HYSTERETIC BEHAVIOUR OF MICROBEAM STRUCTURE IN ELECTRO-ELASTIC ANALYSIS

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ABSTRACT

Electrostatically actuated micro-beams are widely used in many MEMS devices including switches, resonant sensors, etc. [1, 2], and Figure 1 shows a typical example. Stoppers should be positioned between beam and the counter electrode to prevent the beam from hitting the electrode and thus short-circuiting, since the beam could lose stability at its equilibrium position when applied voltage exceed a critical value or pull-in voltage. But beam doesn’t return to its original stable position with the decrease of applied voltage during release stage, namely a hysteretic behaviour. The analysis of hysteresis is critical in design to find out the two stable positions during pull-in and release.

However, the hysteretic behaviour may be challenging to predict for some complicated microbeam structures, especially in the stage of release with decreasing voltage. FEA could be a good method, but only few have successfully simulated the hysteresis, or only at the very first stage before pull-in, because the instable stage after pull-in causes difficulties in the calculation of electrostatic forces. But a method is found in “ANSYS Workbench”, an FEA software, to successfully simulate the hysteric behaviour. Standard workflows are created to model the hysteresis in different stage, and can be used for various microbeam structures.

Standard electro-elastic analysis using coupled-field element in ANSYS can quickly find out the pull-in voltage and last equilibrium position before the beam collapse, with the aid of a nonlinear convergence plot to reveal the divergence which implies instability. For the non-stable stage after pull-in, rather than directly calculating the electro-elastic force, a static structure analysis is run as an initial model with a largely deflected beam, then by using a special contact element, the true beam status when it’s hitting the stopper is obtained. This status is used as the initial status when the applied voltage begins to decrease, therefore, an entire hysteresis for microbeams can be found, as shown in Figure 2, the two distinct equilibrium stages (B and D) can be seen during the increase and decrease of applied voltage, respectively. The hysteresis in many applications needs be reduced to achieve a long-term reliability, depending on many factors including the position of stoppers. The parameterization analysis in ANSYS Workbench can certainly and efficiently contribute to optimization.

In addition, electro-elastic analysis for microbeam with a deformed shape under various loads can be further coupled into electric analysis to obtain captive responses, and HFSS (another ANSYS product), to get RF (radio frequency) responses. Figure 3 shows an entire workflow, and more detail can be found in the extended abstract.

REFERENCE

[1] E. Cretu, L.A. Rocha and R.F.Wolffenbuttel, “Micromechanical voltage reference using the pull-In of a beam”, IEEE Trans. on Instr. and Meas. Vol. 50, N°6, pp. 1504-1507, Dec. 2001.

[2] H.A.C. Tilmans, and R. Legtenberg, "Electrostatically driven vacuum-encapsulated polysilicon resonators, Part 2, Theory and performance", Sensors and Actuators A 45(1994) 67-84.

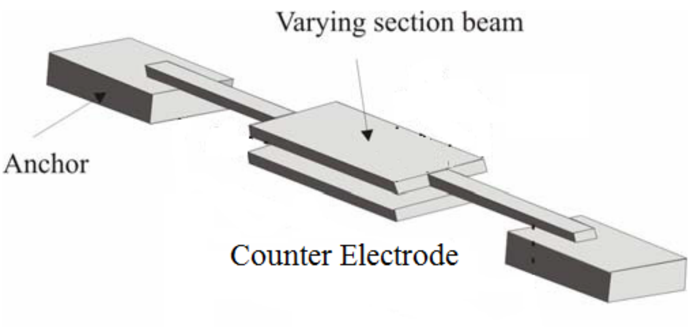

Figure 1: Typical microbeam structure as a MEMS switch

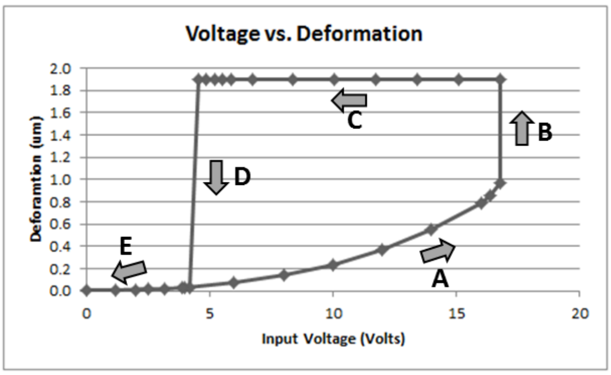

Figure 2: Hysteretic behaviour of a microbeam by ANSYS

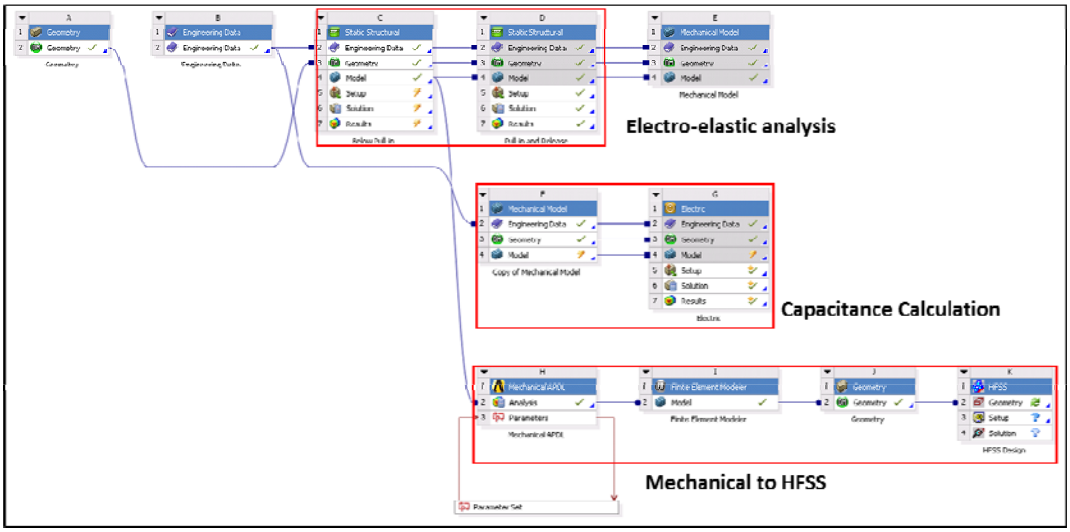

Figure 3: Overview of the standard workflow for hysteretic behaviours of a microbeam structure, with the coupling to other physical disciplines

KEYWORDS

Hysteresis, Micro-beam, MEMS, ANSYS Workbench, Electro-Elastic