OPTIMIZING THE PERFORMANCE OF MEMS ELECTROSTATIC COMB DRIVE ACTUATOR WITH DIFFERENT FLEXURE SPRINGS

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Excerpt from the Proceedings of the 2012 COMSOL Conference in Bangalore
MEMS

- Microelectromechanical systems (MEMS) are very small devices or groups of devices that can integrate both mechanical and electrical components.

- MEMS can be constructed on one chip that contains one or more micro-components and the electrical circuitry for inputs and outputs of the components.

- The term MEMS first started being used in the 1980’s.

- Microcomponents make the system faster, more reliable, cheaper and more capable.
MEMS is based upon three blocks:-

- **Microsensor**: It measures a physical parameter (such as pressure, acceleration) and reports it in the form of an electrical signal (e.g. Temperature, Vibration, Rotation etc.).

- **Microactuator**: It converts the electrical signal into mechanical form of energy e.g., resonating beams, switches and micropumps. In other words, actuators are used to convert the non-mechanical input energy into mechanical output energy.

- **Control Unit**: They manage and control the whole system by analyzing the data, reaching the appropriate conclusion and determining the actions required.
Actuator

*It converts non mechanical input energy into mechanical output energy.*
ELECTROSTATIC COMB DRIVE ACTUATOR

- Comb Drive actuator is the main application of Electrostatic Actuator
What is comb drive?
What is COMB DRIVE?

• Comb-drive actuator consists of interdigitated finger structures, where one comb is fixed and other is connected to complaint suspension. This suspension can have different shapes and different designs.

• The combs are arranged so that they never touch. Typically the teeth are arranged so that they can slide past one another until each tooth occupies the slot in the opposite comb.
• Applying a potential difference across the comb structure will result in deflection of the movable comb structure, this deflection is due to generated electrostatic forces in the system.

• The position of the movable fingers is controlled by balance between electrostatic forces and the mechanical forces. Mechanical forces are generated through spring structures. They directly depend upon the stiffness of the flexures. By changing the flexures, mechanical forces change which changes displacement.
PRINCIPLE OF COMB DRIVE

• The Electrostatic force is based on Coulomb’s law. It states that electrostatic force is directly proportional to the magnitude of each charge and inversely proportional to the square of the distance b/w two charges.

\[ F = \frac{Q_1 Q_2}{4\pi \varepsilon_0 r^2} \]

• Mainly depends upon size of structures and distance between two electrodes.
APPLICATIONS

• RESONATORS
• ELECTROMECHANICAL FILTERS
• OPTICAL SHUTTERS
• MICROGRIPPERS
• VOLTMETERS
OBJECTIVE

Large deflections at low actuation voltage.
SPRING DESIGNS

1. FIXED – FIXED FLEXURE
2. CRAB LEG FLEXURE
3. FOLDED FLEXURE
Fixed–Fixed beam.
2) Crab-Leg Flexure

![Diagram of crab-leg flexure with labels L1, L2, b, thigh, and shin.]
3) Folded-Flexure
DIMENSIONS

1) Comb length = 30µm
2) Comb Width = 3µm
3) Gap between moving comb and fixed combs = 7µm
4) Overlapping area = 20µm
5) Spring length = 280µm
6) Spring width = 2µm
7) Gap between spring legs = 19µm
8) Thickness of Actuator = 2µm
9) No. of Moving combs = 4
10) No. of Fixed Combs = 5
1. Capacitance (C) is:
\[ C = \frac{2n\varepsilon_0 t(y_0 + y)}{g} \]
y0 + y = change in overlapping area in y direction
\( t = \) thickness
\( g = \) gap spacing b/w combs
\( y = \) comb displacement
\( y_0 = \) initial overlap

2. Electrostatic Force (Fel) is:
\[ F_{el} = \frac{n\varepsilon_0 t V^2}{g} \]
\( V = \) Actuation Voltage
\( n = \) No. of combs

3. Spring Constant (K) is:
\[ K = 2Et\left(\frac{W}{L}\right)^3 \]
\( W = \) Width
\( L = \) Length
\( t = \) thickness

4. Displacement (Y) is:
\[ Y = \frac{n\varepsilon_0}{2Eg} \left(\frac{L}{W}\right)^3 V^2 = \frac{\text{Force}}{\text{SpringConstant}} \]
Simulation of Fixed-fixed Flexure
Simulation Of Crab Leg Flexure
Simulation of Folded Flexure
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Fixed-Fixed Flexure</th>
<th>Crab Leg Flexure</th>
<th>Folded Flexure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage (V)</td>
<td>460</td>
<td>200</td>
<td>130</td>
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<tr>
<td>Displacement (µm)</td>
<td>5.9</td>
<td>4.0</td>
<td>2.85</td>
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<tr>
<td>Capacitance (pF)</td>
<td>417</td>
<td>372</td>
<td>352</td>
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<tr>
<td>Finger overlap (µm)</td>
<td>6</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Force (N)</td>
<td>0.085</td>
<td>0.015</td>
<td>0.0056</td>
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<tr>
<td>Parameters</td>
<td>Fixed-Fixed Flexure</td>
<td>Crab Leg Flexure</td>
<td>Folded Flexure</td>
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<tr>
<td>-------------------</td>
<td>---------------------</td>
<td>------------------</td>
<td>---------------</td>
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<tr>
<td>Voltage (V)</td>
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<td>130V</td>
<td>130V</td>
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<tr>
<td>Displacement (µm)</td>
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<td>Force (N)</td>
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<tr>
<td>Capacitance (pF)</td>
<td>326</td>
<td>328</td>
<td>352</td>
</tr>
</tbody>
</table>

![Graph showing voltage vs. displacement for different flexures](image-url)
As the folded flexure length increases, spring stiffness decreases which increases displacement.

\[ K = 2Et\left(\frac{W}{L}\right)^3 = \frac{\text{Force}}{\text{Displacement}} \]
## Parameters by Folded Flexure Spring

<table>
<thead>
<tr>
<th>No. of Moving Fingers</th>
<th>4 fingers</th>
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<tbody>
<tr>
<td>Spring Length(µm)</td>
<td>280</td>
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<td>250</td>
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<td>Voltage (V)</td>
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<tr>
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<td>130</td>
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<td></td>
<td>130</td>
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<td>Displacement (µm)</td>
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<td>1.704</td>
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<td></td>
<td>1.063</td>
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<td>336</td>
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<td></td>
<td>327</td>
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<tr>
<td>Finger Overlap(µm)</td>
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<tr>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
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<tr>
<td>Force (N)</td>
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<tr>
<td></td>
<td>0.0051</td>
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<tr>
<td></td>
<td>0.0050</td>
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</table>
Thank You