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Decomposition of symmetric mass–spring vibrating systems using groups, graphs and linear algebra

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SUMMARY

The main objective of this article is to develop a methodology for an efficient calculation of the eigenvalues for symmetric mass–spring systems in order to reduce the size of the eigenproblem involved. This is achieved using group-theoretical method, whereby the model of a symmetric mass–spring system is decomposed into appropriate submodels. The eigenvalues of the entire system is then obtained by calculating the eigenvalues of its submodels. The results are compared to those of the existing methods based on graph theory and linear algebra. Examples are provided to illustrate the simplicity and efficiency of the present method. Copyright © 2006 John Wiley & Sons, Ltd.

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KEY WORDS: decomposition; symmetry; mass–spring system; eigenvalues; group theory; canonical forms; graphs; natural frequency

1. INTRODUCTION

Symmetry has been widely studied in science and engineering [1–5]. Large eigenvalue problems arise in many scientific and engineering problems [6–8]. While the basic mathematical ideas are independent of the size of matrices, the numerical determination of eigenvalues and eigenvectors requires additional considerations as the dimensions and the sparsity of matrices increase. Special methods are needed for efficient solution of such problems.

Methods are developed for decomposing the graph models of structures in order to calculate the eigenvalues of matrices with special patterns [9]. The eigenvectors corresponding to such patterns are studied in Reference [10]. The application of these methods is extended to the vibration of mass–spring systems [11], and free vibration of frames [12].

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