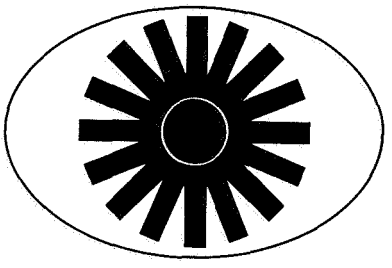
SPACE TECHNOLOGY REPORT 69-53

Yearly Report on Nonlinear Analysis of Shells of Revolution

NASA Grant NGL 44-001-044

By
James A. Stricklin
Principal Investigator



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Submitted to

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C.

January 25, 1969

Submitted by

SPACE TECHNOLOGY DIVISION

Texas Engineering Experimentation Station
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ABSTRACT

The accomplishments during the last year include a nonlinear stability analysis of the Apollo aft heat shield and a stress analysis of the Subsystems Test Bed. Three papers have been presented at national and regional conferences and three papers have been published in the AIAA Journal.

INTRODUCTION

Research Grant NGL 44-001-044 was initiated in January 1967 as a result of structural problems on the Apollo aft heat shield and has subsequently been used for the analysis of various structural problems that have arisen of the Manned Spacecraft Center. For example, recent accomplishments under this grant include the presentation of a short course at MSC on the finite element method of structural analysis and the stress analysis of the Subsystems Test Bed. Excellent correlation has been obtained between theoretical and experimental results. Additional background information has been presented in previous progress reports.

The Subsystems Test Bed can best be described as a can with 16 radial and numerous circumferential stiffeners. There are currently many design configurations under consideration for the STB. For example, one configuration consists of connecting as many as sixteen of the units into a series.

The STB is currently being tested experimentally at the Manned Spacecraft Center and has been analyzed by Texas A&M University. The results to date show excellent agreement between theory and experiment. Two copies of the analysis are enclosed and three other copies have been sent to Dr. Stebbins of MSC for internal use.

ACCOMPLISHMENTS

Analysis

Reference 1 presents the results of a stability analysis of the Apollo aft heat shield. The details of the method of analysis were given in a

paper (Ref. 2) presented at the 2nd Air Force Conference on Matrix Methods in Structural Analysis. Copies of Refs. 1 and 2 have been sent to NASA Headquarters.

Reference 3 presents the stresses and deflections of the Apollo aft heat shield under a large variety of static loadings and the preliminary results for the Subsystems Test Bed. A comparison of experimental and theoretical influence coefficients for the four vertical posts is given on page 152 of Ref. 3. Two copies of this reference are enclosed.

The stress and stability analyses of the aft heat shield were conducted under the assumption that transverse shear deformations are not important. A study of the influence of transverse shear deformations in the honeycomb core was conducted and the results are presented in Ref. 4. The results confirm the assumption that transverse shear deformations are not significant. Copies of this paper will be forwarded in the future.

The method and results for the nonlinear analysis of shells of revolution are present in Ref. 5. Numerous requests for the computer code have been received from firms in the United States and also from England and India. Reprints of this paper will be forwarded as soon as they are available.

Developmental

A large effort has been devoted to the development of a realistic triangular element for the analysis of plates and shells. Considerable progress has been made and the results have been published in Refs. 6, 7, and 8. Copies of References 6 and 8 are enclosed. The most significant result of this research effort is the development of a nine degree of freedom

triangular element which shows good convergence characteristics. It is believed that the element will be quickly accepted by the aerospace industry.

The computer code for the nonlinear dynamic analysis is operational and initial results have been submitted for publication in the AIAA Journal. These results pertain to the dynamic buckling of shallow shells under step pressure loading. This problem has been studied by other researchers but until now the various results did not agree. This paper is listed as Ref. 9 and copies are enclosed.

In summary, three papers have been presented at national or regional meetings and three papers have been published in the AIAA Journal.

PROPOSED RESEARCH

The research proposed for the coming year has been presented in the request for renewal. To review, the coming year shall be devoted to the nonlinear dynamic analysis, nonlinear thermal analysis, and the development of a curved triangular element.

After discussion with Dr. Stebbins of MSC it was decided that the applications shall be devoted to determining design curves for structures for future spacecraft. In addition, attention will be devoted to the development of new mathematical tools.

In summary the last year has been quite productive and several challenging problems have been outlined for the coming year.

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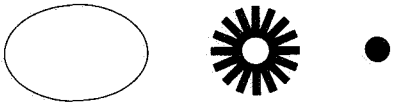

Space, energy, matter and man, symbolize the broad areas into which the diverse TEES divisions conduct research and development

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

—Alfred Nobel