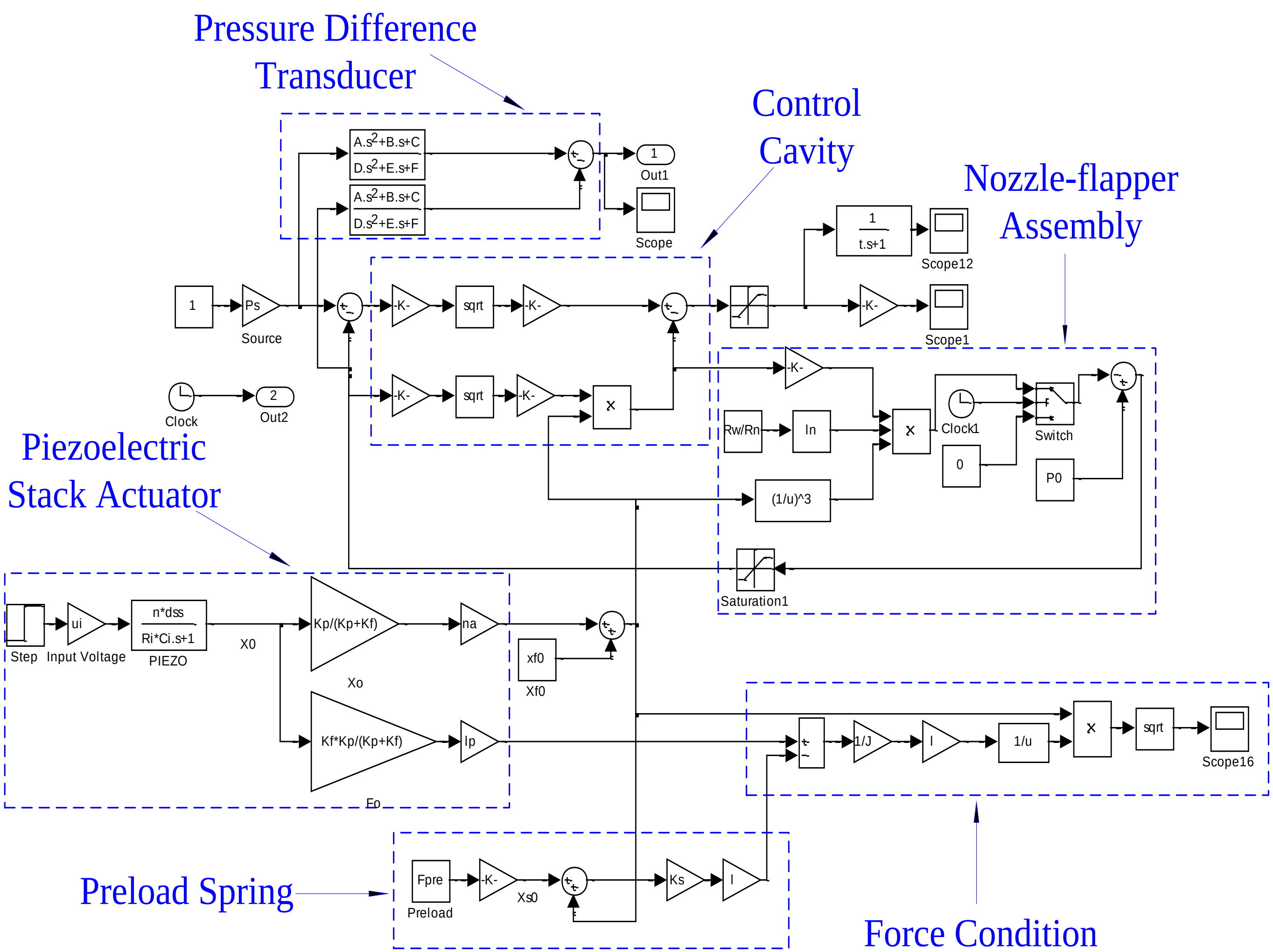
a. Pressure difference



b. Flowrate

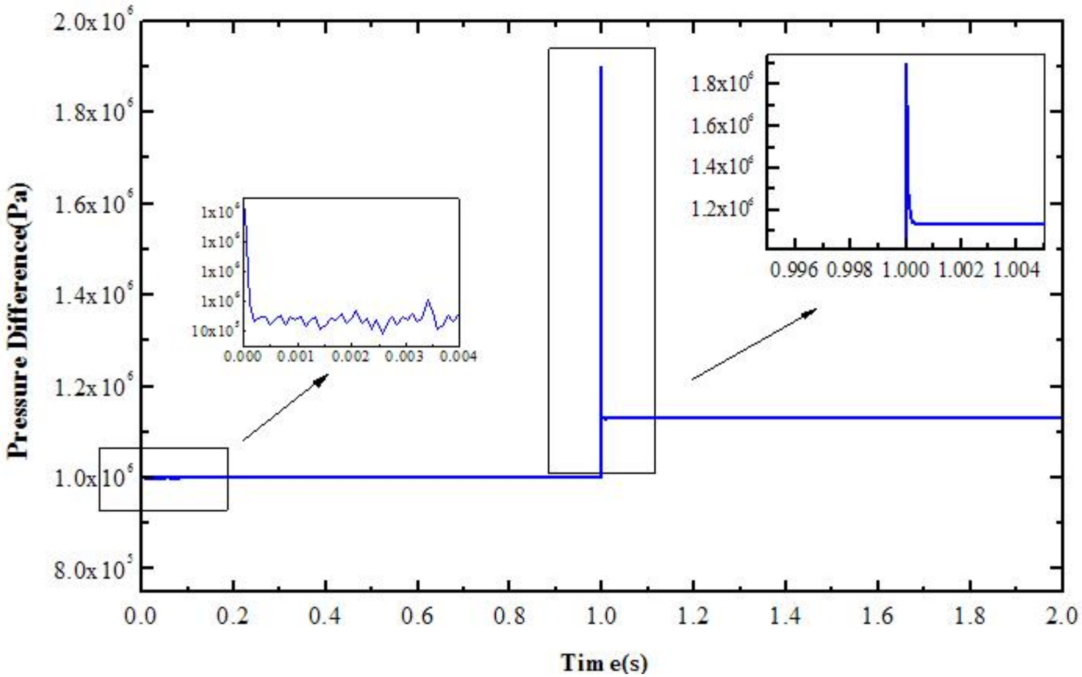
Performance of piezoelectric stack stimulating system

Modeling and Simulation

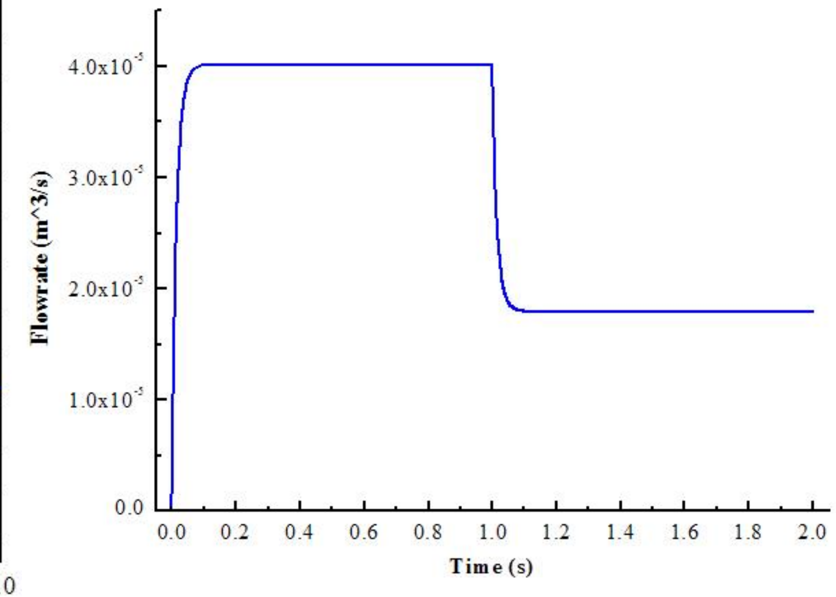


Simulink Model

Results and Discussion



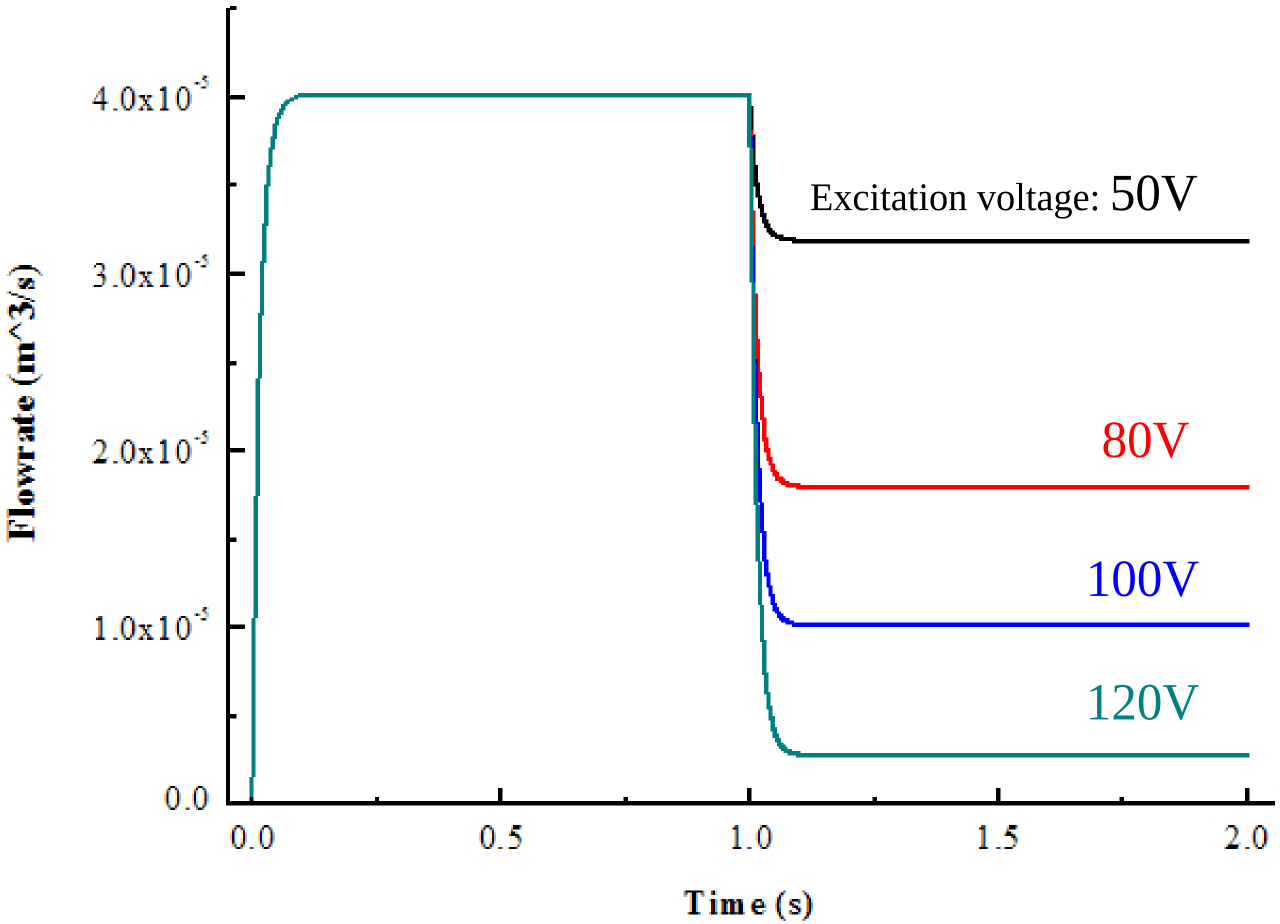
a. Pressure difference



b. Flowrate

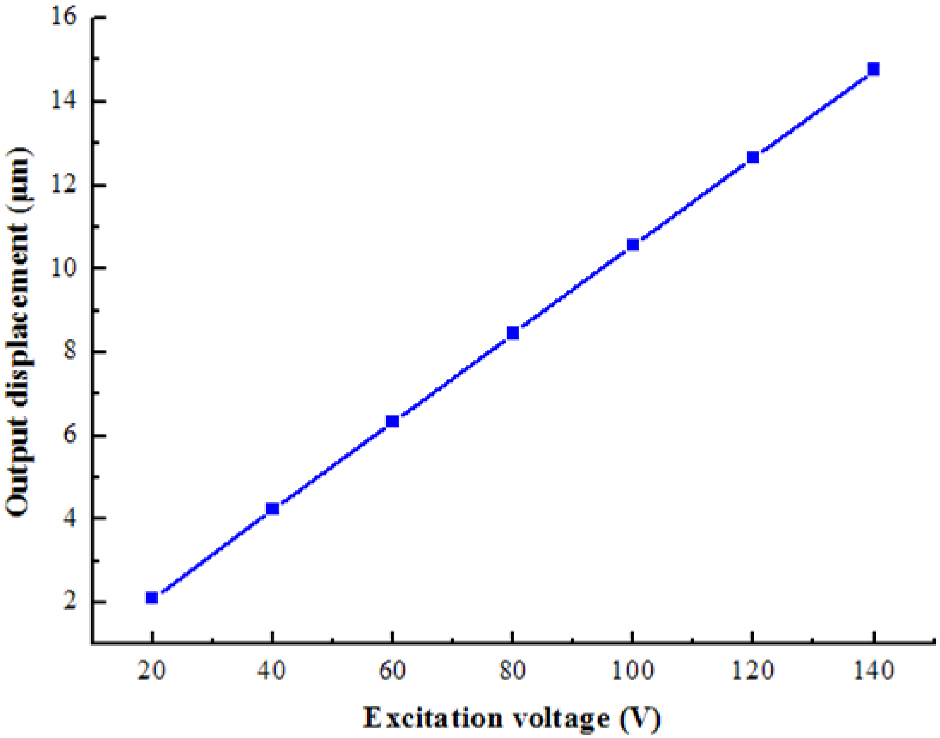
Response of the adopted system to 80V excitation voltage

Results and Discussion

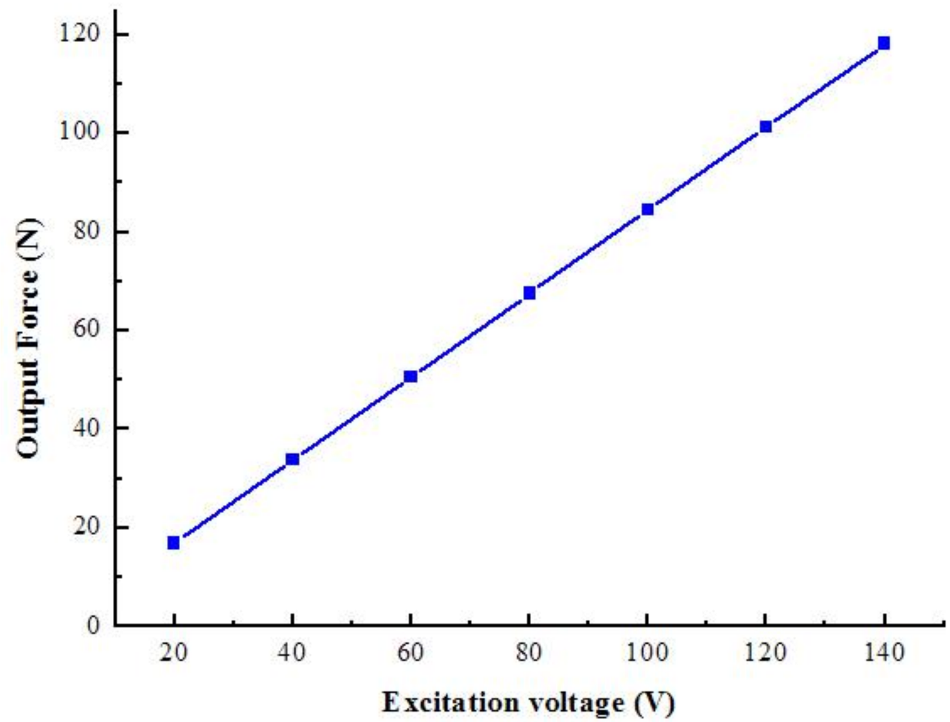


Calibrated flow rate with different excitation voltage

Results and Discussion

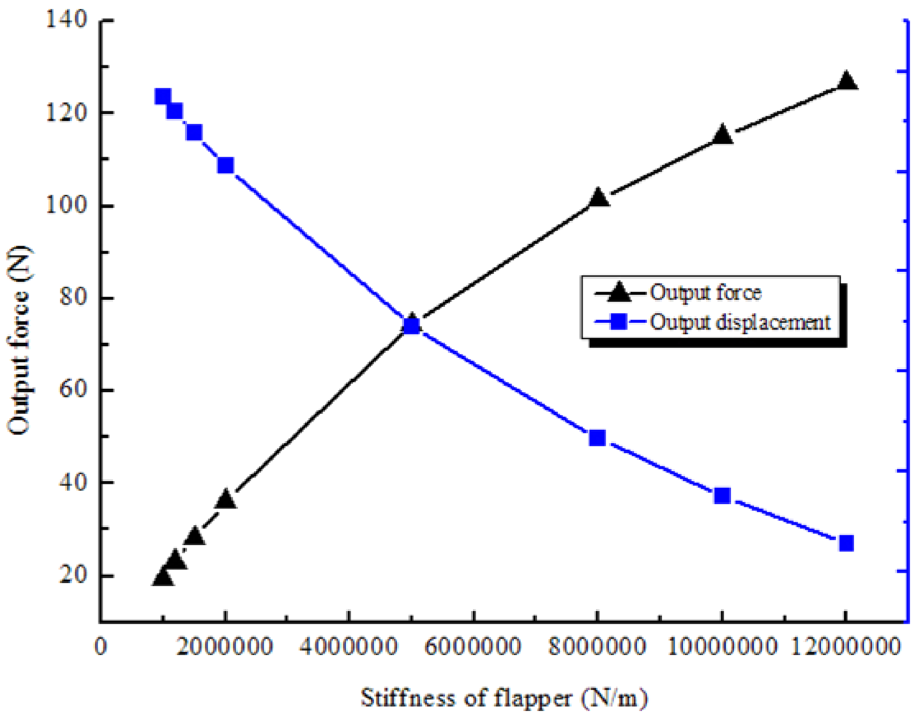


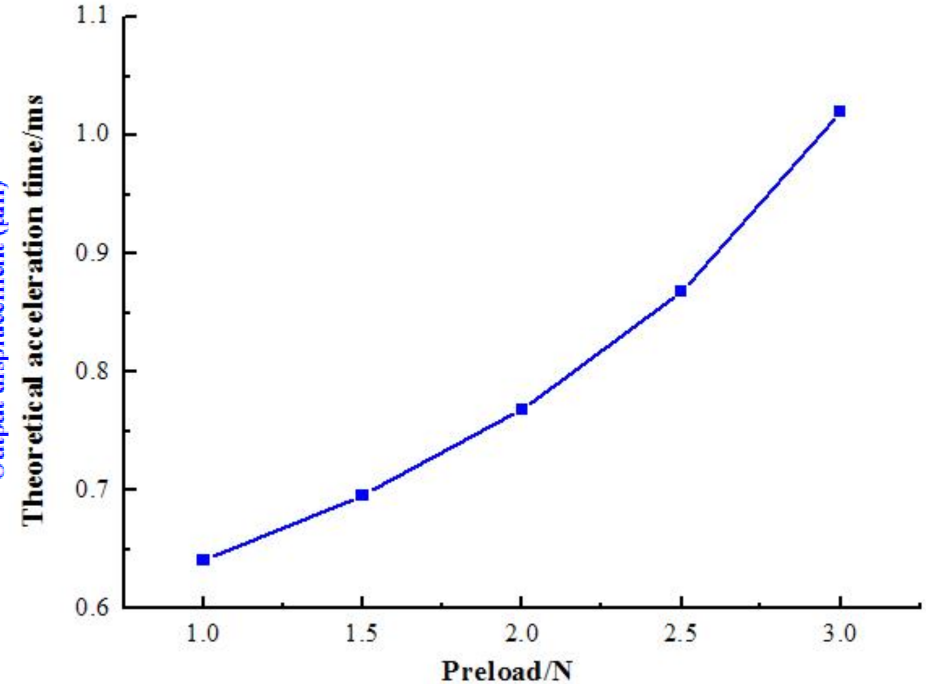
Calibrated flow rate vs excitation voltage



Driving force vs excitation voltage

Results and Discussion





Output force and disp. vs flapper stiffness **Acceleration time vs spring preload**

Conclusions and Ongoing work

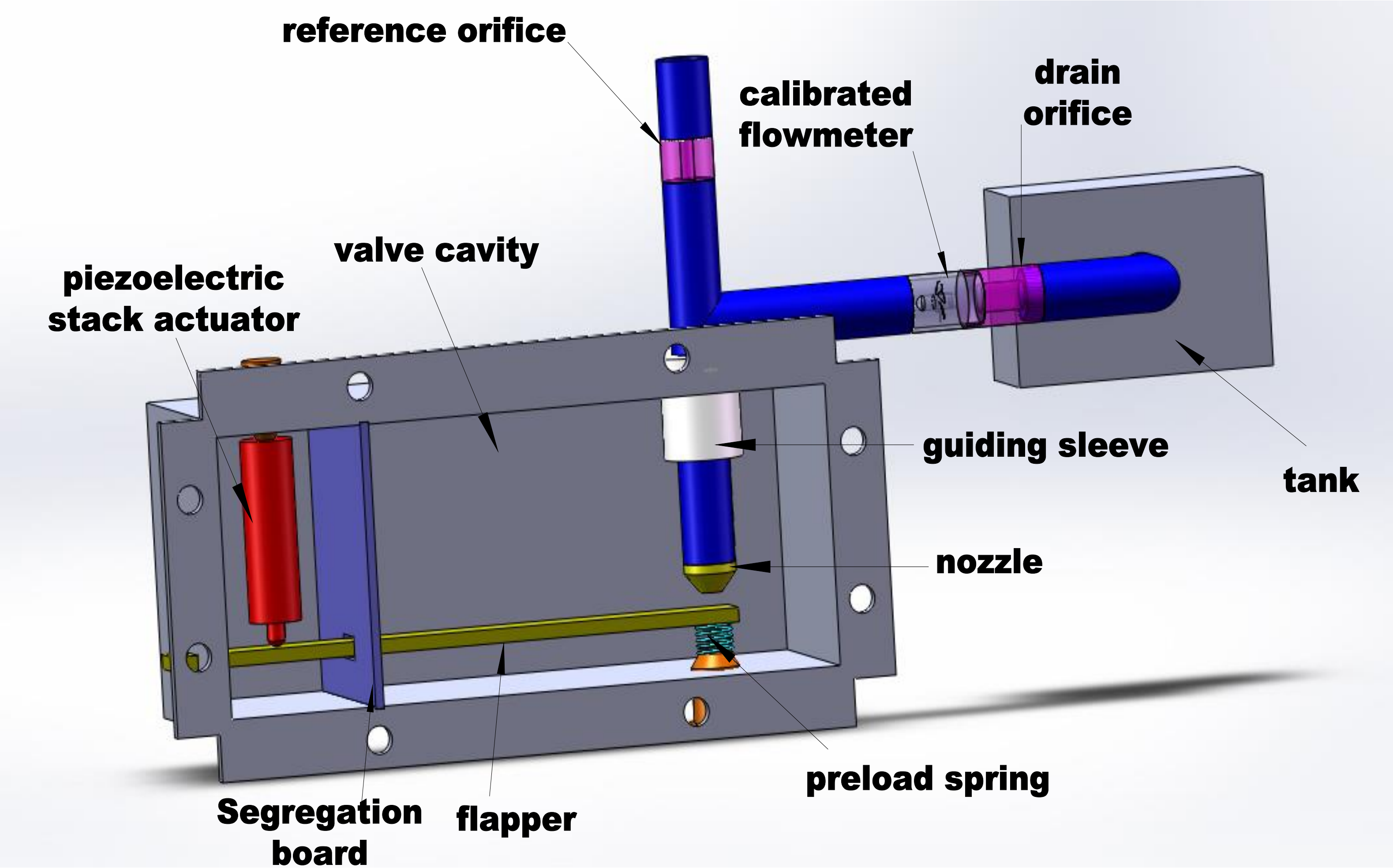
1. As the relatively small output torque the torque motor can provide, diameter of the nozzle can't be set to a large enough value. Oscillation of the flapper can't be neglected.

2. The piezoelectric stack actuator (PSA) can produce much greater force to balance the flow force acting on the flapper. Larger size nozzles are feasible. Piezoelectric structure effectively controls the high-frequency oscillation of the flapper.

3. Dynamic calibration system driven by piezoelectric-stack provides a faster and larger excitation flow than by the torque motor. In the mean time, the PSA can control the flapper flutter more effectively.

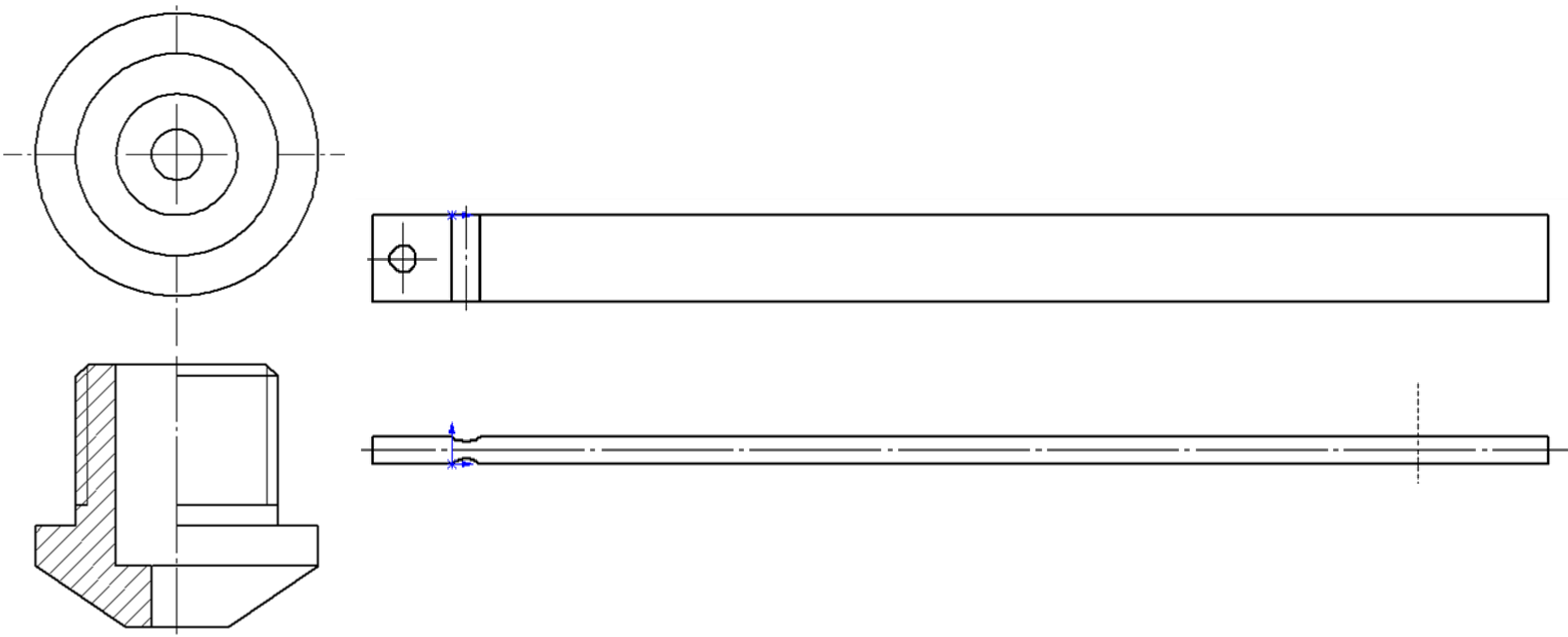
4. Structural parameters of the flapper needs to be carefully designed on the basis of a thorough understanding of the characteristics of PSA. As the preload spring is essential for stabilization of output displacement, its magnitude should be considered carefully.

Conclusions and Ongoing work



Virtual prototype of experimental setup

Conclusions and Ongoing work



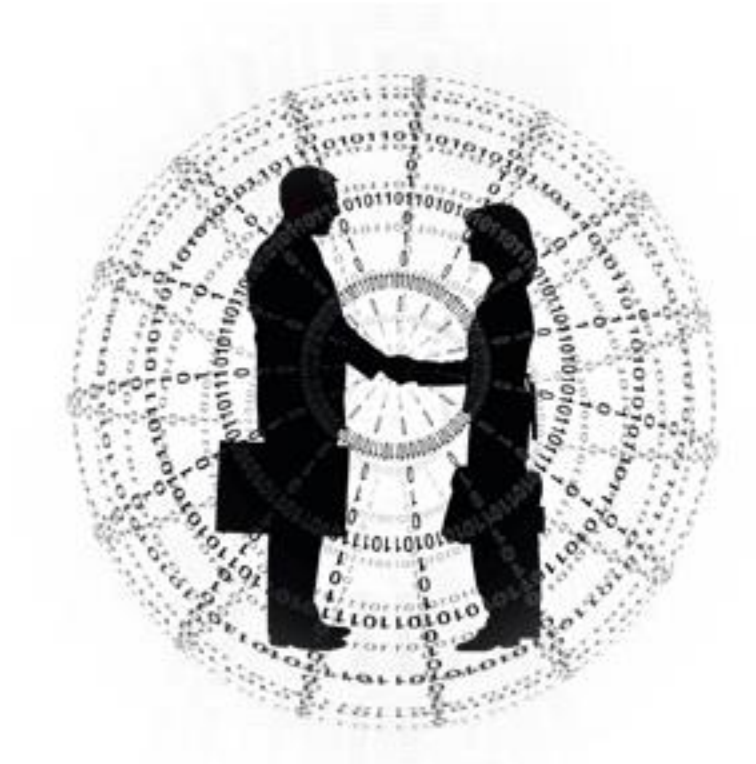
Nozzle-flapper valve under in machining

Conclusions and Ongoing work

Piezoelectric-stack and its power supply

FT Series flowmeters to be calibrated

Primary equipments prepared



Thank you for your attention!