Author's Accepted Manuscript

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PII: S0020-7403(17)30098-X
DOI: http://dx.doi.org/10.1016/j.ijmecsci.2017.01.021
Reference: MS3559

To appear in: *International Journal of Mechanical Sciences*

Received date: 11 May 2016
Revised date: 16 December 2016
Accepted date: 13 January 2017

Cite this article as: Sadegh Sadeghzadeh and M.H. Korayem, Role of mechanica and thermal nonlinearities in imaging by Atomic Force Microscope, *Internationa Journal of Mechanical Sciences* http://dx.doi.org/10.1016/j.ijmecsci.2017.01.021

Role of mechanical and thermal nonlinearities in imaging by Atomic Force Microscope

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Abstract

In this paper, the effects of nonlinearities such as hysteresis, creep and thermal drift of piezoelectric elements on imaging by Atomic Force Microscope have been studied via a semi-analytical approach. The Generalized Differential Quadrature Method (GDQM) has been used to find the dynamic response of a system. Bouc-Wen and PI hysteresis models have been incorporated with the presented linear model to obtain the effects of nonlinearities; and thermal drift has been augmented in an offline scheme. All the sub-models have been validated by comparing their results with the findings of previously reported experiments. Finally, these nonlinear effects have been applied on AFM-based imaging operations, and the obtained results have been evaluated. In comparison with the linear case in which the hysteresis effects are not taken into consideration, in the nonlinear imaging model, depending on the scan direction, the asperities on a rough substrate are sensed at different locations. In the creep case, the high level of error obtained during scan at the ascending points of substrate profile is due to the delay in the time interval in which the input increases. According to the results, the imaging of a standard sample substrate while assuming a 2º temperature change during a 10 min scan of the substrate has yielded a maximum thermal drift error of about 3.3 nm. At the end, based on the presented comprehensive nonlinear imaging model, the coupled effects of creep-hysteresis-thermal drift on the final image have been reported and discussed.

KeyWords; Nonlinearities, Atomic Force Microscope, Imaging, Hysteresis, creep, Thermal drift

1- Introduction

The researchers in various technological fields are now able to more effectively control and manipulate the structures of different materials at increasingly lower scales. Today, the new