Computational Modeling of Synthetic Jets

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Applications

- Separation Control
- Flow Control
- Mixing
- Heat Transfer

Why Comsol?

- Multiphysics Problem
- Other simulations only include Navier-Stokes

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

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
• 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:

\[
If \quad \frac{1}{Sr} > C \quad \rightarrow \text{jet}
\]
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
The graph in black is from the Datasheet of THUNDER. Manufactured by FACE International.
Axisymmetric SJ Actuator Model
### Numerical Results

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Diam. (m)</th>
<th>height (m)</th>
<th>Potential (V)</th>
<th>viscosity (Pa.s)</th>
<th>Vel max. (m/s)</th>
<th>Reynolds</th>
<th>Stokes</th>
<th>1/Sr</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2e-03</td>
<td>1.4e-03</td>
<td>25</td>
<td>1e-06</td>
<td>3.27e-03</td>
<td>6.54</td>
<td>5.01</td>
<td>0.26</td>
<td>no jet</td>
</tr>
<tr>
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<td>2e-03</td>
<td>1.4e-03</td>
<td>50</td>
<td>1e-06</td>
<td>3.27e-03</td>
<td>6.54</td>
<td>5.01</td>
<td>0.26</td>
<td>no jet</td>
</tr>
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<td>1.4e-03</td>
<td>200</td>
<td>1e-06</td>
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<td>5.01</td>
<td>0.24</td>
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</tr>
<tr>
<td>4</td>
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<td>1.4e-03</td>
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<td>1e-06</td>
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<td>24.2</td>
<td>0.50</td>
<td>96.29</td>
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<td>1.4e-03</td>
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<td>96.29</td>
<td>no jet</td>
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<td>1.59</td>
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<td>100</td>
<td>1e-06</td>
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<td>29.2</td>
<td>0.50</td>
<td>116.18</td>
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</tr>
</tbody>
</table>
\[d=2e^{-4} \text{ m}\]
\[V=100 \text{ V}\]
\[f=1 \text{ Hz}\]
\[v=1e^{-6} \text{ Pa.s}\]
\[\text{density}=1\text{kg/m}^3\]
\[1/\text{Sr}=96.29\]
d=2e-3 m
V=100 V
f=1 Hz
v=1e-9 Pa.s
p=1kg/m3
1/Sr=107.43
• 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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