SELECTED TOPICS

In Aerospace Engineering

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TABLE OF CONTENT

CHAPTER SIXTEEN

FORMULATION OF KERNEL FUNCTION FOR AERODYNAMIC LOADING ON AIR VEHICLE

CHAPTER SEVENTEEN

UNSTEADY AERODYNAMIC THEORY OF LIFTING SURFACE

CHAPTER EIGHTEEN

NUMERICAL EVALUATIONS OF HYPERGEOMETRIC CYLINDRICAL FUNCTIONS

CHAPTER TWENTY THREE

ALTERNATE APPROXIMATE FUNCTION FOR KERNEL FUNCTION OF PLANAR OSCILLATING LIFTING SURFACES

CHAPTER TWENTY FOUR

APPROXIMATE FUNCTION FOR NEAR-FIELD KERNEL FUNCTION OF NON-PLANAR LIFTING SURFACES

CHAPTER TWENTY FIVE

APPROXIMATE FUNCTION FOR FAR-FIELD KERNEL FUNCTION OF OSCILLATING NON-PLANAR LIFTING SURFACES

CHAPTER FOURTEEN

TORSIONAL STIFFNESS MATRIX OF NON-PRISMATIC BEAM ELEMENTS

14.1. Introduction

This chapter describes the procedure to develop the torsional stiffness matrix of beam element having arbitrary variation of torsional stiffness distribution along its span. To obtain analytical formulation, the stiffness matrix is constructed from the flexibility matrix. A Bernoulli-Euler differential equation that relates the torsional moment and twist deformation angle is derived first. The general rational function resulting from the integration of the Bernoulli-Euler is transform to asimpler rational function using the DMRF procedure given in Chapter 16.

14.2. Torsional - Twist Deformation Relation

Consider a tapered torsional bar element of length L made of an isotropic elastic material of shear modulus G as shown in Fig. 22.1. In the present section, we assume that the cross-section torsional rigidity $J = J(x)$ about the x axis varies as an arbitrary polynomial function in x as follow:

$$J(x) = J_c \prod_{j=1}^{N} (x - c_j)^{m_j} \tag{14.1}$$

Based on the sign convention of Fig. 22.1, one can write the nodal moment-displacement relation for the torsional deformation of the element in the form:

$$\begin{Bmatrix} N_1 \\ N_2 \end{Bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix} \tag{14.2}$$