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ON THE FEASIBILITY OF A
TRANSIENT DYNAMIC DESIGN ANALYSIS METHOD

ANNUAL REPORT

May 1, 1991 - April 30, 1992

by

Patrick F. Cunniff
George J. O'Hara



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Department of

MECHANICAL ENGINEERING

of

THE UNIVERSITY OF MARYLAND

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EXECUTIVE SUMMARY

This Annual Report summarizes the progress that has been made during the first year of the two-year grant from the Office of Naval Research, grant number N00014-91-J-4059. Progress made on the three major components of the grant are reviewed and a projection is included on what remains to be done. This report is accompanied by the following three separate documents:

1. The paper "Time History Analysis of Systems as an Alternative to a DDAM-Type Analysis" which was presented at the 62nd Shock & Vibration Symposium in October, 1991 and is included in the Proceedings. This paper is also under review for publication in the Journal of Shock and Vibration.

2. A copy of the manuscript "Some Thoughts on Perccived DDAM Problems" which has been submitted to the Society of Naval Architects & Marine Engineers for presentation at the annual meeting of SNAME to be held in New York in November, 1992. The paper is currently under review.

3. The technical report "Scaling for Shock Response of Submarine Equipment".

INTRODUCTION

The dynamic behavior of structures subjected to mechanical shock loading provides a continuing problem for design engineers concerned with shipboard foundations supporting critical equipment. There are two particular problems associated with shock response that are currently under investigation. The first topic explores the possibilities of developing a transient design analysis method that does not degrade the current level of the Navy's shock-proofness requirements for heavy shipboard equipment. The second topic examines the prospects of developing scaling rules for the shock response of simple internal equipment of submarines subjected to various attack situations. This effort has been divided into two tasks: chemical explosive scaling for a given hull; and scaling of equipment response across different hull sizes.

The computer is used as a surrogate shock machine for these studies. Hence, the results of the research can provide trends, ideas, suggestions, and scaling rules to the Navy. In using these results, the shock-hardening program should use measured data rather than calculated data.

STATUS OF PROJECT

Three technical problems which relate to the shock response of shipboard structures that are under investigation are as follows:

- A study on the feasibility of a transient dynamic design

analysis method;

- An examination of chemical explosive scaling for shock response of submarine equipment;

- An investigation of scaling for the shock response of submarine equipment attached to different hull sizes.

The progress made on each problem is described herein along with separate documents that have been completed during the first year.

The progress made on the transient dynamic design analysis method includes a paper that was presented and published in the Proceedings of the Shock & Vibration Symposium in October, 1991. and a manuscript that has been submitted to the Society of Naval Architects & Marine Engineers for their annual meeting in November, 1992. The contents of each of these papers are described in the next section of this report. Work continues on developing a transient method for structures that are more complex than those treated to date.

The work on the chemical explosive scaling for shock response of submarine equipment has been completed. The results of this endeavor are contained in the enclosed technical report.

Work recently begun on the examination of scaling for equipment attached to different hull sizes. No specific results are available for publication at this time.

PART I - SHOCK AND VIBRATION SYMPOSIUM PAPER

Title: "Time History Analysis of Systems as an Alternative to a DDAM-Type Analysis"

Authors: G.J. O'Hara and P.F. Cunniff

Abstract: This paper reports on the degree of success that may be achieved by using simple equipment-vehicle models that produce time history responses which are equivalent to the responses that would be achieved using spectral design values employed by the Dynamic Design Analysis Method(DDAM). The equipment models are limited to one and two-degree of freedom systems; the vehicle to which the equipment is attached consists solely of a rigid mass; and the shock excitation is produced by an ideal impulse that is applied to the vehicle mass so as to produce an initial velocity. Although the case of the single-degree of freedom equipment presents no difficulties in performing a transient analysis that reproduces the DDAM-like response, it is shown that there are no unique values for the vehicle mass and for the magnitude of the impulse, but that they are interrelated. In the case of the two-degree of freedom equipment, the transient analysis duplicates the response that would be experienced using the DDAM-like input values, provided the shock design value in the first mode is less than the shock design value in the second mode. Otherwise, solutions are not possible. Brief comments are also provided for the special case of an equipment composed of a very light mass attached to a large mass, and for the case of an equipment with

repeated natural frequencies.

PART II - SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS PAPER

Title: "Some Thoughts on Perceived DDAM Problems"

Authors: P.F. Cunniff and G.J. O'Hara

Abstract: Commonly perceived problems associated with DDAM include the following: a transient dynamic analysis is both a unique and better solution; if a structure has repeated fixed base frequencies DDAM fails to account for them; if a structure has two fixed base modal frequencies very close to each other, the beating response is so long in time that the combinatorial rules for response are not realistic; and a very small appendage attached to a larger component can cause erroneous values in shock input. Basic concepts and terminology associated with normal mode analysis are presented to demonstrate their role in DDAM, along with a procedure for developing transient equipment-vehicle models for simple systems that produce time history responses that are different, and yet, equivalent to the damaging potential of a DDAM input. Having developed this background, the perceived problems with DDAM are examined by means of examples which should help to clarify these erroneous notions.

PART III - CHEMICAL EXPLOSIVE SCALING FOR SHOCK RESPONSE OF SUBMARINE EQUIPMENT

Previous analysis and studies at the University of Maryland and elsewhere have illustrated the difficulty in relating the equipment response at different charge weights for the same shock factor. Earlier work showed a promising scaling law that appears valid over a wide range of charge sizes for the same hull. This report examines how far this range may be extended for both lower charge weights and higher charge weights; compares linear and parabolic least square fits of the data which are in the form of equipment peak acceleration versus shock factor; introduces new scaling rules for equipment weight and equipment frequency for single-degree of freedom equipment; and points out the hazards of extrapolating shock design values over a wide range of shock factor using a limited range of response data.

PART IV - SCALING FOR SHOCK RESPONSE OF SUBMARINE EQUIPMENT ATTACHED TO DIFFERENT HULLS

The second phase of the scaling problem is an attempt to develop a scaling rule for equipment attached to different submarine hull sizes. If a scaling rule for hull size can be developed for equipment shock response, it may be possible, when coupled with the study on chemical charge size scaling, to predict the shock response across hull size, charge weight, equipment weight, and equipment frequency. This investigation is

being carried out using linear scaling between boats.

ACKNOWLEDGEMENTS

Robert Pohland and Robert Wagner, students in the Mechanical Engineering Department, are recognized for their contributions to the research program, especially the computer computations and graphics.