STRUCTURES RESEARCH

ANNUAL REPORT

Prepared for

NASA CENTER OF RESEARCH EXCELLENCE
SCHOOL OF ENGINEERING
NORTH CAROLINA A&T STATE UNIVERSITY

by

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A. AREA SUMMARY

The main objective of the structures group is to provide quality aerospace research within the Center for Aerospace Research- A NASA Center of Excellence at North Carolina Agricultural and Technical State University. The group includes dedicated faculty and students who have a proven record in the area of structures, in particular space structures. The four students who are currently in the program have distinguished themselves academically in addition to being leaders in various student organizations.

The participating faculty in the structures group have had several years of experience working with the Guidance and Control Division at NASA Langley Research Center. They developed accurate mathematical models and effective computational algorithms to characterize the flexibility parameters of joint dominated beam-truss structures. Both experimental and theoretical modelling has been applied to the dynamic mode shapes and mode frequencies for a large truss system.

During the past few months, the above procedure has been applied to the hypersonic transport plane model. The plane structure has been modeled as a lumped mass system by Doctor Abu-Saba while Doctor Shen applied the transfer matrix method with a piecewise continuous Timoshenko tapered beam model. Results from both procedures compare favorably with those obtained using the finite element method. These two methods are more compact and require less computer time than the finite element method. The group intends to perform experiments on structural systems including the hypersonic plane model to verify the results from the theoretical models.

Focus

Space technology has been going on a fast track. NASA has committed itself to remain globally competitive in this field. The NASA Center for Research Excellence at North Carolina A & T State University is aimed at providing NASA with the needed expertise to achieve its goal of staying ahead in space technology.

The goal of the structures group is to develop procedures that can accurately predict the dynamic behavior of a variety of structural systems which can be used as components of space as well as sub-orbital structures. The evaluation of the accuracy of the predictions will be verified by experimental methods.

Long Range Objectives

1. Establish the geometric parameters for an hypersonic plane that is capable of operating at mach four and higher.
2. Specify the size and material for the various components for the hypersonic plane.
3. Apply thermal forces and forces due to fluid dynamics to structural systems and verify their effects.

4. Establish an analytical model for the hypersonic plane and determine its dynamic characteristics.
5. Provide the dynamic characteristics to the guidance and control group.
6. Establish test procedures and perform tests to verify theoretical results.
7. Train graduate and undergraduate students to perform specific tasks in the development of the above.
8. Build up the structural laboratory to a level that enables the structures group to provide governmental and private clients with appropriate expertise in the area of aircraft structures.

B. AREA RESEARCH PROJECTS

Project No. 1:

Dynamic Analysis of the Joint dominated Beam, Elias G. Abu-Saba, $20,000, NASA, continuation of an on-going project. This project began in 1986 and will end on December 31, 1993.

Publications Resulting from this Project:

1. "Dynamics of the Joint Dominated Beam", Elias G. Abu-Saba, Archibald N. Sherbourne and Raymond C. Montgomery; Engineering, Construction and Operations in Space, ASCE Conference, Albuquerque, NM, August 29-31, P. 495-505.
2. "Design of the Scole Boom Based on the Dynamic Analysis of the Joint dominated Beam", Elias G. Abu-Saba, Raymond C. Montgomery and William M. McGinley, Conference sponsored by NASA Langley Flight Research Center and Flight Systems Research Laboratory of UCLA, Lake Arrohead, CA, October 31- November 1,1988
3. "Mini-Mast Dynamic analysis Using the Truss-Beam Model", Elias G. Abu-Saba, William M. McGinley and Raymond C. Montgomery, Third Annual Conference on Aerospace computational control", Oxnard, CA., August 28-30, 1989
4. "Simplified Truss-Beam and Space Technology", Elias G. Abu-Saba, William M. McGinley and Raymond c. Montgomery, Workshop on Computational Techniques in Identification and Control of Flexible Flight Structures, Lake Arrowhead, CA., November 1-2, 1989
5. "The Truss-Beam and Space Technology", Elias G. Abu-Saba, William M. McGinley and Raymond C. Montgomery, Engineering, construction and Operation in Space, Space II., ASCE Conference, Albuquerque, NM., April 22-26, 1990, Vol2, P. 1112-1121.
6. "Dynamic analysis of the Truss-Beam System", Abu-Saba, McGinley and Montgomery, Journal of Aerospace Engineering, ASCE, New York, VOL. 4 NO. 4 October, 1991, P. 347- 354

Project No. 2

Distributed Parameter Modeling of Large Flexible Space Structures, Shen, J. Y., NAG - 1 - 1436 , 1-1- 1992 to 12-31- 1994, $380,000.

Publications Resulting from this Project:

1. "Likelihood Estimation for Distributed Parameter Models of Large Beam-Like Structures", J.Y.Shen, J.K. Huang and L.W. Taylor, Jr. Journal of sound and Vibration (1992), 155(3), pp. 467-480.
2. "Damping Models for Distributed Parameter Estimation of Large Beam-Like Structures", J.Y. Shen, J.K. Huang and L.W. Taylor, Jr, Pacific- Rim International conference on Modelling, Simulation and Identification, Vancouver, Canada, August 4-6, 1992.
3. "Application fo Transfer Matrix Method to Estimate the Model Characteristics of the NASA Mini-Mast Truss", NASA Workshop on Distributed Parameter Modelling and Control of Flexible Aerospace Systems, Williamsburg, VA., June 8-10, 1992.

C. AREA PROGRAM ACTIVITIES

The structures group began its activity in the Center on May 16, 1992. Dr. Abu-Saba put only five weeks during the summer of 1992 while Dr. McGinley worked for two months. Four undergraduate students were employed by the structures group only for the summer. Another set of undergraduate students were employed effective August 15, 1992.

Faculty:

Name:	Elias G. Abu-Saba
Classification:	Coordinator
Citizenship:	US
Research Activity:	Provides analytical support to the structural group such as mathematical modeling for the hypersonic plane
Telephone:	(919) 334-7575 Room 455, McNair Hall North Carolina A & T State University Greensboro, NC 27411

Name:	William M. McGinley
Classification:	Co-coordinator
Citizenship:	Canadian (Permanent Resident)
Research Activity:	Provides experimental support and consults on finite element modelling of structures
Telephone:	(919) 334-7575 Room 454, McNair Hall North Carolina A & T State University

Greensboro, NC 27411

Name:	**Ji-Yao shen**
Classification:	**Associate Researcher**
Citizenship:	**China (Labor Permit, Applying for Permanent Residency)**
Research Activity:	**Uses transform functions as an application to hypersonic plane to determine the eigen values and the mode shapes of the mathematical model.**
Telephone:	**(919) 334-7575**
	Room 456, McNair Hall
	North Carolina A & T State University
	Greensboro, NC 27411

Students:

Name:	**James Cox, II**
Citizenship:	**US**
GPA:	**3.597**
Research Advisor:	**Abu-Saba**

Name:	**Raymond Dobbins**
Citizenship:	**US**
GPA:	**3.110**
Research Advisor:	**Abu-Saba**

Name:	**Eddie Fitts**
Citizenship:	**US**
GPA:	**3.426**
Research Advisor:	**Abu-Saba**

Name:	**Jerome Redmond**
Citizenship:	**US**
GPA:	**3.520**
Research Advisor:	**Abu-Saba**

The four students listed above are being trained in aerospace structures research. They began participation in the center activities in August, 1992 and have been assigned a number of specific tasks to accomplish. These tasks include the determination of the weight of the hypersonic transport plane, its surface area, its overall density, its moment of inertia, and the masses for the mathematical model. The Structures group coordinator has been holding weekly seminars with the students and the co-investigators to discuss the approach and the development of the mathematical model. Dr. Abu-Saba is the academic advisor to these students.

D. FACULTY AND STUDENTS PARTICIPATION

Dr. Abu-Saba provided the theoretical background for the lump mass modelling for dynamic analysis of the truss-beam. The truss-beam system is widely used in the construction of space structures and aircraft frames. Theoretical understanding of this system is basic to any effort in the area of structural design of aircraft, space vehicles and space structures. In addition to this contribution, Dr. Abu-Saba provided the management requirements for the structural group.

Dr. McGinley has been responsible for the experimental component of the structures group effort. He has devised the testing procedure, outlined the testing requirement and acquired the necessary equipments to perform the testing of the truss-beam specimen. He was also responsible for training and supervising the students in experimental procedures. Dr. McGinley has also provided assistance in the finite element modelling.

Several tasks have been conducted by the structures group. These tasks have been primarily performed by the four students listed in the budget report above under the supervision of Dr. McGinley. The various tasks that have been performed are:

1. Each student was required to read the project proposal and familiarize themselves with the ultimate goals of the project.
2. The students were involved in general lab familiarization tasks which included small demonstration tests, lab facility and equipment maintenance.
3. Strain gauging of the truss-beam specimens was completed and the resistance of each gauge was verified and recorded. This had to be replaced a number of times due student inexperience.
4. The support apparatus for the vertical test configuration was fabricated.
5. The static load application apparatus for the vertical configuration was fabricated.
6. The air pad supports are being modified to attempt to reduce some of the apparent flutter.
7. The air compressor was torn down and inspected. The air compressor pump was malfunctioning and was replaced.
8. The computer analysis program was being modified to incorporate a more efficient numerical solver and to allow easier modification of the program for the future analysis of more complex systems.
9. The acquisition and experimental analysis program is under development.

Short term goals of the group's effort are outlined below.

1. Evaluate the accuracy of the plane truss-beam model.
2. Modify the plane truss-beam model to improve the accuracy of prediction.
3. To expand the analytical model to three dimensions.
4. Modify the computer program to incorporate the expanded model.
5. Provide the guidance and control group with a rough analytical model for the hypersonic plane including the stiffness and mass matrices.
6. Write two articles and submit them for publication and present one conference

technical report on the testing procedure for the truss-beam.

Work Schedule:

Abu-Saba

1. May 16, 1992 - June 6,1992
   Provided analytical model to McGinley for use in experimental procedure and assisted McGinley and the students in understanding the theoretical basis for the model.

2. July 20, 1992 - August 13, 1992
   Review activities of McGinley and students and investigate transfer of information learned previously into aircraft frame application.

3. August 24, 1992- December 18, 1992
   a. Evaluate the accuracy of the plane truss-beam model.
   b. Modify the plane truss-beam model to improve the accuracy of prediction.
   c. To expand the analytical model to include three dimensions.
   d. Modify the computer program to incorporate the expanded model.
   e. Develop equations of motion for a rough analytical model of the hypersonic plane.

McGinley

1. May 16, 1992 - June 16, 1992
   Introduced students to the project, familiarized the students with the lab facilities and supervised the strain gauging of the truss beam specimen.

2. July 15, 1992 - August 13, 1992
   Reviewed with students computer program for predicting dynamic behavior of the truss-beam, modified existing program. Completed the gauging and calibrated these strain gauges.

3. August 24, 1992- December 18, 1992
   a. Replace malfunctioning compressor pump.
   b. Perform static testing on truss-beam
   c. Perform dynamic testing on truss-beam.
   d. Assist Dr. Shen and Dr. Abu-Saba in finite element modelling of the hypersonic transport plane.

Shen

1. August 24, 1992- December 18, 1992
   Assist Dr. Abu-Saba in the development of the theoretical model for the hypersonic plane and prepare computer packages for the solution of the equations

of motion.

Students

1. May 23, 1992- June 19, 1992
   a. Became familiar with the goals of the project.
   b. Became familiar with the lab facilities
   c. Performed some checks on the equipment in readiness to perform test on the specimens.

2. June 20, 1992-July 17, 1992
   a. Continued strain gauging of specimen.
   b. Modified existing computer program.
   c. General lab familiarization and training in testing through demonstration.

3. August 24, 1992- December 18, 1992
   Students will assist both faculty members in completing the tasks listed for the appropriate period.

Publications

1. "Piecwise Continuous Timoshenko Beam Model for the Dynamic Analysis of Tapered Beam-Like Structures", J. Y. Shen, E. G. Abu-Saba, W. M. McGinley, L. Sharpe and L. W. Taylor, Jr., Submitted to the 1st SES-ASME-ASCE Joint Meeting, University of Virginia, Charlottesville, Virginia, June 6-9, 1993.
2. Lumped Mass Modelling for the Dynamic Analysis of Aircraft Structures", E. G. Abu-Saba, J. Y. Shen and W. M. McGinley, Submitted to the 1st SES-ASME-ASCE Joint Meeting, University of Virginia, Charlottesville, Virginia, June 6-9, 1993.
3. "Likelihood Estimation for distributed Parameter Models of Large Beam-Like Structures", J. Y Shen, J. K. Huang and L. W. Taylor, Jr. Journal of sound and Vibration (1992), 155(3), pp. 467-480.
4. "Damping Models for Distributed Parameter Estimation of Large Beam-Like Structures", J. Y. Shen, J. K. Huang and L. W. Taylor, Jr, Pacific- Rim International conference on Modelling, Simulation and Identification, Vancouver, Canada, August 4-6, 1992.
5. "Application of Transfer Matrix Method to Estimate the Model Characteristics of the NASA Mini-Mast Truss", NASA Workshop on Distributed Parameter Modelling and Control of Flexible Aerospace Systems, Williamsburg, VA., June 8-10, 1992.

E. AREA FINANCIAL REPORT

Line Items	Allotment	Expenditure
Faculty Salary Fringe (24%) and Indirect Cost (55%)	$70,000	$59,290
Student Salary Student Stipend Indirect Cost (55%)	$26,500	$19,522
Travel	$ 4,000	$ 3,435
Scientific Equipment	$20,000	$19,405
Direct Cost Office Supplies Subscriptions Books/Journals	$ 4,500	$ 4,500
TOTAL	$125,000	$106,152

Equipment Purchased

1. **Vendor:** Measurement Group — **Cost: $447.48**
   Items : Bridge Completion Modules and wire
   Purpose: To expand the strain gauge monitoring capacity of the Structures Lab so that the gauges connected to the truss specimens can be individually monitored.

2. **Vendor:** Newark Electronics — **Cost: $299.05**
   Items : Pots, etc. for strain gauge monitor circuits
   Purpose: To expand the strain gauge monitoring capacity of the Structures Lab so that the gauges connected to the truss specimens can be individually monitored.

3. **Vendor:** National Instruments — **Cost: $3,199.72**
   Items : Signal Conditioning Modules and Circuits
   Purpose: To expand the strain gauge monitoring capacity of the Structures Lab so that the gauges connected to the truss specimens can be individually monitored. This expansion will also allow for future more complex testing to be performed.

4. **Vendor:** Southern Calibration and Service — **Cost: $708.10**
   Items : Repair and Calibration of Material Tester
   Purpose: The tension actuators on the Forney Material Tester are broken and need repair before they may be used for testing the joint specimens for the Truss Beam model evaluation.

5. **Vendor:** W. W. Grainger **Cost: $1,419.92**
Items : Air compressor Pump and Welder Accessories.
Purpose: The air compressor pump is malfunctioning and must be replaced so that the air pad supports can be used for the testing of Truss Beam specimens. The welding accessories are required for fabrication of the various apparatus.

6. **Vendor:** Ensco **Cost: $1,741.00**
Items : Electric hydraulic pump and accessories
Purpose: To expand the loading capability of the Structures Lab to facilitate future testing of structural frame systems.

7. **Vendor:** Strain SERT **Cost: $1,590.00**
Items : Load cell
Purpose: To expand the load monitoring capability of the Structures Lab to facilitate future testing of structural frame systems.

8. **Vendor:** National Instruments **Cost: $6,500**
Items : Signal Conditioning Modules and Circuits, Upgrade on A/D Board
Purpose: To expand the monitoring capacity of the Structures Lab so that the sensors connected to the truss specimens can be individually monitored. This expansion will also allow for future more complex testing to be performed.

9. **Vendor:** Schaevitz Engineering **Cost: $100,000.00**
Items : Velocity, large displacement and acceleration sensors
Purpose: To expand the sensor capabilities of the structures lab to allow more complex monitoring of scale models of the HST structural systems

10. **Vendor:** Bibey Machine **Cost: $8,000**
Items : HST Model for dynamic characteristic testing
Purpose: This will be for the fabrication of the model of the HST structural system that will be tested to confirm and evaluate both the structural analytical models and, ultimately some of the control strategies

11. **Vendor:** Strain SERT **Cost: $4,0000**
Items : Load cells
Purpose: To expand the low load monitoring capability of the Structures Lab to facilitate future testing of structural frame systems.