A new behaviour for electrostatic actuator Experimental investigation

Dr. Moftah M Bakush*   Dr. Hussein M Magboub

Dr. EL-Mahdi M Abousetta

***Electrical and Electronic Engineering Department, Faculty of Engineering, Al-Fateh University**
**** Computer Engineering Department, Faculty of Engineering, Al-Fateh University**

Abstract

Controlling miniature structures , such as small cantilever used in scanning force microscopy, using electrostatic actuator has gained a considerable interest. The behaviour of such an electrostatic actuator has been theoretically modelled and simulated for both dc and ac applied voltages [1]. This paper presents a control system realizing linear electrostatic actuation and presents an experimental results.

1-Introduction

Electrostatic actuators used at micrometer level have a strong position in microengineering applications [1] . Their capability with CMOS processes , low temperature dependence , and low power consumption has placed a growing interest on them. Theoretical analysis of electrostatic actuators behavior [2] such as a cantilever used in scanning force microscopy , has reveled a non-linear relationship between the dc electrostatic displacement and the applied electric field.

In order to investigate experimentally the behaviour of the cantilever when excited by an electrostatic force the following situations were taken into consideration.

- Study the static deflection when only a d.c. bias voltage is applied.
- Study the dynamic deflection (vibration) when a d.c. and an a.c. voltage are applied.
- Investigation of the non-linear behaviour.

Although electrostatic actuators used at micrometer have a strong position in micro-engineering applications [2] due to their compatibility with CMOS processes, non contact behaviour , low temperature and low power consumption, they have non-linear relationship between the applied field and electrostatic displacement [3,4].In order to be able to use electrostatic actuator in microposition and suppress cantilever oscillations it's behaviour must be linearized. It is confirmed experimentally in this paper that if square root of the total drive field is applied then cantilever behaviour is linearized as predicted from theoretical considerations [1].

2- Experimental set up and investigation.

Electrostatic drive is a two parallel plates separated by an air gap. One plate is usually fixed (electrode) and the other (Cantilever) is free to move as shown schematically in figure (1).

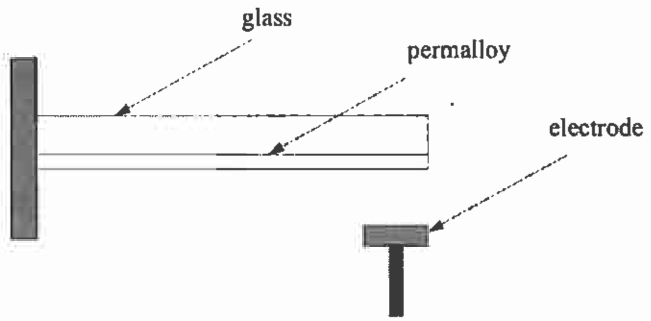

Figure (1) Experimental cantilever and electrode configuration.

Due to the attractive nature of the electrostatic device and the interacting behaviour between the two electrodes, it is very difficult to estimate the initial gap between them. Therefore, a series of experiments were carried out to estimate the initial gap and to make a comparison with the theoretical work presented in the previous work [1]. The electrode movement was calibrated by attaching a small scaled wheel at the bottom of the electrode. This wheel is divided into equal sectors with 15 µm each. The experimental arrangement used in this work is depicted schematically in figure (2). A function generator with built-in dc offset capability was used to provide the drive field. A computational integrated circuit was used to generate the square root of this drive field. The dynamic behaviour of the cantilever with and without the square rooter was measured using optical beam deflection [5].

3- Static deflection.

In this experimental the gap is assumed to be that given by the wheel scale (15, 30, 45 µm). While the gap is assumed, the applied d.c. voltage is varied from 0 to 30 V. The measured values show the expected V^2 behaviour. Figure(3) shows the measured data together with predicted values for a given gap. The results obtained show that the agreement between predicted and measured data is good.

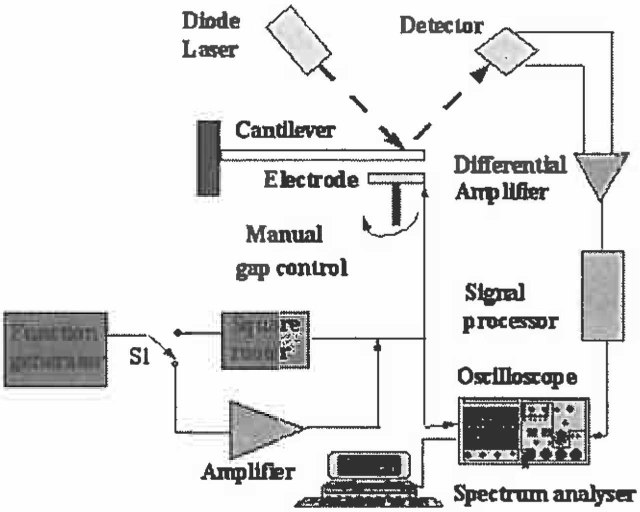

Figure (2) Experimental arrangement.

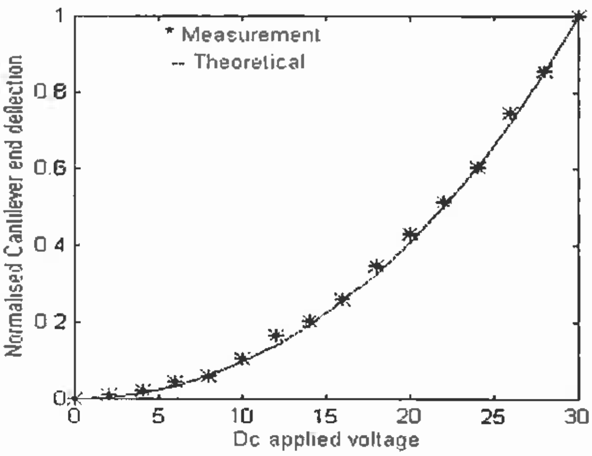

Figure (3). Static deflection curve of the cantilever as a function of the applied d.c. voltage

4-Dynamic deflection

The dynamic behaviour of the cantilever is described using the set-up given in figure (2). The cantilever is deflected electrostatically by deriving the fixed electrode by constant dc voltage and varying ac voltages using a function generator. For this work different low frequencies signals were used. The low frequency value was used to represent the real movement of the cantilever when the micropositioning is undertaken.

The following figures illustrate the cantilever behaviour when it is statically deflected by applying 4 V dc voltage and dynamically vibrated by varying ac voltages from 0 to 8 V. As can be seen from figures (4-8) the cantilever has non-linear behaviour as expected by the theoretical model described in previous paper [1].The cantilever response becomes increasingly non-linear due to generate higher order frequency component as the ac drive level is increased. Figures (9) and (10) show that linear response can be produced by using a square root circuit as expected from the theoretical model. The power spectrum of this response shown in figure (10) emphasize the process as a linearizing operation.

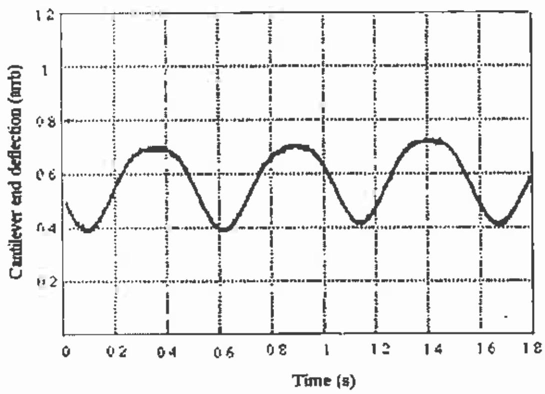

Figure (4) Cantilever dynamic deflection (V_{dc} =4 V and V_{ac}= 2 V) sine wave signal

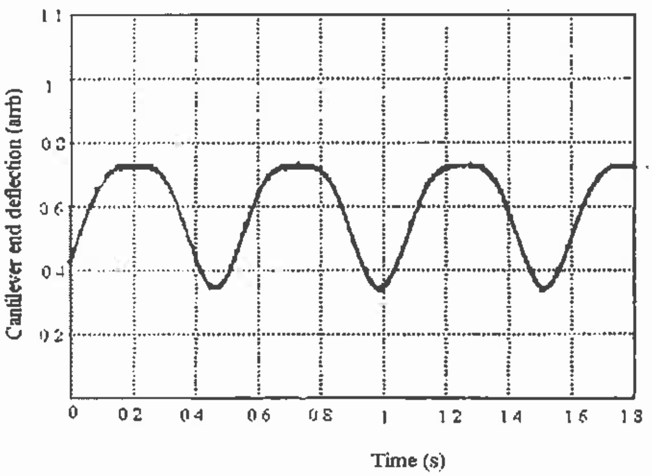

Figure (5) Cantilever dynamic deflection (dc = 4 V and ac = 4 V).

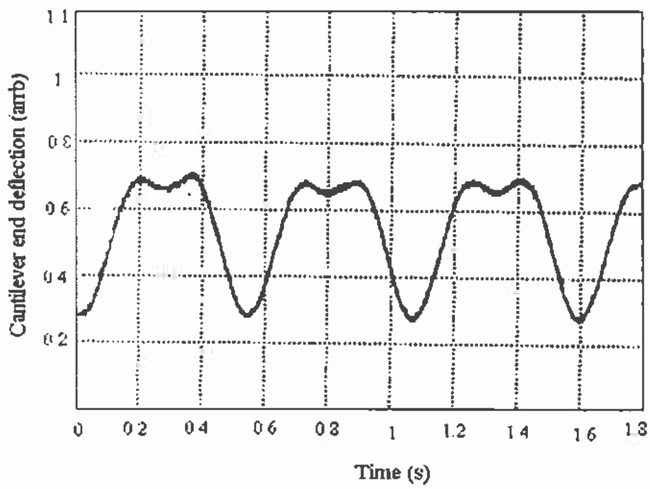

Figure (6) Cantilever dynamic deflection (dc = 4 V and ac = 6 V).

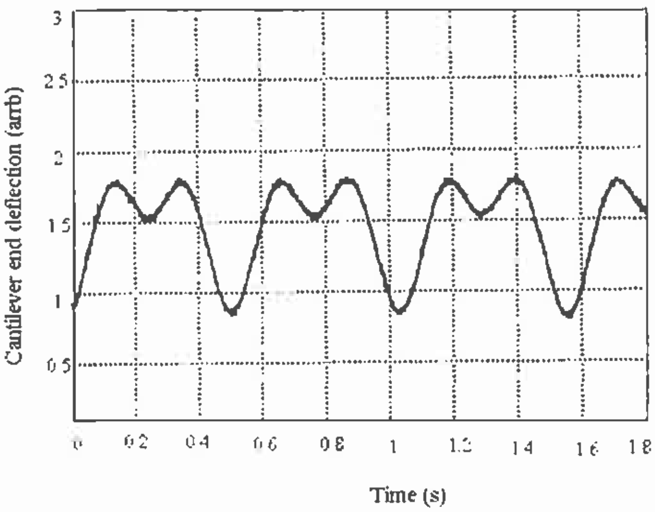

Figure (7) Cantilever dynamic deflection (dc = 4 V and ac = 8 V).

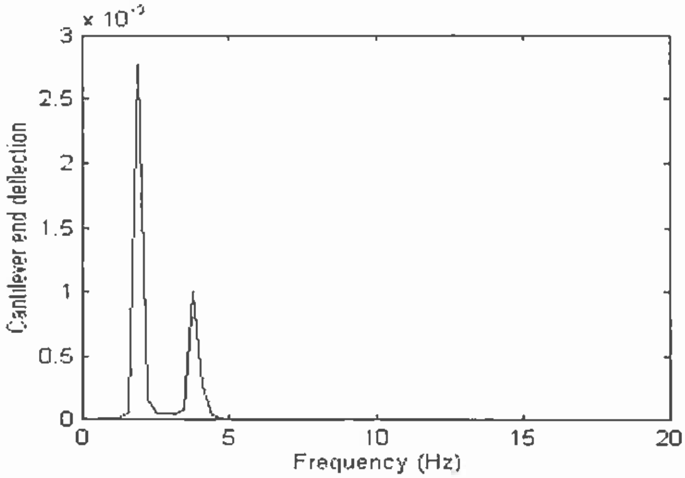

Figure (8) Power Spectrum of deflection cantilever signal (dc = 4 V and ac = 8 V)

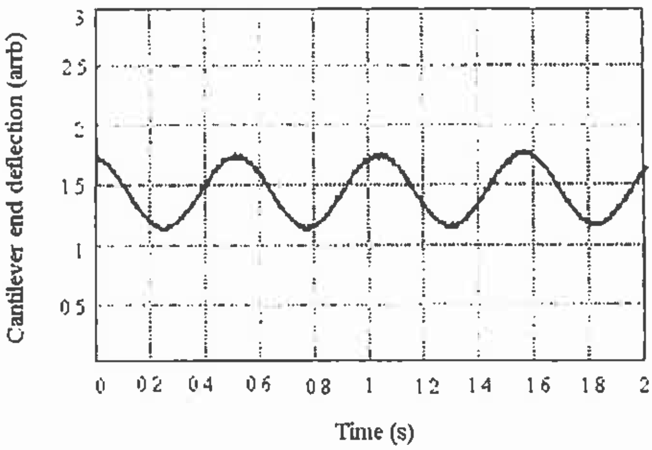

Figure (9) Cantilever behaviour after square rooter is used (sinewave signal).

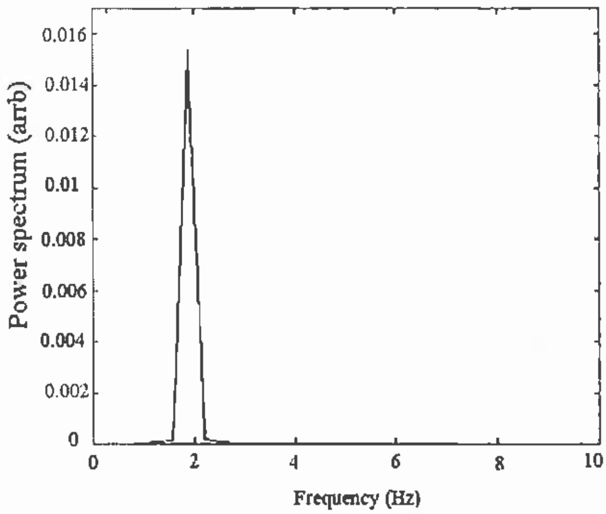

Figure (10) The power spectrum of the above signal.

5-Summary.

The performance of the electrostatic actuator with applied dc and ac voltages is experimentally demonstrated. This study is carried out to investigate the ability of this type of actuation and its use in micropositioning applications . The results produced show that the agreement between the experimental results and pervious theoretical model is very good.

الملخــــص :

التحكم في سلوك التركيبات الصغيرة جداً مثل الكابول الصغير المستخدم في جهاز المسح بالقوة الميكروسكوبية بأستخدام المشغل الكهروستاتيكى قد أكتســب اهتمام ملحوض. سلوك هذا المشغل قد تمت محكاته رياضياً تحت تأثير فرق الجهد الثابت و المتغير في بحت سابق. في هذا البحث السلوك الخطي لهذا المشغل قد تم التحقق منه معملياً .

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