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APPENDIX II

MULTICELL THEORY

STRUCTURAL MODELING FOR MULTICELL COMPOSITE ROTOR BLADES

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EXTENDED ABSTRACT

Introduction

Composite material systems are currently primary candidates for aerospace structures. One key reason for this is the design flexibility that they offer. It is possible to tailor the material and manufacturing approach to the application. Two notable examples are the wing of the Grumman/USAF/DARPA X-29 and rotor blades under development by the U.S.A. Aerostructures Directorate (AVSCOM), Langley Research Center.[1]

A working definition of elastic or structural tailoring is the use of structural concept, fiber orientation, ply stacking sequence and a blend of materials to achieve specific performance goals. In the design process, choices of materials and dimensions are made which produce specific response characteristics which permit the selected goals to be achieved. Common choices for tailoring goals are preventing instabilities or vibration resonances or enhancing damage tolerance.

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An essential, enabling factor in the design of tailored composite structures is structural modeling that accurately, but simply, characterizes response. Simplicity is needed as cause-effect relationships between configuration and response must be clearly understood and numerous design iterations are required. The objective of this paper is to present a new multicell beam model for composite rotor blades and to validate predictions based upon the new model by comparison with a finite element simulation in three benchmark static load cases.

Outline of the Present Work

The most significant difference between single cell and multicell thin-walled beams is in the analysis of torsion. The first step is to determine the shear center of the multicell section which is needed to establish the twisting kinematics. In the present approach, an innovative application of the unit load theorem is employed which utilizes the St. Venant torsion solution as a basis. This approach leads to closed form expressions for the coordinates of the shear center that are in terms of physically meaningful parameters.

Torsion-related warping, which earlier works[2,3,4] on single cell theory indicate is important, is determined in a manner similar to that of Benscoter.[5] In contrast to obtaining the stiffness matrix using the principle of virtual work[2], the unit load theorem is employed also to find the flexibility matrix, which is inverse of the stiffness matrix. Therefore, flexibilities are directly found, which is convenient for application.

After the above analytical steps are completed, the global beam theory is created in a manner similar to the single cell case.[2]

Application

The present model is applied to a two cell beam. The model cross section is shown in Figure 2. The benchmark static load cases appear in Figure 3. The first case is bending due to a tip load, the second is pure torque and the third is axial loading due to a centrifugal force.

The predictions are compared with an extensive finite element simulation[6] based upon orthotropic shell elements. They are found to be in very good agreement as can be seen in Figures 4, 5 and 6.

Concluding Remarks

A multicell beam theory is developed and validated. Predictions based upon the new model are compared with an extensive finite element simulation as the means of validation.

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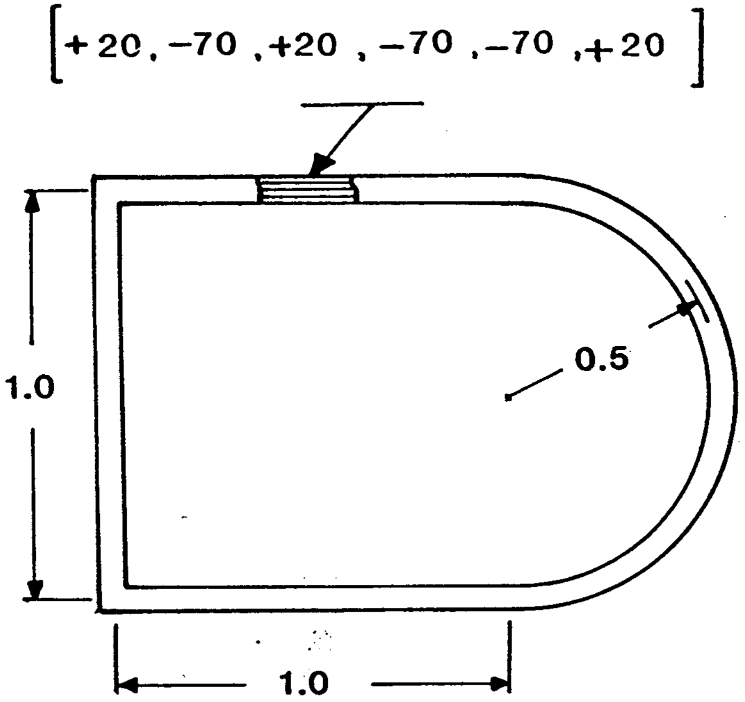


FIGURE 1. SINGLE CELL BEAM CROSS SECTION

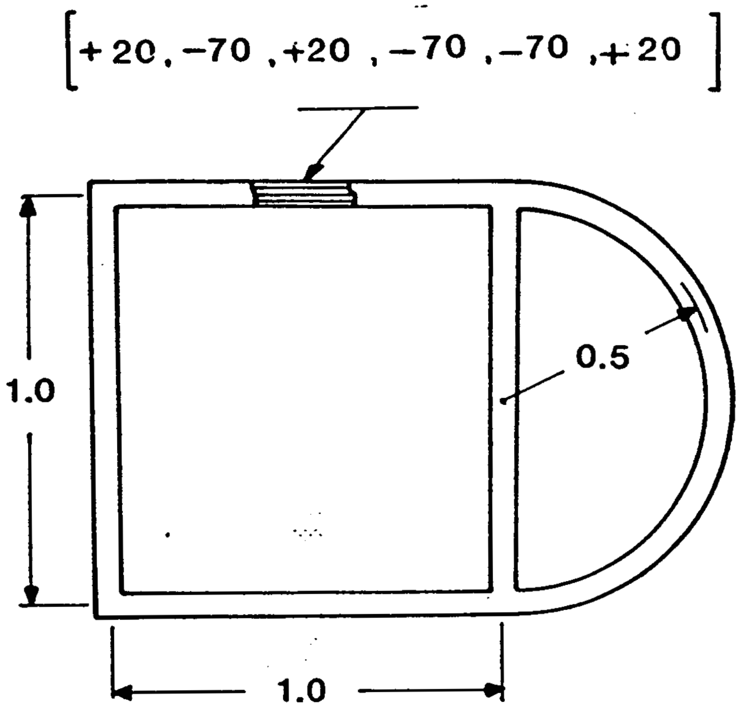
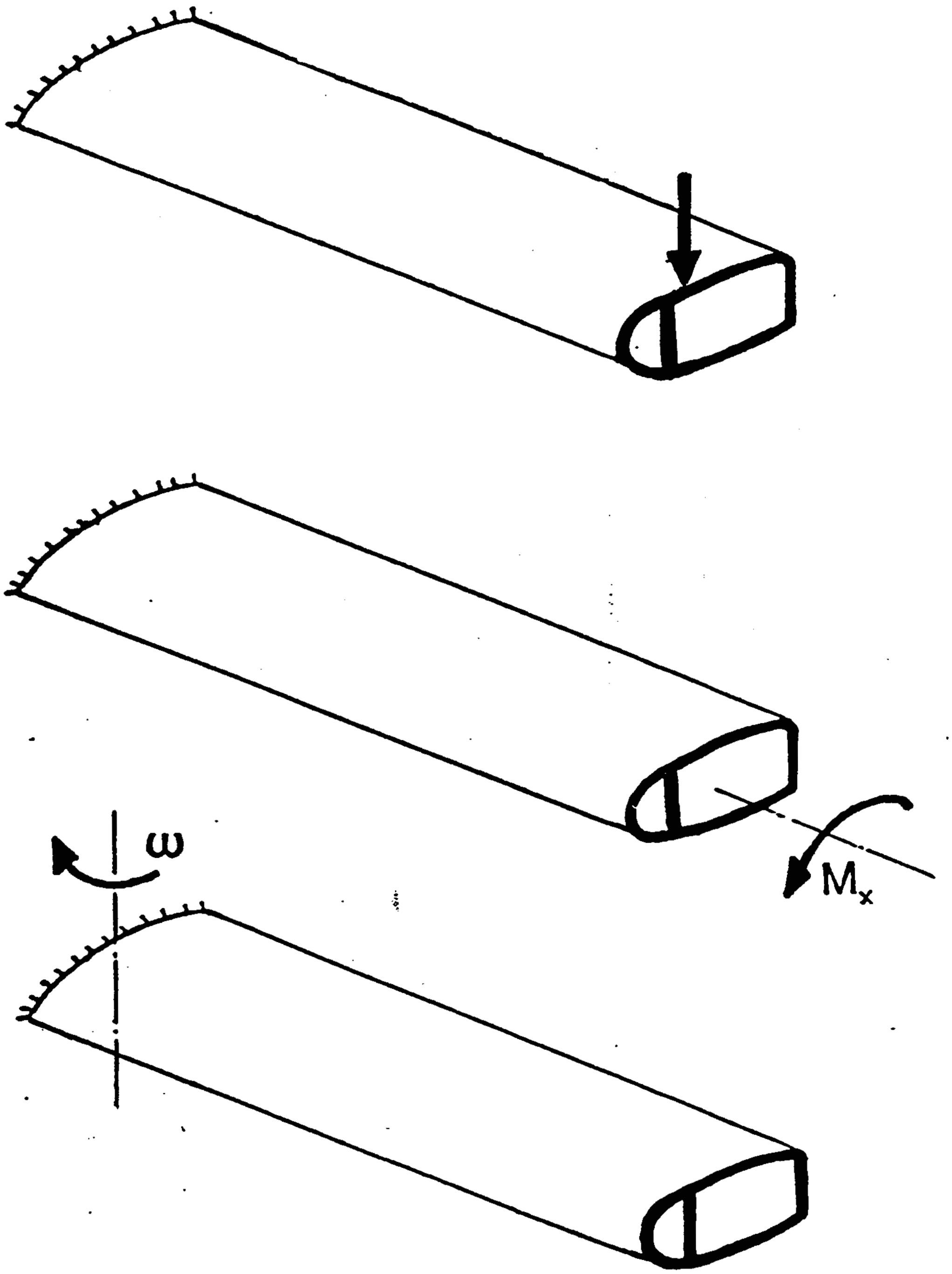


FIGURE 2. TWO CELL BEAM CROSS SECTION

FIGURE 3. GENERIC STATIC LOAD CASES



TIP LOAD

PURE TORSION

CENTRIFUGAL LOADING

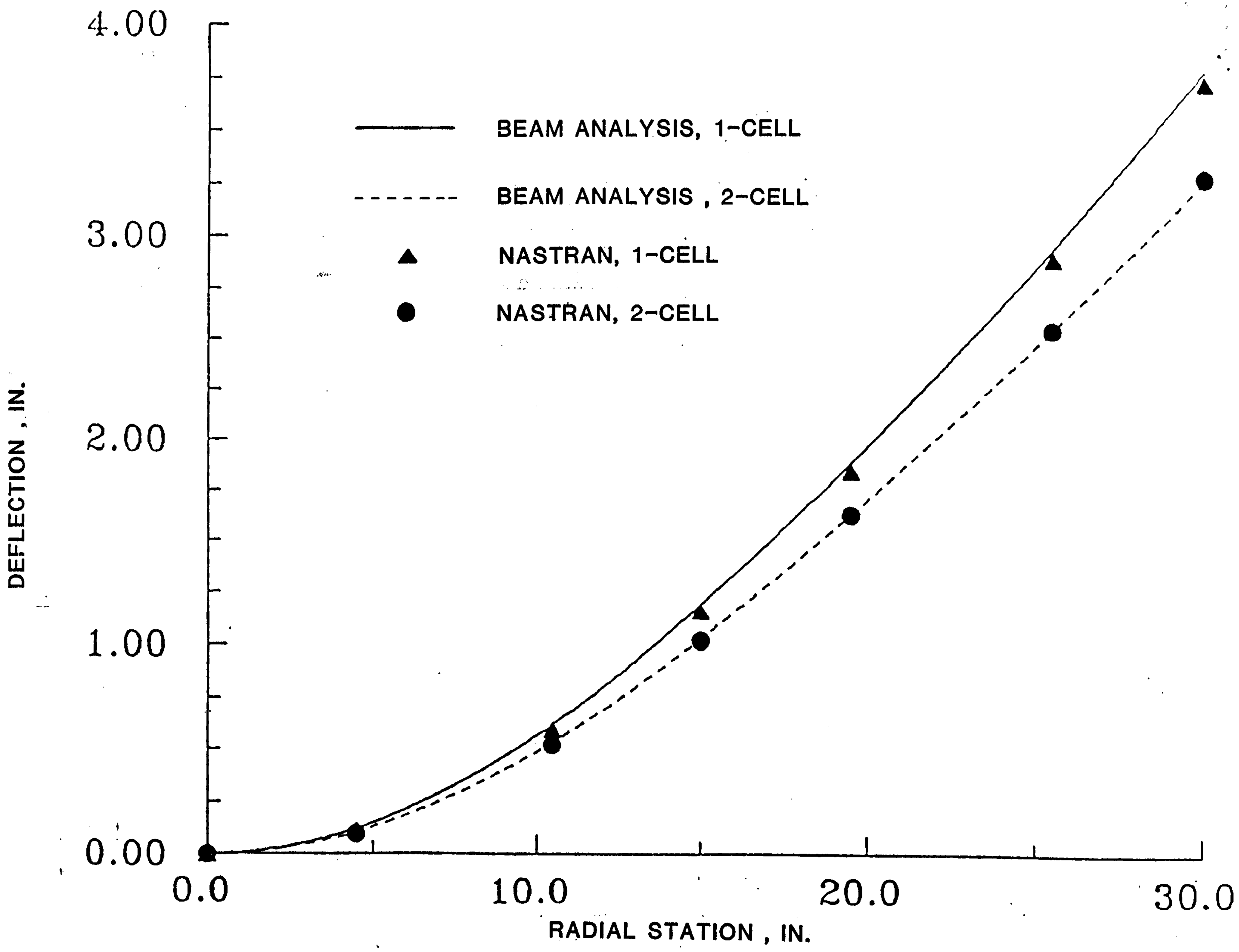


FIGURE 4. DEFLECTION DUE TO TIP LOAD

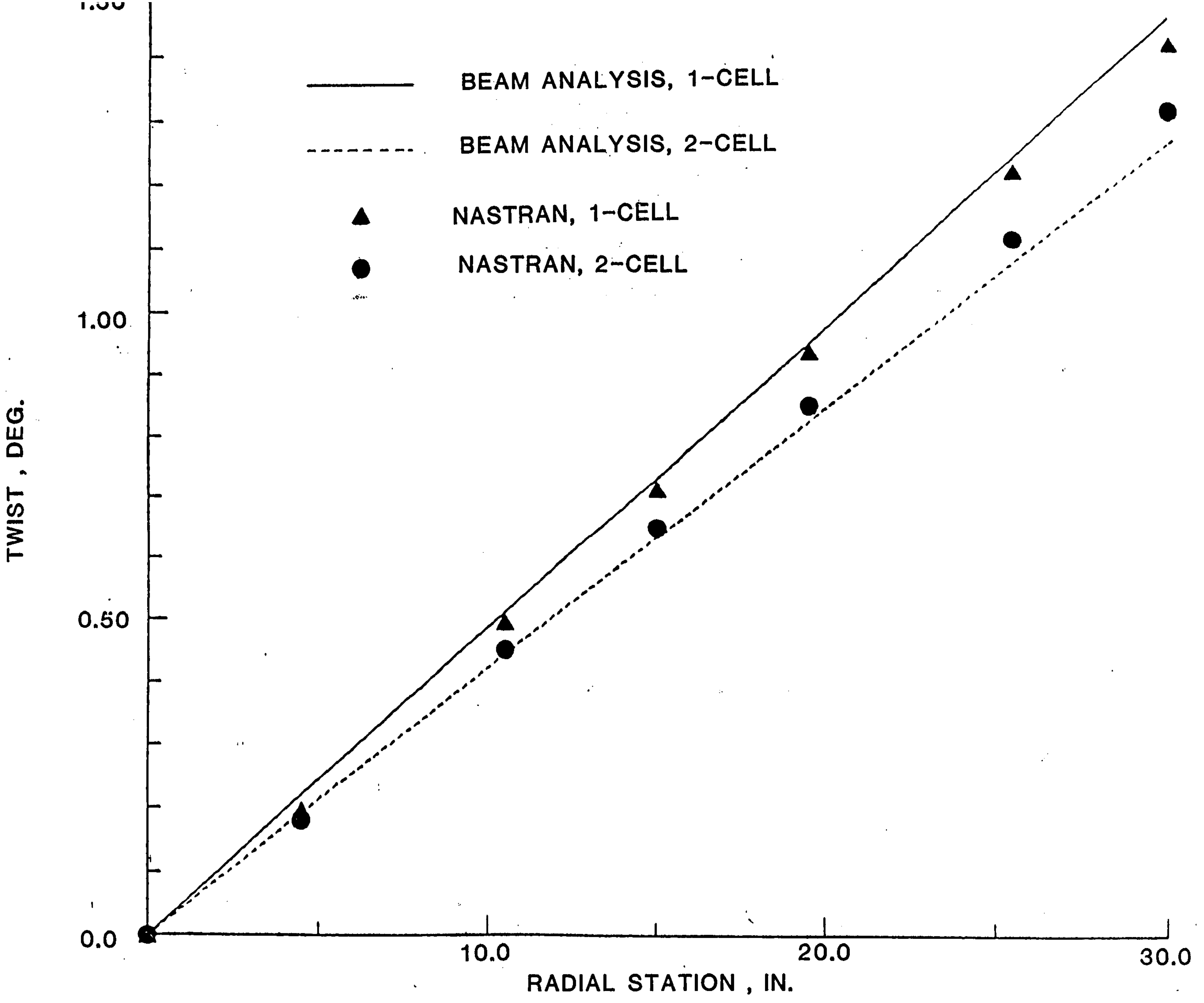


FIGURE 5. TWIST DUE TO PURE TORQUE

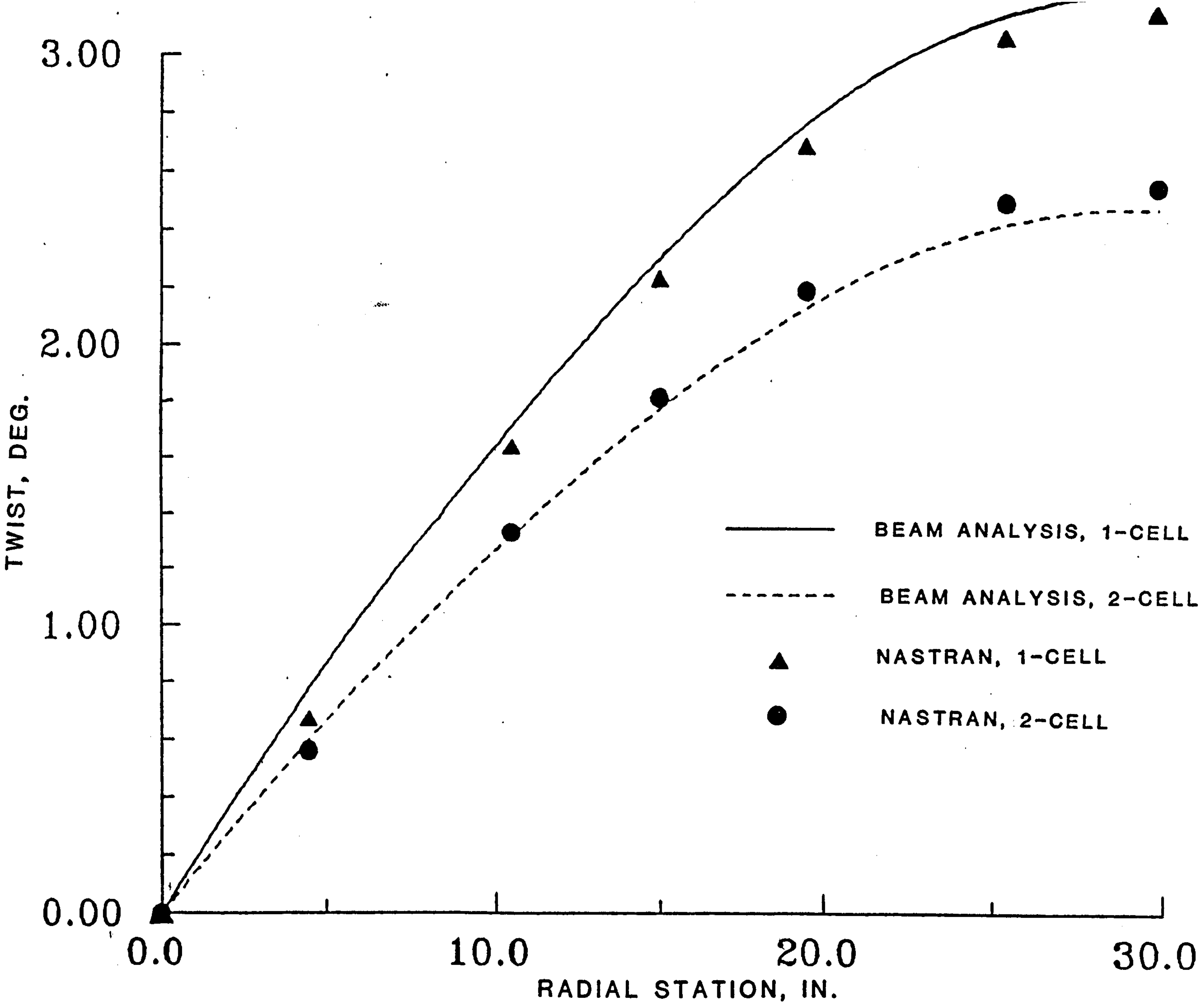


FIGURE 6. TWIST DUE TO CENTRIFUGAL FORCE