A study of the self-oscillating regime in the problem of an atomic force microscope in the contact mode

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Abstract. In this paper a microscope with a sensitive element in the form of a cantilever beam is operating in the frequency contact mode. The problem is to obtaining approximate analytical expressions describing the dynamics of the sensitive element in the case of forced oscillations, taking into account the pre-stressed state. Using asymptotic and variational methods of mathematical physics, a model is constructed and estimates are obtained, the result is compared with a numerical solution by the finite element method. The key focus in this work is the analysis of the nonlinear dynamics of the sensitive element of an atomic force microscope and the selection of the information signal from the nonlinear effects associated with the interaction of the indenter and the sample. Due to the generality of the method, the range of applicability of these results would not be limited to an atomic force microscope and they would also prove efficiency in designing gyroscopic instruments.

Introduction

The atomic force microscope (AFM) shown in Figure 1 is designed to measure the parameter of the surface δ (the distance between the tip and the sample). In the classical formulation of the AFM problem [6], the studied object is forced by harmonic signal at the resonant frequency of the cantilever. Further, depending on which parameter is used to restore the parameter δ, two main AFM operation modes are distinguished - frequency and amplitude modulation [4]. In the first case, the surface topography is restored by changing the vibration frequency of the sample, on the other hand the same is done according to the values of the amplitude of the AFM vibrations. The first version of the experiment is more attractive than the second one in that it exhibits smaller errors and inaccuracies in data acquisition [5],[6]. The only and most important problem of the experiment is that the resulting frequency response of this system is nonlinear [4], which makes it difficult to unambiguously determine the surface parameter of the object under study.

In this paper, we propose to consider the case of generalized nonlinear excitation, which depends on the generalized coordinates of a given system and to establish the possibility of the presence of a limit cycle and self-oscillations in a given system for a certain, given excitation force.

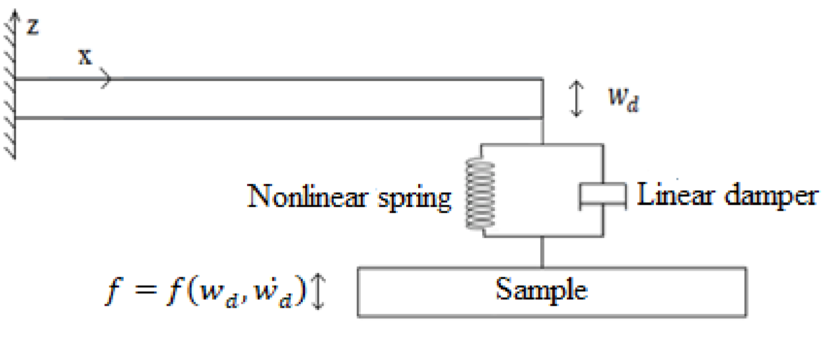

Figure 1: Schematic view of the AFM.

In this work we study the dynamics of AFM in contact mode. In contrast to the standard harmonic excitation force acting on the sample, the generalized function of the degrees of freedom and time was considered. With a certain choice of this function, it is possible to organize a limit cycle in this system and use it to remove information about the object under study, which can take interest in the applied plan.

References

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