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Deflection Analysis of IPMC Actuators Under AC Voltages using DIC Method

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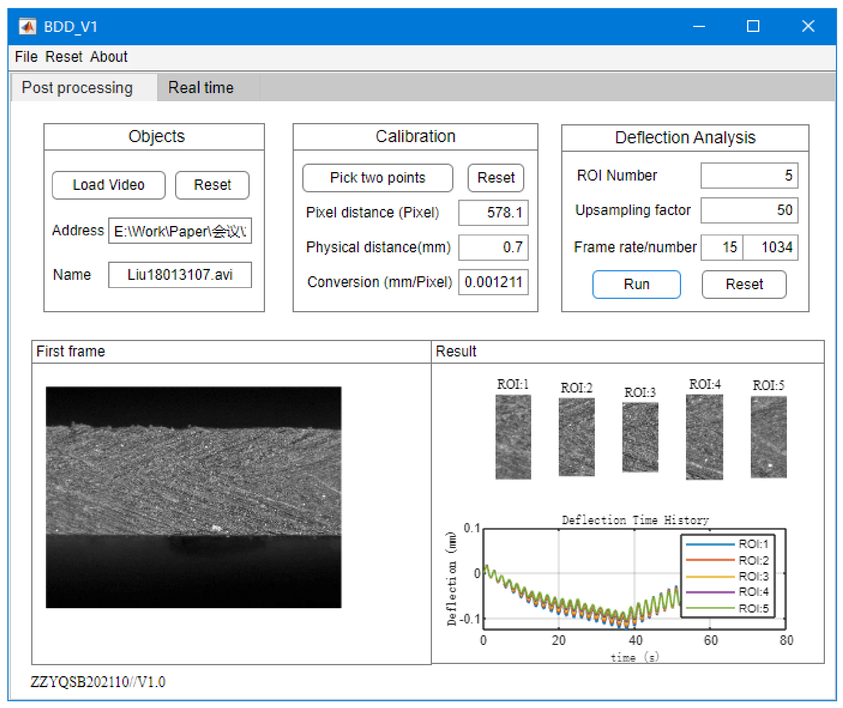
• Background:

The deflection response characteristics of ionic polymer-metal composite (IPMC) cantilever actuator under alternating current (AC) excitations are investigated in the present work. A program based on numerical calculation platform MATLAB for digital image correlation (DIC) analysis with multiple regions of interest (ROI) is developed to study the micro-scale dynamic lateral movement processes of the fabricated IPMC sample with Pt electrodes, which are recorded by a digital microscope.

• 2D DIC technique with multiple ROIs:

A user-friendly interface has been built into the software package using MATLAB (R2022a) App Designer.

- Loading video. Click Load Video button and select captured video images.
- Calibration. The scaling factor with units of mm/pixel is estimated from the known physical dimension on the object surface.
- Deflection analysis. Multiple target tracking is required to measure the deflections at different points on IPMC cantilever actuator.

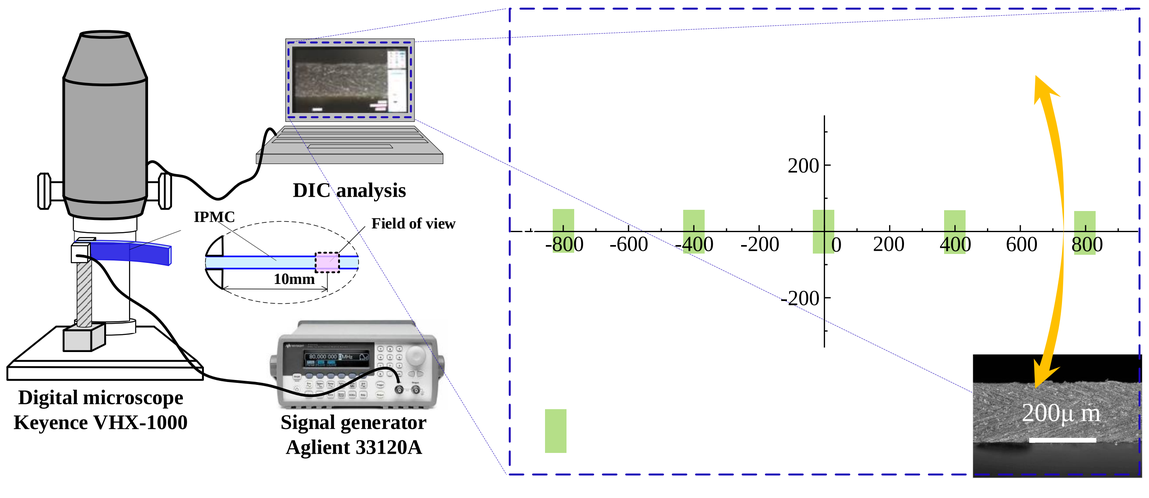


User interface of the beam deflection extraction software

• 2D DIC technique with multiple ROIs:

Nafion-based IPMC actuator sample with Pt electrodes was manufactured by a typical four-step technique.

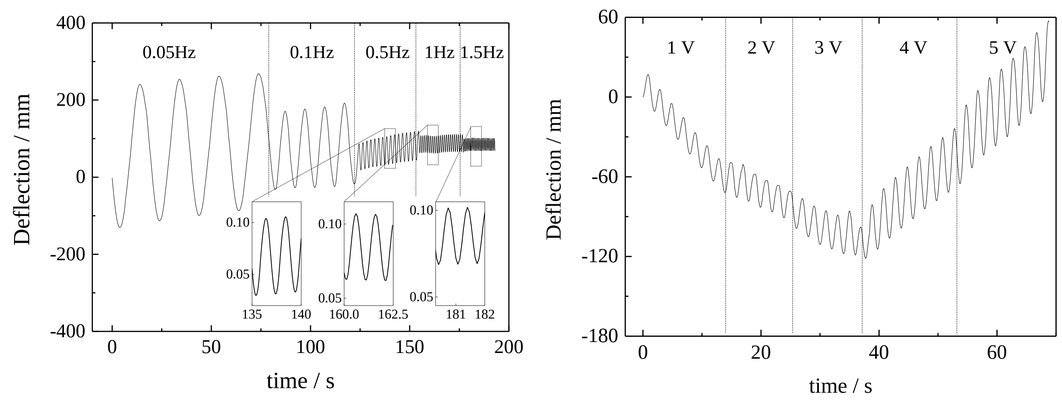
- The IPMC material with a thickness of 0.7 mm was cut into dimensions of 40 mm × 10 mm.
- The sample was fully hydrated and cantilevered at one end by two Ag electrodes with a contact area of 10mm^2.
- All measurements were conducted in air at 50%RH and 26 °C.
- Five rectangle areas were set as ROIs to calculate the deflection of the sample.



Schematic of the experimental setup and field of view image

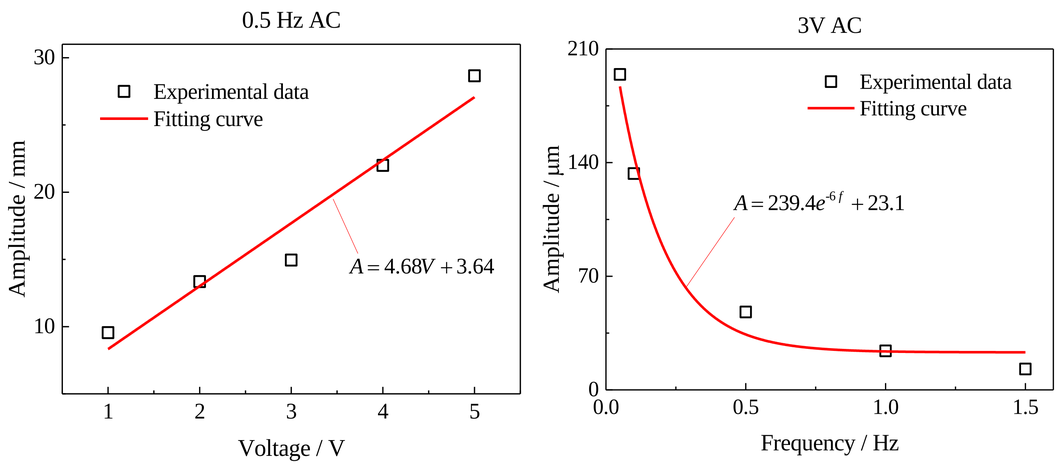
• Results:

- IPMC cantilever actuator vibrates with the same frequency of the AC excitation voltages. The vibration amplitude of the sample decreases (increases) with the increase (increase) of excitation frequency (voltage). And the oscillation center of the actuator occurs offset vibration.



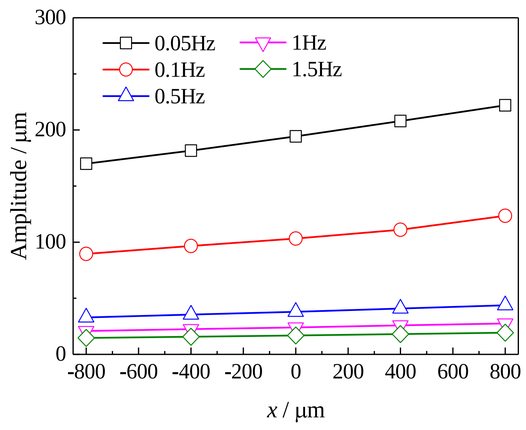
Deflection of IPMC actuator under 3V AC and 0.5Hz AC applied

- The vibration amplitude can be expressed as a function of voltage (frequency) using a fitting curve based on experimental data.



Experimental relationship curves

- Deflection amplitude increases from the clamped side of the actuator to the free side, and the deflection curves conforms to the first mode shape.



Vibration amplitudes of the sample at different points

Conclusion

Specific observations from the experimental results can be summarized as follows:.

- The multi-point measurement capacity of the developed program based on DIC method is confirmed through deflection tests of the IPMC cantilever actuator under AC excitations, is powerful for beam structure deflection measurements.
- The vibration amplitude increases linearly with the increase of excitation voltage and has approximately a negative exponent relation with excitation frequency. The deflection curve of the actuator under AC excitation is the first mode.