Status Report No. 11

THE BUCKLING OF CYLINDRICAL SHELLS

NASA Grant NsG 18-59

May 1966

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Buckling of Conical Shells - Experimental Work

Work has been completed on the development of the plating of thin conical shells for buckling experiments. By the use of inclined anodes in the plating bath, satisfactory tolerances on the thickness distribution have been obtained.

Work is continuing on the development of a suitable method to measure initial imperfections and the subsequent deformation under loading of both cylindrical and conical shells. The measuring device will be a reluctance type pick up that is capable of measuring a deflection of 10^{-3} inches within $\pm$ 5 per cent. The pickup makes no contact with the shell and so is ideally suited for use with thin shells. A typical calibration curve for the pickup is shown in Figure 1.

Since there will be a vast amount of data generated during these experiments, an automatic data handling system is being developed. Both analogue (X-Y Plotter) and digital data (Punched Cards) will be obtained. The digital data will be reduced to deflections in inches using the calibration curve of the pickup. The eccentricity between the pickup traversing device and the center line of the shell will be subtracted out of the deflection measurements. In this manner the initial imperfections of the shell can be obtained. In addition, the deflection caused by loading can be obtained by subtracting out the initial imperfections.

The Influence of the Testing Machine Stiffness on the Buckling Load

The report on this project has been completed and is included under separate cover. An abbreviated version of this report will be presented at the Fifth U. S. National Congress of Applied Mechanics,

June 14-17, 1966. In addition, the complete report will be submitted for publication.

Stability of Cylindrical Shells under Moving Pressure Loads

This investigation is concerned with the dynamic stability of infinite length cylindrical shells subject to axisymmetric moving loads. An updated report of this work is included under separate cover.

Present interest in this problem is focused on the use of a Liapounov functional as a stability tool. Its use is expected to considerably reduce the amount of numerical work presently necessary to determine the stability boundaries.

Buckling of Cylindrical Shells with Random Imperfections

In this study the problem of a cylindrical shell under an axial compression load is investigated. The object of the study is to find the probabilities for reaching the state in which the rate of increase of longitudinal stress with respect to the average strain, or end shortening, vanishes. The random variables in this study are the initial imperfections and the axial load. The guiding equations of the problem are those used by Donnell and Wan (Ref. 1) which include the nonlinear terms and are based on small rotations.

The statistical study is based on a deterministic solution of the problem assuming that the imperfections are given and then searching for the axial load which is either an absolute maximum or a "relative" maximum with respect to the longitudinal average strain. The term "relative" as used here refers to the hypothetical cases where a maximum in the usual sense does not occur. Since a general deterministic

solution of this problem is not available, the main effort at the present time is directed to this part, having in mind a statistical application of the solution. For the deterministic approach it is assumed that the imperfections are expressed in the form of a discrete spectrum referred to a basic wave length. The discrete power spectral density of the imperfections is in the form of a symmetric set of Dirac delta functions which are multiplied by the power factors related to each mode. It is also assumed that the power factors for high modes are very small compared to those of low modes and may be neglected. The same assumptions will be made with respect to the solution function for the radial displacement, though it is true only for the linear case. The last assumption is based on the fact that, for low normal modes, the problem is practically linear.

Two approaches to the solution are being examined for the deterministic problem. The first is the conventional one based on double trigonometric series and the Galerkin procedure, or an energy method. This leads to a nonlinear system of algebraic equations which can be handled by means of approximate techniques. The second approach is based on improper integral representations of the solution which leads to improper nonlinear integral equations. The second approach has not yet been investigated thoroughly enough to verify its applicability.

The Dynamic Stability of Shallow Arches and Other Nonlinear Structures

Experiments have shown that the behavior of arches under static loads agrees very well with analytical results. In particular, the

buckling load can be predicted accurately using the infinitesimal disturbance criterion. However, very few dynamic loading experiments exist that are of sufficient quality to substantiate the dynamic buckling load predicted by analysis. In addition, the analyses that do exist are extremely complicated and specialized in nature.

The objects of this investigation are to develop techniques of dynamic loading that can be carefully controlled and apply this loading to a simple nonlinear structure. These experiments, correlated with analysis, will be used as a tool to substantiate dynamic buckling predictions by analysis. In addition, they will be used to investigate the applicability of simple estimates of the degree of stability of partially loaded nonlinear structures subjected to finite disturbances.

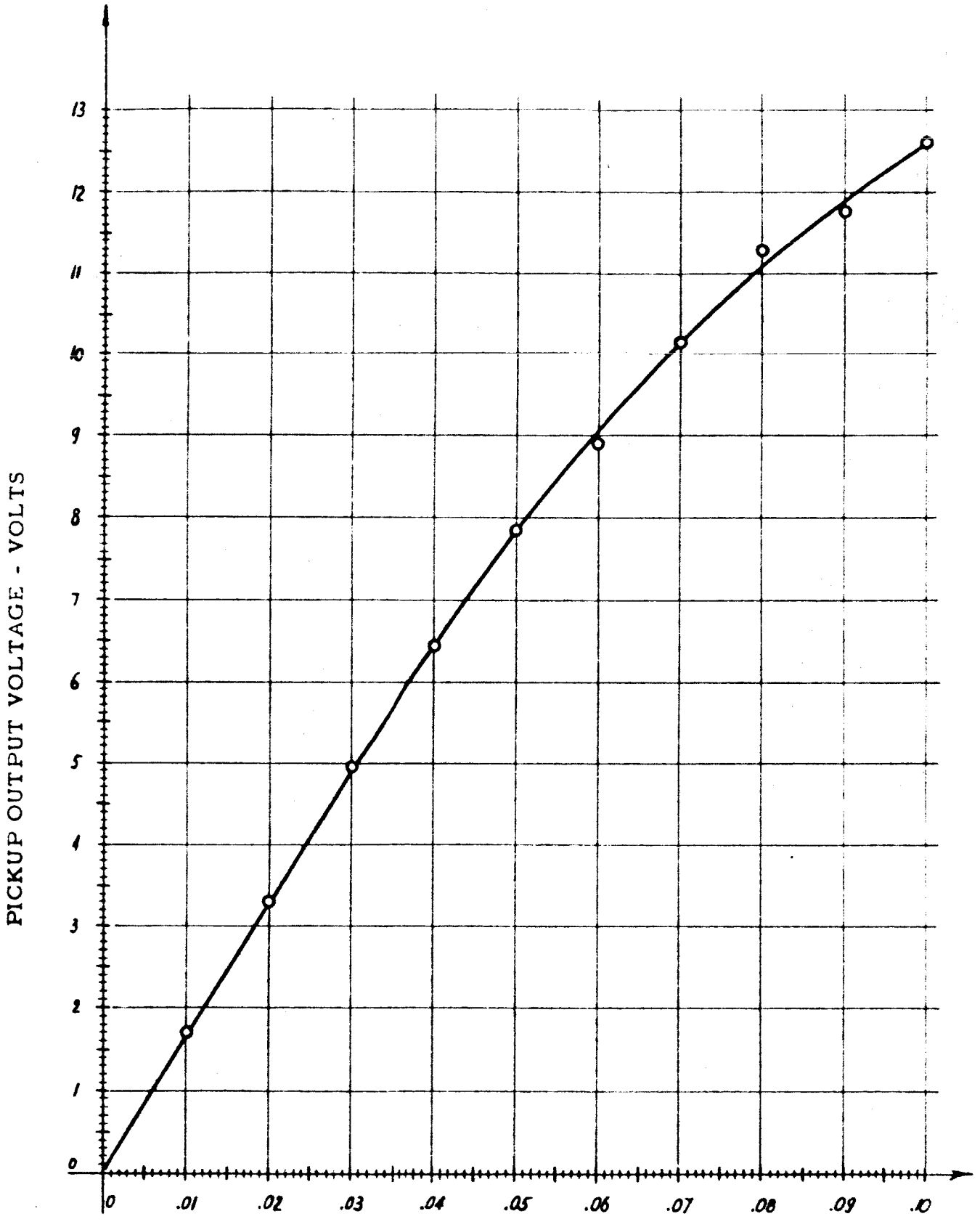
In order to apply an impulsive type of loading, a method of using a spray-on explosive material is being developed. The explosive used is Silver Acetylide-Silver Nitrate. A series of experiments is being carried out to investigate the impulse, detonation rate, and pressure-time history of this explosive.

Buckling of Cylindrical Shells with Initial Imperfections

Experimental work on the buckling of a cylindrical shell with an initial imperfection of a know shape is continuing. The effort is currently directed towards obtaining more experimental data and attempting to correlate existing experimental data with the presently available analysis.

Reference

1. Donnell, L. H and Wan, C. C.: "Effect of Imperfections on Buckling of Thin Cylinders and Columns under Axial Compression". J. Appl. Mech., Vol. 17, No. 1, p. 73, 1950.


PICKUP OUTPUT VOLTAGE - VOLTS
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DISPLACEMENT FROM SURFACE - INCHES

FIGURE 1