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Computational Modeling of Synthetic Jets

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Outline

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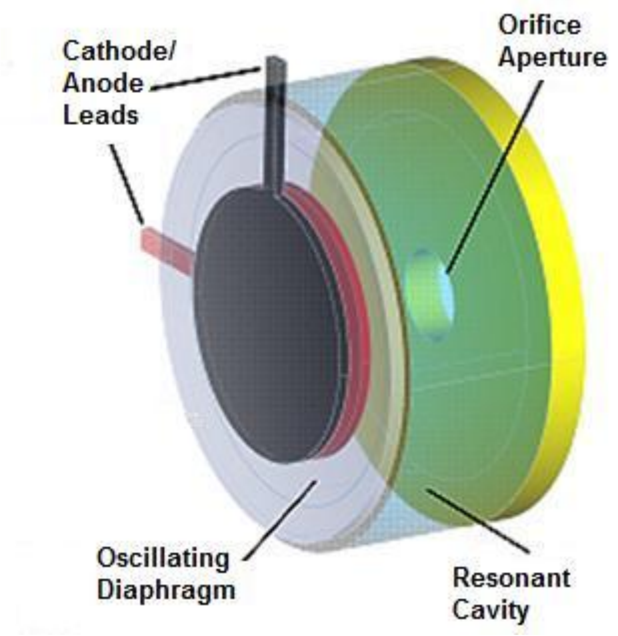


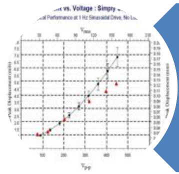
Tridimensional Schematic of the Synthetic Jet Actuator. Image from (Morpheus Laboratory, University of Maryland, 2009)

Applications

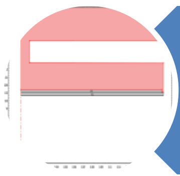
- Separation Control
- Flow Control
- Mixing
- Heat Transfer

Why Comsol?

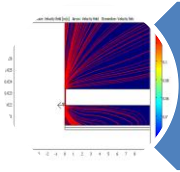
- Multiphysics Problem
- Other simulations only include Navier-Stokes



1. Validation of the Disk 3-D Model



2. Axisymmetric Model



3. Analysis of the Relevant Dimensionless Numbers according to different parameters of the model

4. Conclusions

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Dimensional Analysis of the Problem

- The vortex ring formation depends on the velocity field of the fluid at the aperture of the Actuator
- The average velocity cannot be the characteristic velocity because it is zero
- Max. Velocity (U) was chosen as the characteristic velocity.

$$U = f(d, v, \omega)$$

- Since there are 4 variables and 2 dimensions, the problem can be described with 2 non dimensional numbers

Reynolds Number

$$Re = \frac{Ud}{v}$$

Stokes Number

$$S = \sqrt{\frac{\omega d^2}{v}}$$

These two numbers be related through the Inverse of the Strouhal Number:

$$\frac{1}{Sr} = \frac{Re}{S^2}$$

According to Holman et al. 2005, the criterion of formation for synthetic jets can be defined as follows:

$$If\ \frac{1}{Sr} > C \ \rightarrow jet$$

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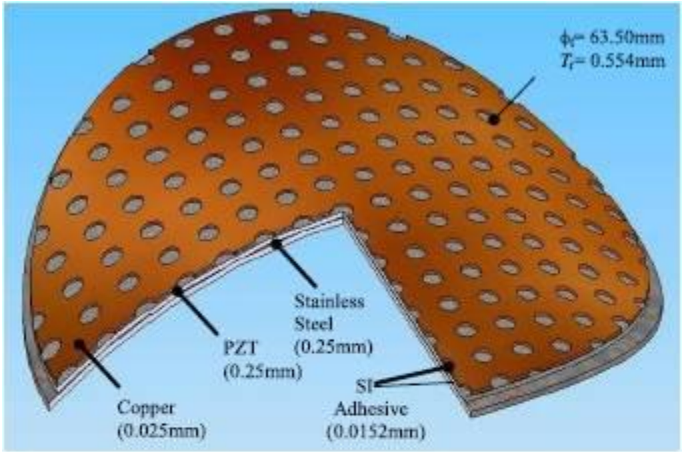
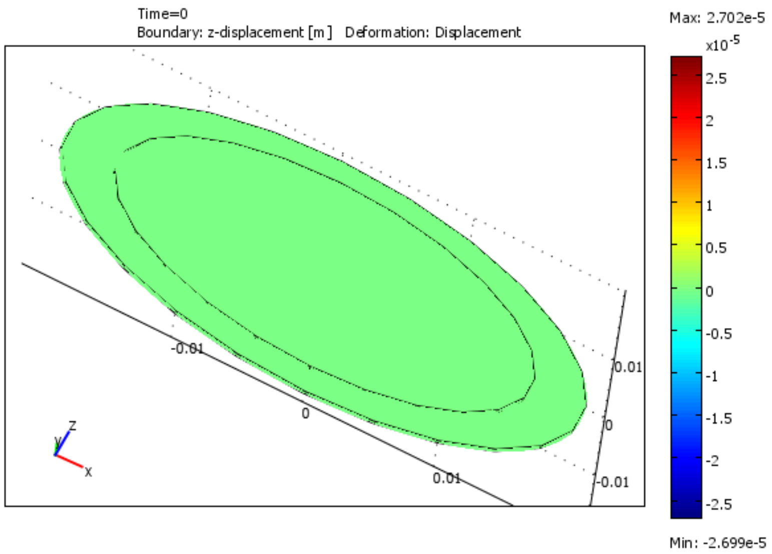
3D Piezoelectric Disk Model



Schematic of the piezoelectric diaphragm showing all the components of the same. Image from (Mane, Mossi, & Bryant, 2008)



3D Model of the Disk in Comsol 3.4

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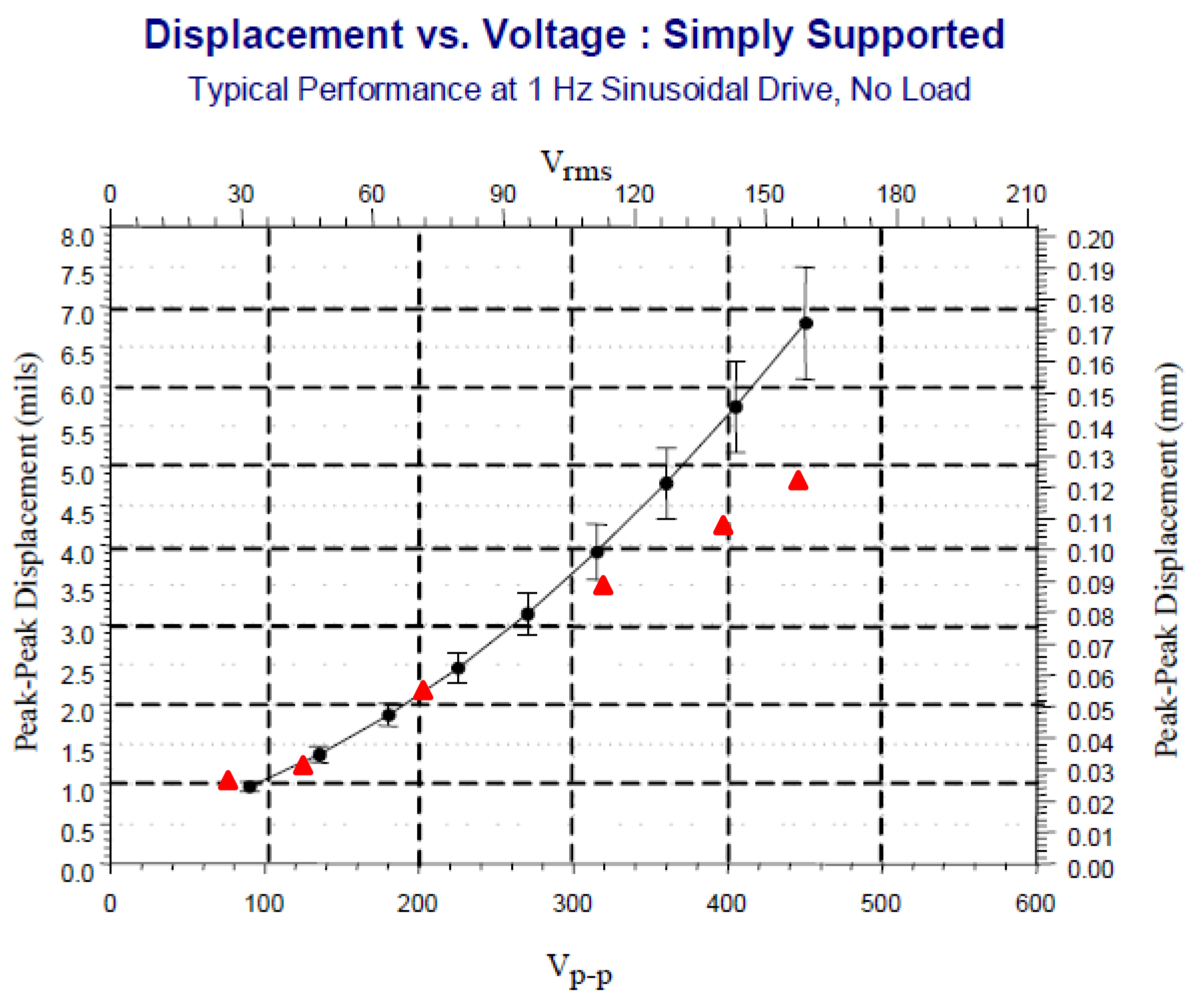
3D Piezoelectric Disk Model



The graph in black is from the Datasheet of THUNDER. Manufactured by FACE International

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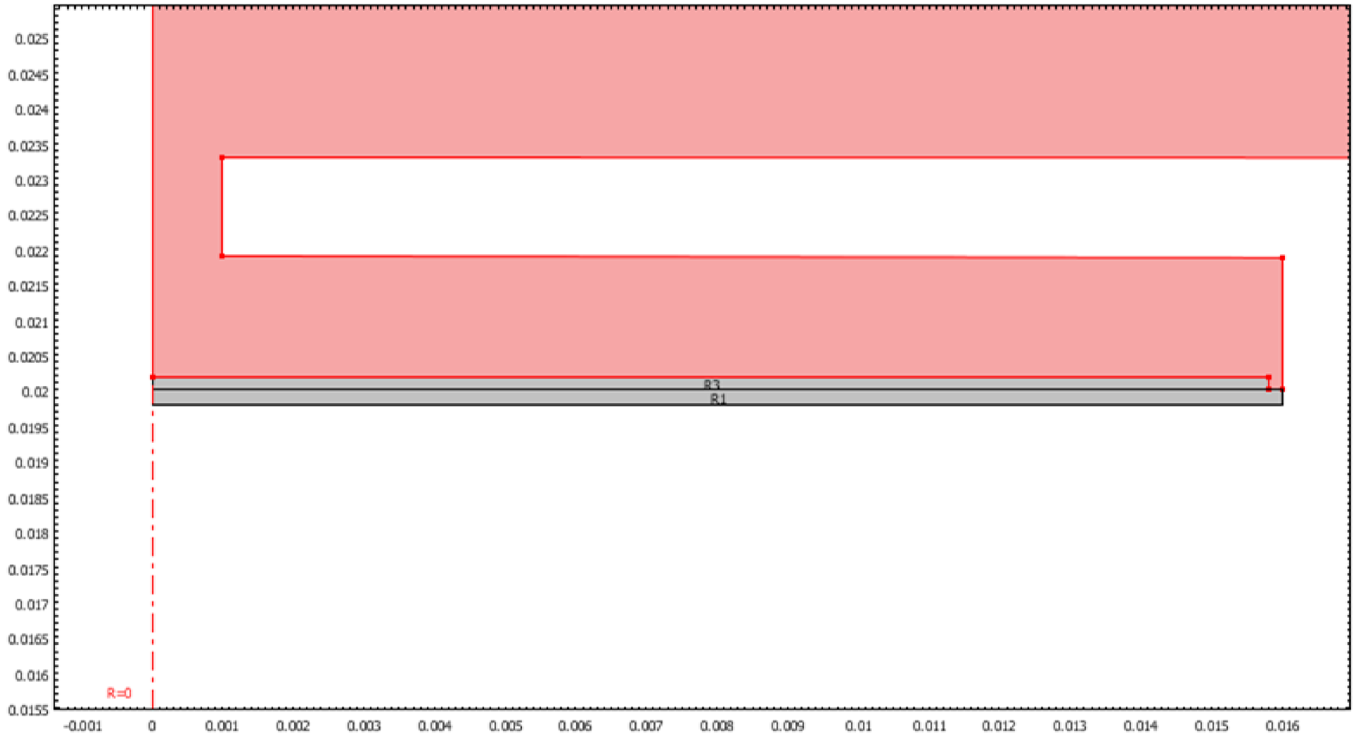
Axisymmetric SJ Actuator Model



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Numerical Results

Exp. No.	Diam. (m)	height (m)	Potential (V)	viscosity (Pa.s)	Vel max. (m/s)	Reynolds	Stokes	1/Sr	Criterion
1	2e-03	1.4e-03	25	1e-06	3.27e-03	6.54	5.01	**0.26**	**no jet**
2	2e-03	1.4e-03	50	1e-06	3.27e-03	6.54	5.01	**0.26**	**no jet**
3	2e-03	1.4e-03	200	1e-06	3.02e-03	6.05	5.01	**0.24**	**no jet**
4	2e-04	1.4e-03	100	1e-06	1.21e-01	24.2	0.50	**96.29**	**no jet**
5	2e-04	1.4e-03	500	1e-06	1.21e-01	24.2	0.50	**96.29**	**no jet**
6	2e-04	1.4e-03	100	1e-07	0.135	270	1.59	**107.43**	**jet**
7	2e-04	1.4e-03	100	1e-06	0.146	29.2	0.50	**116.18**	**jet**

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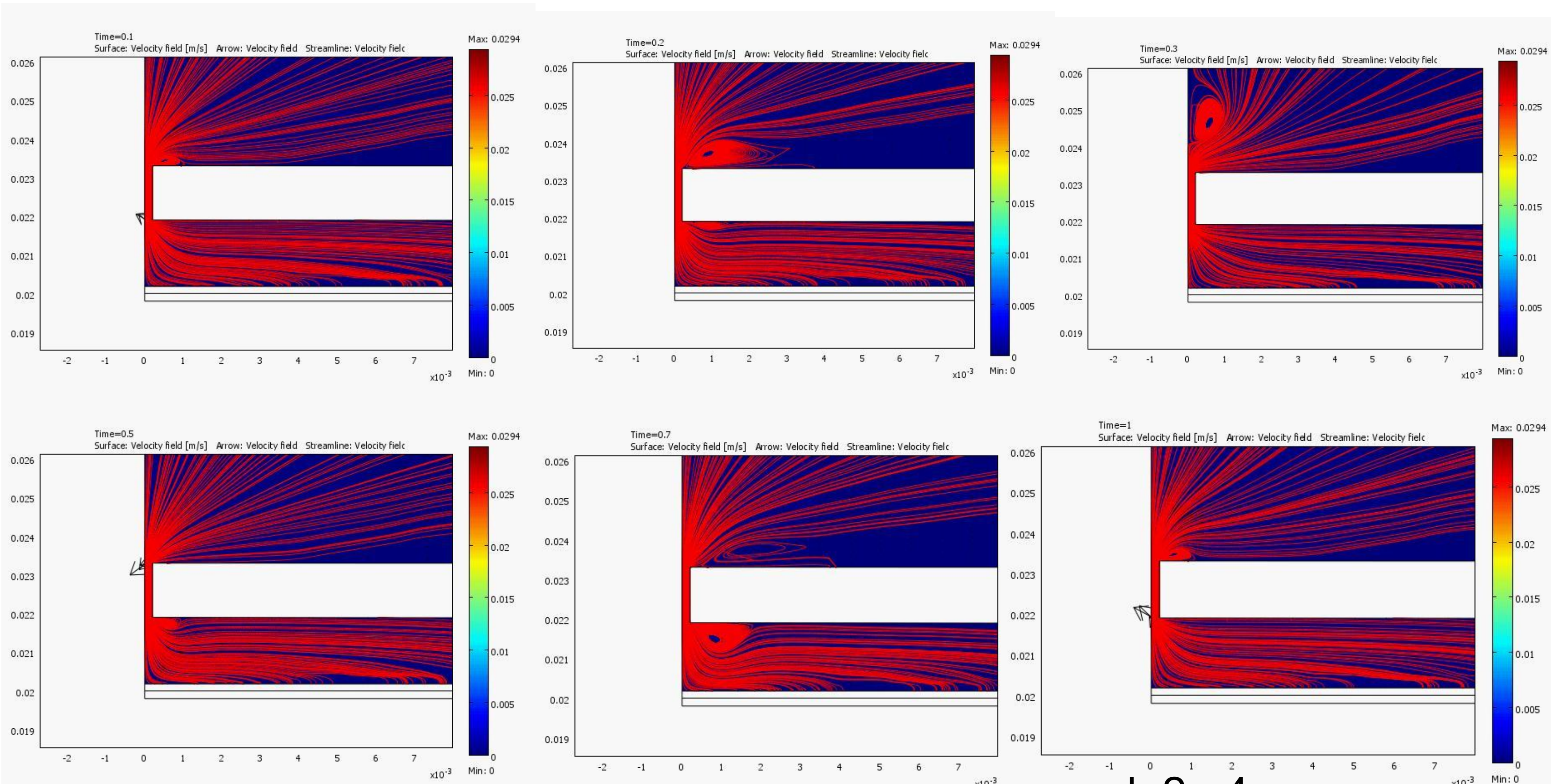
No Jet - #4 in table



d=2e-4 m

V=100 V

f=1 Hz

v=1e-6 Pa.s

density=1kg/m3

1/Sr=96.29

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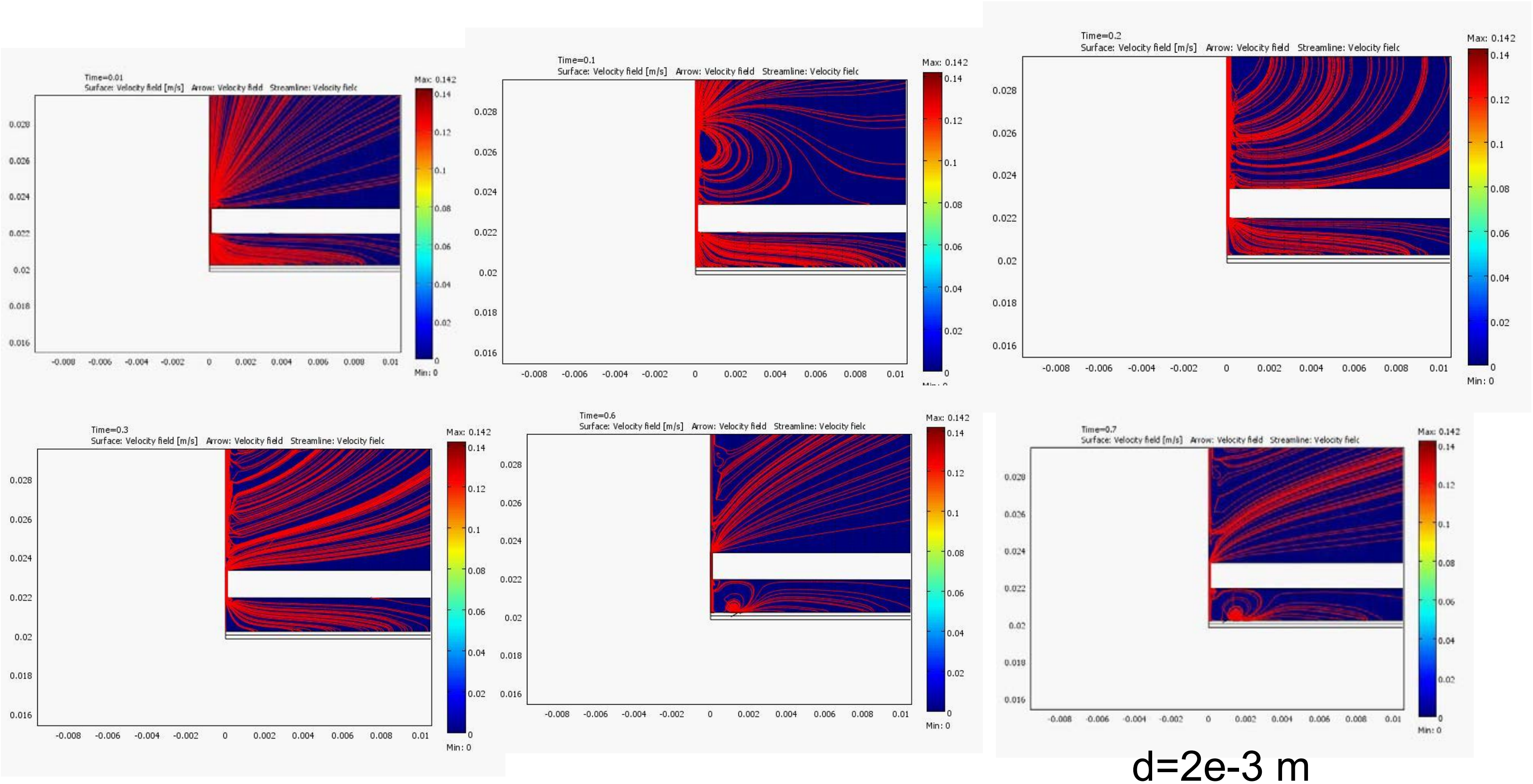
Jet - # 6 in table



d=2e-3 m

V=100 V

f=1 Hz

v=1e-9 Pa.s

p=1kg/m3

1/Sr=107.43

Conclusions

- The fluid velocity is weakly dependant of the applied voltage
- The fluid velocity is strongly dependant of the aperture diaphragm
- The jet formation criterion is in the order of hundreds
- There exists vortex ring formation in the inside of the cavity

- Study of the influence of other geometric parameters such as: actuator’s height, Disk diameter, etc
- Study of the influence of the frequency in the SJ formation
- Coupling of the acoustics module
- Comparison with the Lumped Element Model
- Study of the influence of the vortex rings interactions with the diaphragm in the quality of SJ formation

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References

1. Alan Barnett et al, Finite Element Approach to Model and Analyze Piezoelectric Actuators, *JSME International Journal*, 476-485 (2001)

2. Quentin Gallas et al, Lumped Element Modeling of Piezoelectric-Driven Synthetic Jet Actuators, *AIAA Journal*, 240-247 (2003)

3. Ryan Holman, Formation Criterion for Synthetic Jets, *AIAA Journal*, (2005)

4. Uno Ingard, On the Theory and Design of Acoustic Resonators, *The Journal of the Acoustical Society of America,* 1037-1061 (1953)

5. Poorna Mane et al, Experimental design and analysis for piezoelectric circular actuators in flow control applications, *Smart Materials and Structures* (2008)

7. Vincent Piefort, Finite Element *Modelling of Piezoelectric Active Structures*, Ph.D. thesis. Bruxelles, Belgium: Université Libre de Bruxelles, Department for Mechanical Engineering and Robotics (2001)

8. Christopher Rumsey, *Proceedings of the 2004 Workshop on CFD Validation of Synthetic Jets and Turbulent Separation Control,* Hampton, Virginia: NASA. (2007)

9. B. Smith et al, The Formation and Evolution of Synthetic Jets, *Physics of Fluids*, 2281-2297 (1998)

10. Yukata Takagi et al, Dielectric Properties of Lead Zirconate, *Journal of the Physical Society*, 208-209 (1951)

11. David Durán et al, *Computational Modeling of Synthetic Jets*, Mechanical Engineering Thesis (2010)