Applied Mathematical Modelling 40 (2016) 3535–3549

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Dynamic response of a moving load on a micropolar half-space with irregularity

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ARTICLE INFO

Article history:
Received 6 April 2014
Revised 6 May 2015
Accepted 30 September 2015
Available online 19 October 2015

Keywords:
Coupling factor
Frictional coefficient
Micropolar
Moving load

ABSTRACT

Due to its ability to explain size effects on a small length scale by considering additional degrees of freedom, micropolar theory is preferred for describing media with complex microstructures such as soil, composite materials, granular and powder-like materials, masonry, bones, and liquid crystals. In this study, a theoretical model is presented to investigate the response of a moving load on a micropolar half-space with irregularity. We obtain the closed-form expressions for normal stress, shear stress, and tangential couple stress. The effects of friction, microstructure, and irregularity in the medium are studied by introducing the frictional coefficient (R), coupling factor (N), and irregularity factor (x/a). We discuss the effects of varying the half-space depth and irregularity on the stresses. Two different cases of irregularity are compared, i.e., rectangular and parabolic.

1. Introduction

The theoretical response of a moving load on a half-space has been investigated frequently in the past. This type of study is useful for modifying different models such as bridges, railways, beams subjected to pressure waves, and piping systems subjected to two-phase flow. The main reason for studying this problem with a micropolar medium is related to the technological and geophysical conditions. The classical theory of elasticity explains the behavior of these materials, which are considered as a continuum in the mathematical sense, such as steel, aluminum, concrete, and coal, but it is not suitable for explaining the behavior of materials such as polymers, cellular solids, and crystals with microstructures. In particular, this theory does not explain discrepancies that occur with elastic vibrations at a high frequency and small wavelengths. Thus, it is necessary to develop size-dependent consistent continuum mechanics to analyze the behavior of materials on a microscale and to explain the macroscale behavior. Voigt [1] first tried to eliminate the shortcomings of the classical theory of elasticity by assuming that the interaction between two particles in a body through an area element within a material is transmitted by the force vector but also by a couple (moment) vector, which gives rise to couple stresses in elasticity. However, the complete theory of asymmetric elasticity was developed by Cosserat and Cosserat [2], who assumed that the body comprises interconnected particles in the form of small rigid bodies and deformation of the medium is described by the displacement vector as well as by the independent rotation vector. Furthermore, Eringen [3] generalized the classical theory of elasticity by considering that the directors are rigid and that there are three rotational degrees of freedom in addition to the three classical displacement degrees of freedom. Eremeyev et al. [4] presented elastic variants of the micropolar theory in a modern version. Altenbach and Eremeyev [5] highlighted

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http://dx.doi.org/10.1016/j.apm.2015.09.102

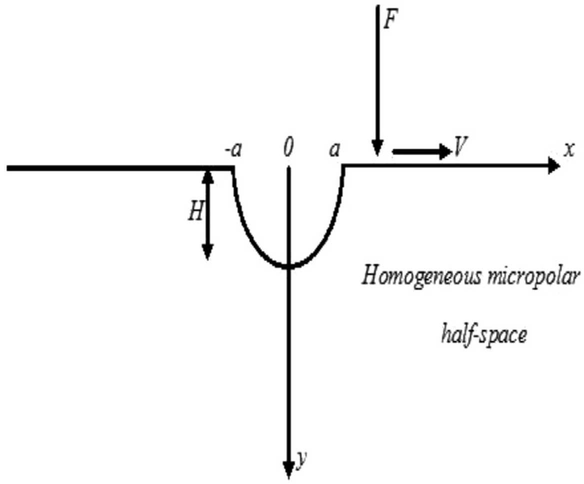

Fig. 1. Geometry of the problem.

the three-dimensional Cosserat type model and its suitability for describing complex media such as micro-inhomogeneous materials, polycrystalline and cellular solids, foams, lattices, masonries, particle assemblies, magnetic rheological fluids, and liquid crystals. Recently, Altenbach and Eremeyev [6] studied the strain rate tensors and constitutive equations for inelastic micropolar materials.

In the classical theory of elasticity, the steady state response of a moving load in an elastic half-space has been discussed several times. In particular, Sneddon [7] outlined the stress produced by a pulse of pressure moving along the surface of a semi-infinite solid. The steady state solution to the problem of a moving load over an elastic half space was provided by Cole and Huth [8]. Mukherjee [9] traced out the stresses that develop in a transversely isotropic elastic half-space due to a normal moving load over a rough surface. The problem of a uniformly moving load on a layered half-plane was discussed by Sackman [10]. Miles [11] determined the response of a layered half-space to a moving load. A moving load on a plate resting on an elastic half-space was studied by Achenbach et al. [12] while a moving load on a pre-stressed plate resting on a fluid half-space was analyzed by Chonan [13]. Ungar [14] detected the wave generated in an elastic half-space by a normal point load moving uniformly over the free surface. Later, Olsson [15] provided a note on the fundamental moving load problem. The dynamic response of a cracked beam subject to a moving load was examined by Lee and Ng [16], after which Alkeseyeva [17] emphasized the dynamics of an elastic half-space under the action of a moving load. Mukhopadhyay [18] delineated the stress produced by a normal moving load over a transversely isotropic layer of ice lying on a rigid foundation, whereas Selim [19] determined the static deformation of an irregular initially stressed medium. Chattopadhyay and Saha [20] described the dynamic response of a normal moving load in the plane of symmetry of a monoclinic half space. Later, Chattopadhyay et al. [21] determined the stresses produced on a rough irregular isotropic half-space due to a normal moving load. Recently, some notable studies have dealt with irregularity, including [22], Chattopadhyay and Singh [23], and Chattopadhyay et al. [24]. The steady response of a moving load in micropolar solid media was discussed by Ghosh [25]. In addition, Kumar and Gogna [26], and Kumar and Deswal [27] studied the steady state response to moving loads in the micropolar theory of elasticity. However, no previous attempt has been made to study the dynamic response of a moving load on a micropolar half-space with irregularity.

The study of a moving load with different irregularities is of great importance to seismologists and geophysicists for understanding and predicting the behavior of media at different margins of the earth, which motivated the present study. Thus, we consider the stresses produced in an irregular micropolar half-space due to a normal moving load on a free surface. For comparative purposes, we analyze the cases with rectangular and parabolic irregularity in a micropolar half-space without irregularity. We investigate the effects of depth, the irregularity factor, maximum irregularity depth, and the coupling factor on stresses, which we depict graphically.

2. Formulation of the problem

We consider a normal moving load F in a micropolar half-space with parabolic irregularity, which is independent of y and moving with a constant velocity V in the direction of the positive x-axis. The x-axis is chosen as the direction of the moving load and y-axis moves vertically downward. The origin is placed at the middle point of the span of the irregularity, as shown in Fig. 1.

The equation of the upper interface containing the irregularity is

$$y = \varepsilon h(x), \tag{1}$$