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Vibrations and elastic waves in chiral multi-structures

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Abstract

We develop a new asymptotic model of the dynamic interaction between an elastic structure and a system of gyroscopic spinners that make the overall multi-structure chiral. An important result is the derivation and analysis of effective chiral boundary conditions describing the interaction between an elastic beam and a gyroscopic spinner. These conditions are applied to the analysis of waves in systems of beams connected by gyroscopic spinners. A new asymptotic and physical interpretation of the notion of a Rayleigh gyrobeam is also presented. The theoretical findings are accompanied by illustrative numerical examples and simulations.

1 Introduction

Chirality, the property of an object whereby it is not congruent to its mirror image, occurs both through natural and man-made means in various areas of science. The useful and striking effects of chirality have received much attention in recent years, in particular in the development of optical metamaterials [1]. In mechanics, chirality may be introduced by gyroscopic spinners connected to a multi-structure, which may incorporate several elastic components. The present paper utilises an asymptotic analysis to develop a new type of chiral boundary conditions and a subsequent study of a class of spectral problems for chiral elastic multi-structures.

The concept of chiral flexural elements, known as *gyrobeams*, was introduced in [2]. These chiral elements can be used for controlling the attitude and shape of spacecraft during flight [3]. A gyrobeam can be interpreted as a beam with additional stored angular momentum whose effects are controlled by a spatial function governing the "*gyricity*" of the element. This function allows for the coupling of the principal transverse motions in the beam. Several illustrations of the effect of gyricity on the modes and stability of a beam have been presented in