

The Properties of Vibrating Systems, Eigenvalues and Eigenvectors

1. Introduction

We have seen that the equations of motion for lumped parameter systems can be derived by use of free body diagrams (FBD) and Newton's second law of motion. We now look at alternative methods, for derivation of the equations of motion, which may be more convenient when dealing with systems with many degrees of freedom (MDOF).

The dynamic behavior of a structure or system may be modelled in terms of either its stiffness or its flexibility. Thus, the equations of motion may be formulated on the basis of either the stiffness matrix $[k]$ or the flexibility matrix $[d]$. In the stiffness formulation, forces are expressed in terms of displacements, as follows:

$$\{f\} = [k]\{x\} \quad (1)$$

Thus, for an undamped, unforced vibrating system, the differential equations of motion may be expressed as follows:

$$[m]\{\ddot{x}\} + [k]\{x\} = 0 \quad (2)$$

In particular, for an undamped, unforced two DOF vibrating system, the differential equations of motion may be expressed in full, in matrix notation, as follows:

$$\begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \quad (3)$$

On the other hand, in the flexibility formulation, displacements are expressed in terms of forces as follows:

$$\{x\} = [d]\{f\} \quad (4)$$

Thus, for an undamped, unforced vibrating system, the differential equations of motion may be expressed as follows:

$$[d][m]\{\ddot{x}\} + [I]\{x\} = 0 \quad (5)$$

With $[I]$ being the identity matrix, it should be evident from equations (2) and (5) that

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