Analytical model of strongly localized wrinkling modes of mono- and few-layer graphene sheets in or on a compliant strained matrix

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Abstract. We present a study of the wrinkling modes, localized in the plane of mono- and few-layer graphene sheets embedded in or placed on a compliant strained matrix. We provide the analytical model based on nonlinear elasticity of the graphene sheet, which shows that beyond the critical compressive surface stress the spatial localization of the wrinkling mode occurs with soliton-like envelope with localization length, decreasing with the overcritical compressive surface stress.

Introduction

Exceptional physical and mechanical properties of graphene have made it very attractive for the construction of nano- and electro-mechanical devices and as a reinforcing inclusion in polymer nanocomposites. As reinforcing layers in multilayer polymer nanocomposites, the graphene sheets provide longitudinal stiffness that significantly exceeds the corresponding characteristics of the polymer matrix, which ensures high tensile strength of the nanocomposite in the plane of reinforcement. However, under compressive stresses, the ultimate load of a multilayer nanocomposite is determined not by the strength of its components and the level of adhesive bonding, but by the loss of stability of the stiff reinforcing layers embedded in the polymer matrix.

Problem formulation and main results

We provide an analytical description of the wrinkling modes, localized in the plane of mono- and few-layer graphene sheets embedded in or placed on a compliant strained matrix. Wrinkling is accompanied by the softening of bending surface acoustic wave, which is triggered by the compressive surface stress in the graphene sheet produced by compressive strain in the matrix. Softening of the bending surface acoustic wave leads to spatially periodic static flexural deformation (wrinkling mode) of the graphene sheet with a defined wavelength [1,2]. Our main result is that the flexural displacement w is in the form of a static sinusoidal wave, long on the lattice-period scale, with the spatially-dependent amplitude, $w = A(x) \sin (k_0 x)$, which describes a soliton-like envelope of the sinusoidal wave. The localization length of the soliton-like envelope of the wrinkling mode in the graphene sheet decreases with the increase of the overcritical surface strain $\varepsilon_{xx} > \varepsilon_{xx}^{(cr.)}$ that finally results in the formation of strongly localized mode with approximately one-period sinusoidal form (see Fig. 1 for the form of the graphene sheet in a compliant matrix). Because of the inverse antisymmetry in w distribution along the sheet plane and the absence of delamination, the strongly localized wrinkling modes in the graphene sheet embedded in a compliant matrix do not coincide with ripplocations in layered solids [3]. Symmetric along the sheet plane strongly localized wrinkling modes can occur in the graphene on a matrix.

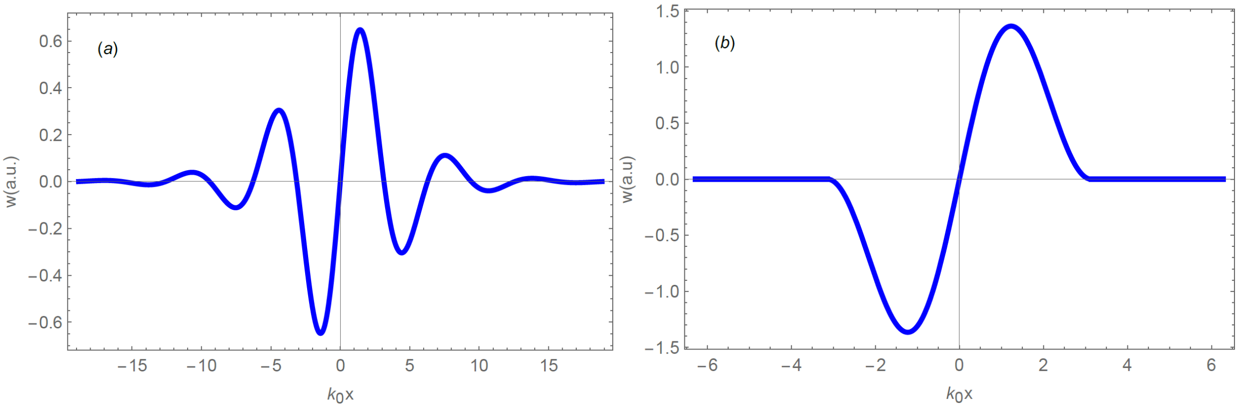

Figure 1: Form of the wrinkling mode for (a) weakly ($\varepsilon_{xx} = 1.1\varepsilon_{xx}^{(cr.)}$) and (b) strongly ($\varepsilon_{xx} = 1.9\varepsilon_{xx}^{(cr.)}$) overcritical compressive surface strain in the graphene sheet in a compliant matrix.

The work was supported by the Russian Foundation for Basic Research, Grant No. 18-29-19135.

References

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