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(DURIP) RESEARCH INSTRUMENTATION  
for  
NONLINEAR MODAL ANALYSIS  
AFOSR - 89-0110

by

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(DURIP) RESEARCH INSTRUMENTATION  
For  
NONLINEAR MODAL ANALYSIS

Abstract

The project provided the necessary instrumentation for modal analysis of slender and flexible structures, which in turn resulted in the development of a structural laboratory in the Department of Mechanical Engineering, University of Puerto Rico. The University has provided matching funds, ME Department has provided laboratory space and the Hewlett Packard Corporation has donated extra equipment necessary to enhance research capability in the area of vibration and structural dynamics.

As the grant received included only funding for purchase of the equipment, other proposals are prepared by the faculty for funding of research on this and related subjects utilizing the acquired equipment. In addition, a number of research and thesis problems on the subject are defined and proposed to be investigated using the facilities acquired.

## GENERAL

First of all, this project provided the basic research instrumentation for the development of a Structural Dynamics Laboratory in the Department of Mechanical Engineering at the University of Puerto Rico, Mayaguez Campus. The equipment has upgraded the capability of the Department to initiate research programs in the following areas:

1. Modeling and Identification of nonlinear dynamics of structures.
2. Crack detection using energy dissipation characteristics and frequency response.

The equipment will be used in research performed by the faculty and graduate students of the Dynamics of Machinery, Structural Dynamics and Material Science disciplines. The equipment was purchased through the University Purchasing Office mainly from Bruel & Kjaer Instruments Inc. (B&K) and Hewlett Packard Corporation (HP) as has been pointed out in the proposal.

The Department of Mechanical Engineering has provided 900 sq. ft of useful laboratory floor space and 240 sq. ft. office space to structural dynamics laboratory.

## EXISTING FACILITIES PRIOR TO THIS PROJECT

Prior to the AFOSR instrumentation grant the Department did not have any research instrumentation in the area of vibrations and structural dynamics. Several undergraduate vibration apparatuses and analog computers were available for performing basic free and forced vibration experiments and simulate

vibration equations on the analog computer. Although at the graduate level and for faculty research in structural dynamics the Department did not have any formal set-up, the following resources have been available.

1. Computer Resources: The Mayaguez Campus of University of Puerto Rico is equipped with modern computer facilities consisting of VAX 8700 and IBM 4341. Furthermore, the Mechanical Engineering Department has approximately 20 IBM PC ATs along with several finite element computer programs which are interfaced with CAD programs and digitizer in order to facilitate the automatic generation of the input data.
2. Instron Testing Machine Model 1332 with servo-hydraulic controls.
3. Humphrey 3-axis motion sensing device model CF75-0101-1 consisting of a small 3-axis, solid state, angular rate transducer and three miniature flexure linear accelerometers
4. Valentine Research G-Analyst capable of measuring side and forward acceleration in a moving vehicle.
5. Accelerometers Kistler Model 8610 and 8628 with charge amplifiers.
6. Omnidata polyrecorder 516C-64-A for recording analog data in the field plus digital interface for down loading into PCS.
7. Rapid System Data Acquisition System R1000 for data acquisition and FFT analysis which can convert and IBM PC to a digital oscilloscope.

8. Four Computer Numerical Control Machines spectralIGHT II which are interfaced with four IBM PC XT's.
9. Two robotic manipulators ARMDRAULIC robots model EHA1052 interfaced with APPLE computer.

#### MAJOR OBJECTIVES OF INSTRUMENTATION REQUEST

The University of Puerto Rico-Mayaguez Campus which has been traditionally an undergraduate teaching institution strives toward the goal of competitive research and graduate programs. Along this line the Department of Mechanical Engineering in recent years has hired a number of faculty members with interest in broad field of structural dynamics. They are Dr. H. Davoodi, Dr. D. Serrano, Dr. N. Perez, Dr. A. Sabzevari and Dr. V. Sundararajan. Dr. Sundararajan who initiated the project was a visiting professor and in July 1989 he returned to Indian Institute of Technology.

The above-mentioned faculty members have strong interest in advancing the state of the art in modal analysis of certain type of structures such as large slender structures used in spacecrafts or light flexible robotic manipulators, as well as using vibration equipment in the study of crack detection. Consequently they and their graduate students will be the primary users of the experimental equipment. They will be using the modal test equipments along with the parameter identification software to develop models of complex structures they would investigate.

Purchased equipments for fulfilling these objectives have arrived during late spring and summer of 1989. They have been set up and tested. They are all in functional conditions, excepts the existing HP plotter. There is need for an interface card to be installed in order to plot results generated through VEC Modal Analysis Software. Necessary action is taken to obtain the interface card.

After preliminary testings of the equipment and familiarization with scope of the facilities a number of research problems are identified. These are presented as possible graduate students thesis problems as well as faculty research projects.

Objectives and constraints of each project is fully described. Some of the titles are as following:

1. Large Amplitude Vibration of Stender Structures
2. Elastic Vibration Coupled with Rigid Body Motion
3. Aeroelastic Vibration of Slender Structures
4. Study of the Response of Base Isolated Secondary Systems
5. Non-zero Mean Ito-based General Approximation Method for Random Vibration Analysis
6. Development of an Experimental/Analytical Approach for Crack Detection Using Energy Dissipation Characteristics & Frequency Response
7. Modal forms and frequencies of UPR-Solar Car Design

Research on some of these has already started. Research proposals are prepared to obtain necessary fundings for salaries and other expenses. In case of project numbers 6 above a prominent vibration professor at Worcester Polytechnic is also invited to cooperate in the research effort.

#### METHOD OF PURCHASES

The original proposal was for funding in the amount of \$90,492 plus \$8,000 as matching funds from the University of Puerto Rico. Air Force Office of Scientific Research granted \$49,837 for purchasing of the following items of permanent equipment:

Dual Channel Signal Analyzer

Accelerometer (2)

IEEE Card

Force Transducers (2)

Amplifiers (2)

Impact Hamer

Modal Software

Graphic Plotter

The funding reduction required a slight change in the planned effort. However with some extra help from the university and certain donations from Hewlett Packard Corporation in form of equipment the overall objectives of upgrading the university research instrumentation in order to improve the capability to perform model analysis research did not change.

As soon as the proposal was funded an extensive study of literature from different manufacturers was carried out and the major items for the project was ordered from Bruel & Kjaer, Hewlett Packard and Measurement Group, Inc. The orders for the equipment were sent as early as March 89 through the University Purchasing Office and by August 1989 they were received. These equipments were then set up and tested.

Dr. V. Sundararajan, principal investigator, attended a three day workshop during March 1st to 3rd 1989 conducted by the Bruel & Kjaer on "Modal Analysis Theory and Applications in Williamsburg, Virginia. In this hands-on workshop instructions were given on the theory and application of modal analysis, proper use of instrumentation and the correct procedure for obtaining good and reliable modal data. The travel funds were provided by the University.

For setting up the equipments, to implement the modal software and to give an on-site training on the use of the Dual channel spectrum analyzer on of the Bruel & Kjaer engineers visited the department. This two day hands-on workshop was attended by five faculty members who are interested to make use of the equipments in their research work. List of equipments acquired, set up and tested is given in the appendix.

#### CONCLUSIONS

An outstanding benefit of this project has been the development of a research laboratory in the area of vibrations and structural dynamics in the Department of Mechanical

Engineering, University of Puerto Rico. This laboratory has improved the capability of the Department to perform research. Based on the initial efforts in this project the university has provided extra assistance and the lab. has received donations in forms of research equipment.

A number of faculty members are preparing research proposals for funding who will utilize much of the equipment purchased on this AFOSR grant for pursuing their research effort on this and related subjects.

A number of thesis topics based on utilization of this AFOSR grant equipment is defined and proposed. This will definitely upgrade the ME graduate program in the area of vibrations.

APPENDIX A

STRUCTURAL DYNAMICS LABORATORY  
MECHANICAL ENGINEERING DEPARTMENT  
UNIVERSITY OF PUERTO RICO  
MAYAGUEZ CAMPUS

Equipments purchased from AFSUR Grant.

**1) ANALYZER**

a) DUAL CHANNEL SIGNAL ANALYZER  
model - 2034 Brtel&Kjær

**2) ACCELEROMETERS**

a) model - 4384 Brtel&Kjær  
with accessory box

b) model - 4370 Brtel&Kjær  
with accessory box

**3) IEC TO IEEE DIGITAL INTERFACE CABLE**

model - 600264 Brtel&Kjær

**4) FORCE TRANSDUCER**

model - 8200 Brtel&Kjær (quantity = 2)

**5) AMPLIFIERS**

a) POWER AMPLIFIER  
model - 2706 Brtel&Kjær

b) CHARGE AMPLIFIER  
model - 2635 Brtel&Kjær

**6) IMPACT HAMMER**

model - 8202 Brtel&Kjær

**7) VEC MODAL ANALYSIS SOFTWARE**

(Includes PC MAP, PC MOD and PC RAM)

**8) PLOTTER**

model - 7475A Hewlett Packard

APPENDIX B

**STRUCTURAL DYNAMICS LABORATORY**  
**MECHANICAL ENGINEERING DEPARTMENT**  
**UNIVERSITY OF PUERTO RICO**  
**MAYAGUEZ CAMPUS**

Equipments purchased from Matching rounds.

**1) AMPLIFIERS**

- a) DUAL MODE AMPLIFIER  
model - 5004                      kistler                      (quantity = 3)
- b) LINE DRIVE AMPLIFIER  
model - 2644                      Brdel&Kjær
- c) POWER SUPPLY AMPLIFIER  
model - 5507                      Techron

**2) ANALYZER**

- FREQUENCY ANALYZER  
model - 2107                      Brdel&Kjær

**3) COMPUTER**

- Compaq 286 computer w/  
Samsung VGA monitor and  
Microsoft bus mouse                      compaq

**4) AD/DA INTERFACE CARD**

- IBM-PC                                      Int. Microware                      (quantity = 2)
- APPLE II                                      (quantity = 2)

**5) DIGITAL MULTIMETERS**

- model - 23                                      Fluke                                      (quantity = 2)

**6) DIGITAL STORAGE ADAPTER**

- model - 2501                                      Dynascan corp                      (quantity = 2)

**7) DIGITAL STRAIN INDICATOR**

- a) power supply                                      model - 2110                      Measurements Group
- strain conditioner                                      model - 2120                      Measurements Group
- and amplifier
- digital readout w/  
peak/hold retention                                      model - 2120                      Measurements Group
- capability
- rack adaptor                                      model - 2150                      Measurements Group
- portable 10 channel                                      model - 2150                      Measurements Group
- enclosure
- 8 inter connecting cables for model                      Measurements Group
- 2130/2131
- b) model - PSD-702                                      BLH

**8) FORCE TRANSDUCER**

- model - 9712A50                                      Kistler

**9) FUNCTION GENERATOR**

- model - 3010                                      Dynascan Corporation

- 10) FURNITURE  
 a) electronic work benches (quantity = 6)  
 b) Storage cabinet (quantity = 2)  
 c) swirl chairs (quantity = 10)
- 11) GPIB-PCII PC INTERFACE & DOS HANDLER  
 model 1010sys
- 12) OSCILLOSCOPE  
 a) DUAL TRACE OSCILLOSCOPE  
 model - 1020 Leader  
 b) OSCILLOSCOPE  
 model - V-660 Hitachi
- 13) PRINTER EPSON  
 model LX-810
- 14) RECORDER  
 a) LEVEL RECORDER  
 model - 2505 Brøtel&Kjær  
 b) RECORDER(X-Y)  
 model - 2211-4-3 Omnigraphics (quantity = 2)
- 15) SHAKER  
 a) model - 4810 Brøtel&Kjær  
 b) model - 4809 Brøtel&Kjær (quantity = 2)  
 c) model - VG-100-8 Vibration Test Systems
- 16) STRAIN GAGES W/ ACCESSORY KIT  
 Measurements Group, BLH
- 17) STROBOSCOPE  
 model - 4912 Brøtel&Kjær
- 18) TRAVELLING MICROSCOPE  
 model - 72,469 Edmund Scientific

APPENDIX C

STRUCTURAL DYNAMICS LABORATORY  
MECHANICAL ENGINEERING DEPARTMENT  
UNIVERSITY OF PUERTO RICO  
MAYAGUEZ CAMPUS

Hewlett Packard donated equipments..

- 1) DUAL CHANNEL DYNAMIC SIGNAL ANALYZER  
model HP3562A
- 2) PULSE/FUNCTION GENERATOR  
model HP8111A