Study of Characteristics of MEMS Thermo-Electric Actuators

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Abstract – **the article presents the results of the studies of the displacement of MEMS electrical-thermo-actuators and decomposition of temperatures depending on the applied voltage. Some fragments of the developed code in the system ANSYS, which allows to automate the process of research, and automatically build graphical dependencies.**

Keywords – **electro-actuator, computer-aided design, MEMS, finite element method, multi-physics analysis.**

I. Introduction

Electrical-thermal micro actuators that operates based on thermal expansion caused by Joule heating are paid a lot of attention these days [1-4]. That is why the task to investigate the most common design of electric actuators was set [5-6] as well as to automate the study process. These devices can have micro sizes and be produced mostly of poly silicon, but can theoretically be made of any conductive material.

Electrical actuators are mainly used to position the micro-mirrors and moving micro devices. To increase the effective forces several actuators can be combined.

The main objective of the analysis is to calculate the spike deflection of actuators depending on the applied voltage to the pads.

II. Principles of work and construction

Electrical-thermal actuator used in MEMS is based on thermal expansion between the thin beam and plate. The potential difference being applied to the electrical contact pads induces leakage of current between them. Resistance exerted by polysilicon to the current that flows in the actuators causes Joule heating. Resistance in a thin beam is greater than in the plate. Thus, a thin beam heats up more than the plate, which results in bending the spike into the side of the plate. The maximum deformation occurs at the end of the matter. The value of devialtion is a function of spike deflection directly proportional to the potential difference. Thus, the cost of the spike deflection can be accurately calibrated depending on the applied voltage.

The design of the actuator is presented in Fig.1.

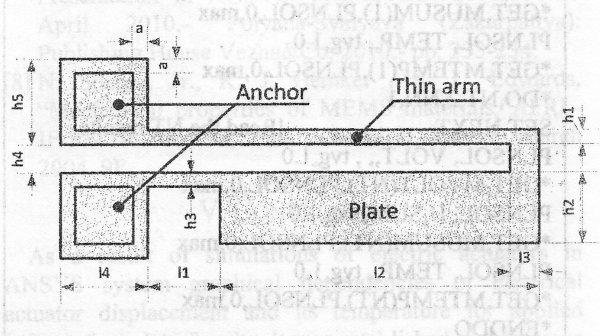

Fig.1. design of the electric-thermal actuator

III. Automation of the graphical dependency calculation and presentation

To get data necessary to build graphical dependencies the applied voltage needs to be changed each time as well as other parameters of the simulation. It was decided to develop a program that would help in the loop to counduct all necessary calculations and automatically build graphical dependencies [7]. Once geometry is built and material properties are set [8], a partition to the finite element mesh is conducted and boundary conditions are set to automate recording of the results obtained using a system developed in ANSYS. Part of the code is presented in Fig. 2.

```
PV=1    ! Starting voltage
KV=5    ! End voltage
SV=1    ! Step
*SET,NN,((KV-PV)/SV+1)
DIM,VV,ARRAY,NN        ! Revelation array  VV
NPP=1
VPLOT
/SOL
*DO,V,PV,KV,SV
/GO
DA,24,VOLT,V                ! Boundary conditions
*SET, VV(NPP),V
NPP=NPP+1
/STATUS,SOLU
SOLVE
*ENDDO
FINISH              !
*DIM,MVOLT,ARRAY,NN          ! Revelation array
MVOLT
```

```
*DIM,MUSUM,ARRAY,NN         ! Revelation array
MUSUM
*DIM,MTEMP,ARRAY,NN         ! Revelation array
MTEMP
/POST1
SET,FIRST                   !Read the first results
/EFACET,1
/SHOW,JPEG,,0               !Makes a screenshot
PLNSOL, VOLT,, , tvg,1.0
*GET,MVOLT(1),PLNSOL,0,max
PLNSOL, U,SUM, tvg,1.0
*GET,MUSUM(1),PLNSOL,0,max
PLNSOL, TEMP,, tvg,1.0
*GET,MTEMP(1),PLNSOL,0,max
*DO,NT,2,NN,1
SET,NEXT                    !Read the NT results
PLNSOL, VOLT,, , tvg,1.0
*GET,MVOLT(NT),PLNSOL,0,max
PLNSOL, U,SUM, tvg,1.0
*GET,MUSUM(NT),PLNSOL,0,max
PLNSOL, TEMP,, tvg,1.0
*GET,MTEMP(NT),PLNSOL,0,max
*ENDDO
/SHOW,CLOSE
FINISH
!Graph Construction
/POST26
FILE,'file','rst','.'
/UI,COLL,1
NUMVAR,200
SOLU,191,NCMIT
STORE,MERGE
FILLDATA,191,,,,1,1
REALVAR,191,191
VPUT,MTEMP(1,1,1),200  ! ID:  2
REALVAR,2,200,,,MTEMP
VPUT,MUSUM(1,1,1),200  ! ID:  3
REALVAR,3,200,,,MUSUM
VPUT,MVOLT(1,1,1),200  ! ID:  4
REALVAR,4,200,,,MVOLT
! Graph of maximum displacement of the applied voltage
! Maximum displacement of the applied voltage
/AXLAB,Y, Maximum displacement [m]
/AXLAB,X, Voltage [V]
/SHOW,JPEG,,0
/SHOW,TIFF,,0
JPEG,TMOD,1
XVAR,4
PLVAR,3,
/SHOW,JPEG,,0
/AXLAB,Y, Maximum temperature [C]
/AXLAB,X, Voltage [V]
XVAR,4
PLVAR,2,
/SHOW,CLOSE
FINISH
```

Fig. 2. Code of the program in ANSYS

The result of the program (Fig. 2) is the distribution of stresses and strains in the plate of accelerometer for different voltages. In addition the program on the basis of pre-recorded data files automatically builds graphical dependencies.

IV. RESULTS

Decomposition of plate deformation in electric actuators for the applied voltage of 3,5 [V]. is presented in Fig.3.

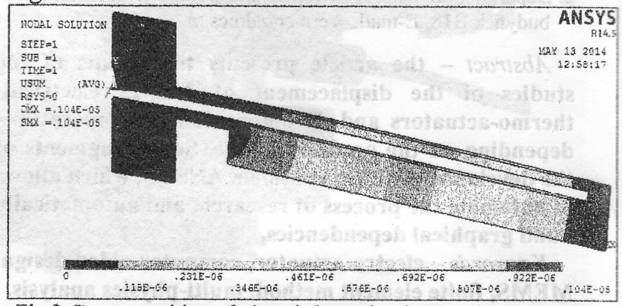

Fig.3. Decomposition of plate deformation in electric actuators

Graph of dependencies between maximum displacement and applied voltage that was automatically generated using the developed program is presented in Fig.4. It can be seen from the graph that with increasing of voltage applied to the actuators, significantly increases the spike displacement of actuators, along with significantly increase of the temperature. This dependencies are presented in Fig.5.

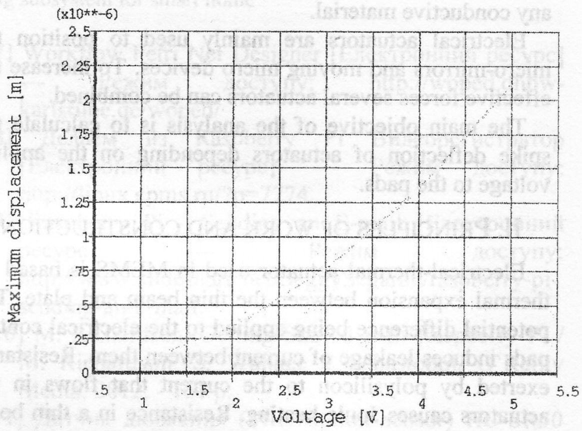

Fig.4. Graph of dependencies between maximum displacement and applied voltage

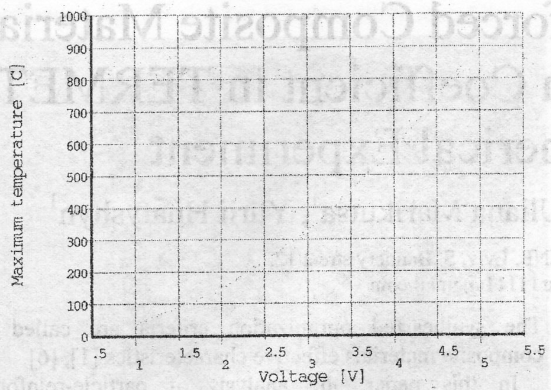

Fig.5. Graph of dependencies of maximum temperature from applied voltage

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V. Conclusion

As a result of simulations of electric actuators in ANSYS system graphical dependencies of electrical actuator displacement and its temperature for applied voltage from 1 to 5 volts. It was established that increase in voltage significantly increased displacement and temperature in the electric actuators, which is not always desirable.

To automate the process of research the code in the ANSYS system was developed, which allows to automate the process of study and automatically build graphical dependencies.

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