Cavity Parameter Effects On Piezoelectric Synthetic Jets

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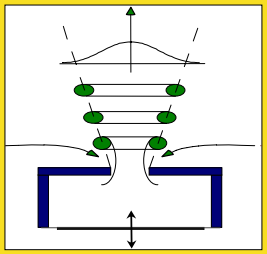
ABSTRACT

A synthetic jet that utilizes piezoelectric composites is studied both numerically and experimentally. Two piezoelectric composite actuators, Bimorph and Thunder®, are modeled using a moving boundary model with a mesh generated using a tri-pave unstructured scheme. The effects of dimensional cavity parameters such as height, and orifice diameter, on the jet maximum velocity are described numerically and experimentally.

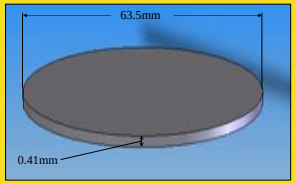
BACKGROUND

Synthetic Jets

Zero Net Mass Flux Jets that are formed at the edge of an orifice by the periodic motion of a diaphragm mounted in a sealed cavity.



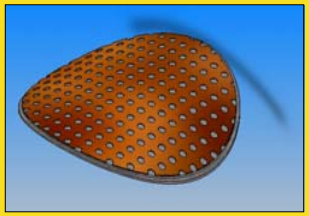
Bimorph



- Two PZT 5A disks bonded at opposite polarities
- Displacement up to 0.3mm at 180Vpp
- Capacitance 130nF

Thunder®

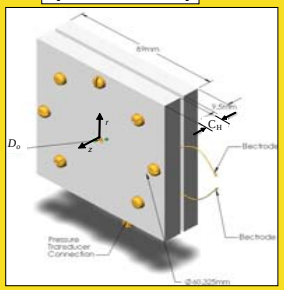
- Top layer of perforated copper, thickness 0.0254mm, diameter 63.5mm
- Middle layer of PZT 5A, thickness 0.254mm, diameter 63.5mm Bottom layer of steel, thickness 0.254mm, diameter 68.5mm
- Displacement up to 0.06mm at 400Vpp
- Capacitance 110nF



- During manufacturing the layers are glued with a polyimide and cured at 320°C
- Due to a difference in the coefficients of thermal expansion among the layers the final diaphragm is prestressed

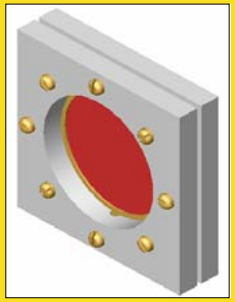
EXPERIMENTAL SETUP

Synthetic Jet Cavity



Cavity Parameters

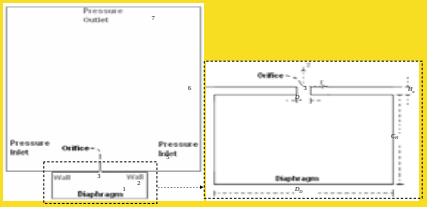
		C_H (mm)	
		5.50	9.55
D_o (mm)	2.00	Cavity I	Cavity II
	3.67	Cavity III	Cavity IV



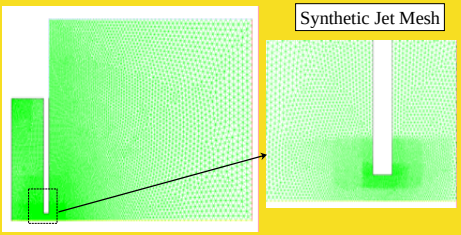
NUMERICAL MODELING

Geometry & Mesh

Synthetic Jet boundary conditions
- Surface 1: u described by the moving diaphragm boundary, $v = 0$
- Surfaces 2, 3, 4, and 5: $u = v = 0$
- Surface 6 (at large radial distance): constant ambient pressure (inlet to domain)
- Surface 7 (at large axial distance) : constant ambient pressure (outlet from domain)



Synthetic Jet Mesh



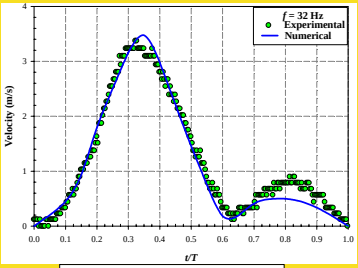
Diaphragm Moving Boundary Conditions

➢Bimorph Logarithmic Profile

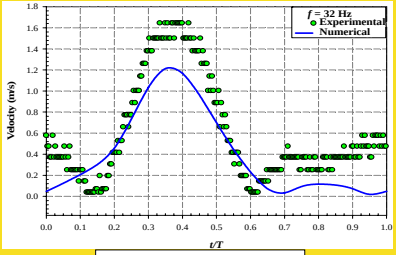
$$u(r,t) = \pi\delta_C f\left[1 - \frac{4r^2}{D_D^2} + \frac{8r^2}{D_D^2}\ln\left(\frac{2r}{D_D}\right)\right]\cos(2\pi f t)$$

➢THUNDER® Parabolic Profile

$$u(r,t) = \left[-f\pi\delta_C \cdot \sin(2\pi f t) + f\pi\delta_C \cdot \sin(2\pi f t)\left(\frac{r}{(D_D/2)}\right)^2\right]$$



Bimorph Logarithmic Profile

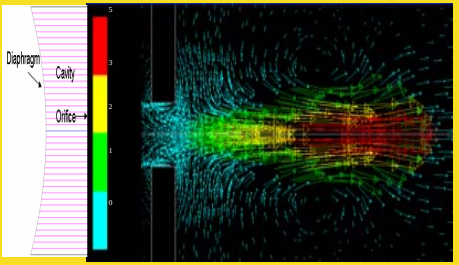


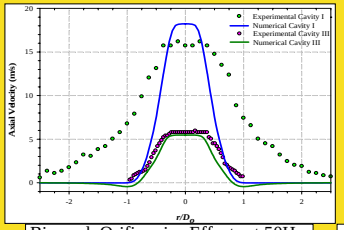
Thunder® Parabolic Profile

RESULTS

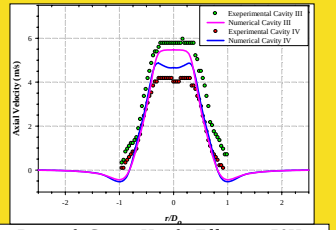
Bimorph

➢ Numerical results over predict the experimental velocities by only 10%
➢ Cavity height effect is not significant
➢ Orifice diameter has significant effect





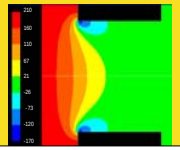
Bimorph Orifice size Effects at 50Hz



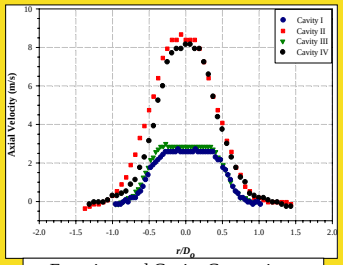
Bimorph Cavity Height Effects at 50Hz

THUNDER®

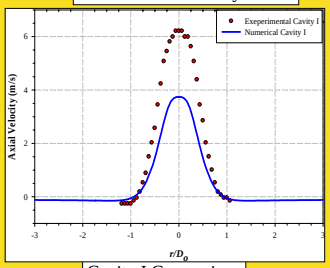
➢ Numerical results under predict experimental results by over 35%
➢ Cavity height has minimal effect on the jet velocity
➢ Orifice diameter has a significant effect



Typical Pressure Distribution Inside a Cavity



Experimental Cavity Comparison



Cavity I Comparison

CONCLUSIONS

❖ Bimorph simulations in good agreement with experimental data
❖ Thunder® simulations under-predicted experimental results due to the complex shape and the pressure developed inside the cavity
❖ For the Bimorph, both cavity height and orifice diameter are significant, but the orifice diameter has a larger effect
❖ In case of Thunder®, only orifice diameter is significant