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PII: S0020-7403(15)00444-0
DOI: http://dx.doi.org/10.1016/j.ijmecsci.2015.12.017
Reference: MS3181

To appear in: *International Journal of Mechanical Sciences*

Received date: 16 June 2015
Revised date: 23 November 2015
Accepted date: 18 December 2015

Cite this article as: Korak Sarkar and Ranjan Ganguli, Benchmark analytica solutions from beams with shared eigenpair, *International Journal of Mechanica Sciences,* http://dx.doi.org/10.1016/j.ijmecsci.2015.12.017

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Benchmark analytical solutions from beams with shared eigenpair

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Abstract

Structures with governing equations having identical inertial terms but somewhat differing stiffness terms can be termed flexurally analogous. An example of such a structure includes an axially loaded non-uniform beam and an unloaded uniform beam, for which an exact solution exists. We find that there exist shared eigenpairs (frequency and mode shapes) for a particular mode between such structures. Non-uniform beams with uniform axial loads, gravity loaded beams and rotating beams are considered and shared eigenpairs with uniform beams are found. In general, the derived flexural stiffness functions (FSF's) for the non-uniform beams required for the existence of shared eigenpair have internal singularities, but some of the singularities can be removed by an appropriate selection of integration constants using the theory of limits. The derived functions yield an insight into the relationship between the axial load and flexural stiffness of axially loaded beam structures. The derived functions can serve as benchmark solutions for numerical methods.

Keywords: Rotating beams, shared eigenpair, gravity-loaded beams, free vibration, test functions

Accepted manuscript

1. List of notations

$EI_1(x)$	=	flexural stiffness variation for baseline non-uniform beam
$m(x) = m$	=	mass per unit length of both baseline and uniform beam
L	=	length of the beam
$w(x,t)$	=	transverse displacement due to bending
$T(x)$	=	axial load variation
EI_2	=	flexural stiffness of the uniform beam
ϕ_i	=	i^{th} mode shape of both baseline non-uniform beam and uniform beam
ω	=	i^{th} mode frequency of both baseline non-uniform beam and uniform beam

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