(NASA-CR-164970) ON THE SHAPE AND ORIENTATION CONTROL OF AN ORBITING SHALLOW SPHERICAL SHELL STRUCTURE (Howard Univ.) 7 p HC A02/MF A01 CSCL 22B
N82-11100
Unclas
G3/14 08355

On the Shape and Orientation Control of an Orbiting Shallow Spherical Shell Structure

by

Peter M. Bainum
Professor of Aerospace Engineering
Department of Mechanical Engineering
Howard University
Washington, D.C. 20059, USA

and

A.S.S.R. Reddy
Graduate Research Assistant
Department of Mechanical Engineering
Howard University
Washington, D.C. 20059, USA

Offered for Presentation at the
Joint IFAC/ESA Symposium
on
Automatic Control in Space
Noordwijkerhout, The Netherlands
July 5-9, ~~1982~~ 1981

On the Shape and Orientation Control of an Orbiting Shallow Spherical Shell Structure*

by

Peter M. Bainum** and A.S.S.R. Reddy[†]

Future proposed space missions would involve large inherently flexible systems for use in communications, radiometry, and in electronic orbital based mail systems. The use of very large shallow dish type structures to be employed as receivers/reflectors for these missions has been suggested. In order to satisfy mission requirements control of the shape as well as the over-all orientation will be often required. The proposed paper is devoted to a study of the shape and orientation control of such an orbiting shallow spherical shell structure and, to the authors' knowledge, represents the first such treatment of this subject.

A related recent paper[1] treated the dynamics and stability of a flexible spherical shell in orbit in the absence of active shape and orientation control. For small amplitude elastic displacements and rigid rotational modal amplitudes, it was seen that the roll-yaw (out-of-plane) motions completely separate from the pitch (in-plane) and elastic motions.

---

*Research supported by NASA Grant NSG-1414, Suppl. 3.
**Professor of Aerospace Engineering, Howard Univ., Assoc. Fellow AIAA. Fellow AAS, Fellow BIS.
[†] Graduate Research Assistant; Member AIAA; AAS.

Furthermore, the pitch and only the axi-symmetric elastic modes are coupled within the linear range (Fig. 1). With the symmetry axis nominally following the local vertical, the structure is gravitationally unstable due to an unfavorable moment of inertia distribution. A rigid light weight dumbbell with heavy tip masses and connected to the shell at its apex by a spring loaded double gimballed joint with damping was proposed to gravitationally stabilize the structure. It was noted that the dumbbell motion could excite only those elastic modes having a single nodal diameter[2] and that to completely damp the system transient motion in all of the important lower frequency modes, the use of an active control system would be required.[1]

The proposed paper represents an extension of Ref. 1 to include in the mathematical model of the dynamics the effects of point actuators located at pre-selected positions on the shell surface (Fig. 2). The formulation of the uncontrolled dynamics assumes an a priori knowledge of the frequencies of all the elastic modes to be incorporated within the system model. For a typical large flexible shell made of aluminum with a base radius of 50m., radius of curvature of 1250.5m. and distance from the center of mass to the apex of 1m., it is seen that the frequencies of the fundamental elastic mode and its basic harmonics are grouped very close together (within one percent) and contrasts distinctly from the modal frequency distribution of a circular thin flat plate with mass equivalent to that of the shell and an identical (base) radius. This close grouping of the frequencies, due the shell curvature, emphasizes the importance of a close consideration of modelling uncertainties and such effects on the control system design -i.e. resonance, observation spillover, etc.

Control laws are designed based on pole clustering[3] and linear quadratic Gaussian techniques.[3] The elements in the control influence matrices are based on the modal shape functions which are evaluated here based on semi-analytic techniques.[2] As an example, three rigid body modes and six elastic modes (both axi-symmetric and non axi-symmetric) are included in the model and six actuators are assumed, none of which lie on a nodal line or circle (Fig. 3). For a least damped modal time constant of 461 sec. it is seen that the maximum torque levels of the order of 1000nt. are required in the absence of the passive dumbbell. Other numerical results and comparisons will be presented and discussed in the complete paper and indicate the improvement in force levels at the expense of the additional mass of the stabilizing dumbbell.

References

1. Kumar, V.K. and Bainum, P.M., "On the Motion of a Flexible Shallow Spherical Shell in Orbit," AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, Paper No. 81-0170.

2. Reissner, E., "On Transverse Vibrations of Thin, Shallow Elastic Shells," Quart. Appl. Math., Vol. 13, No. 2, July 1955, pp. 169-176.

3. Armstrong, Ernest S., "ORACLS - A System for Linear - Quadratic - Gaussian Control Law Design," NASA Technical Paper 1106, April 1978.

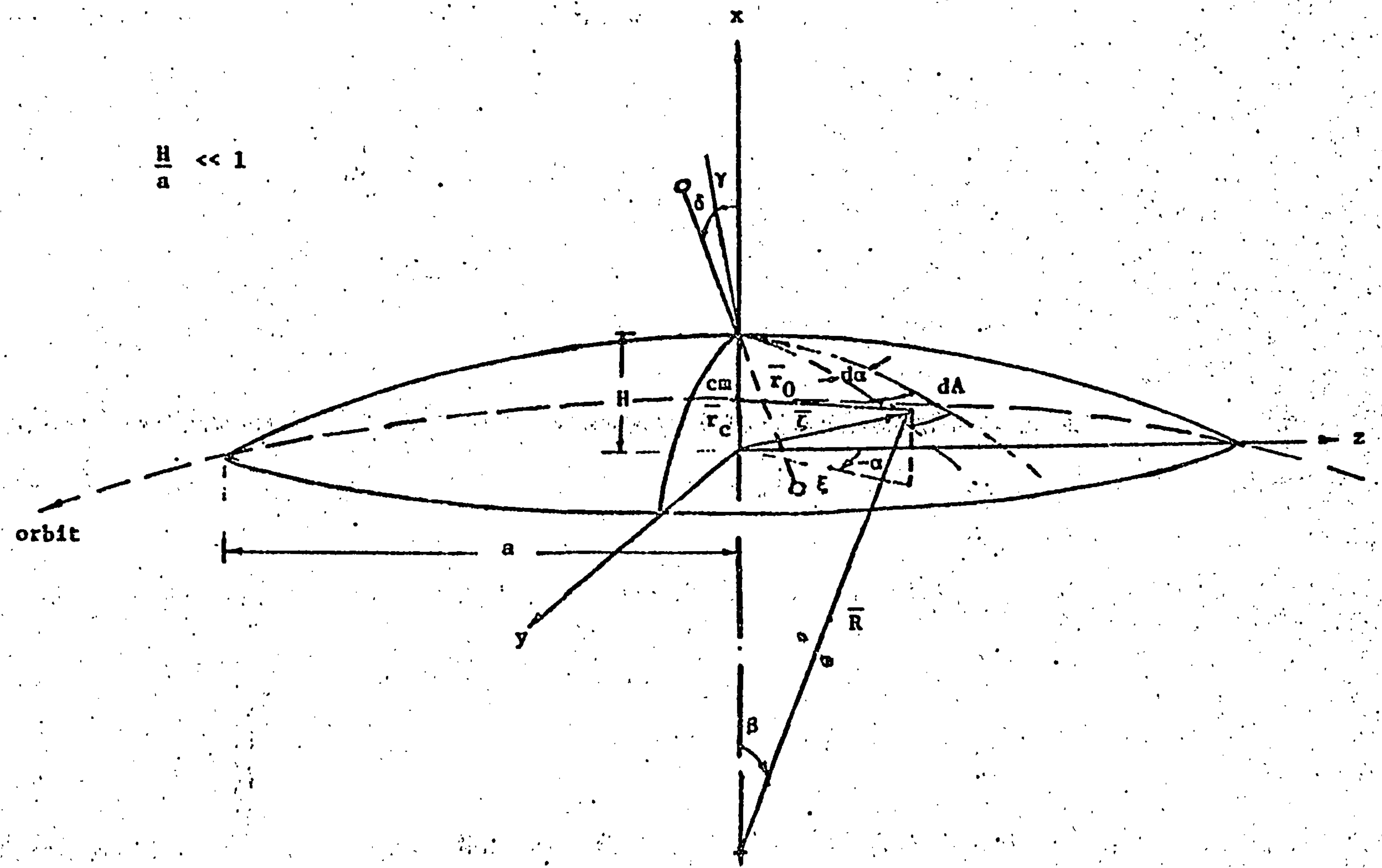


Fig. 1: Shallow Spherical Shell with dumbbell

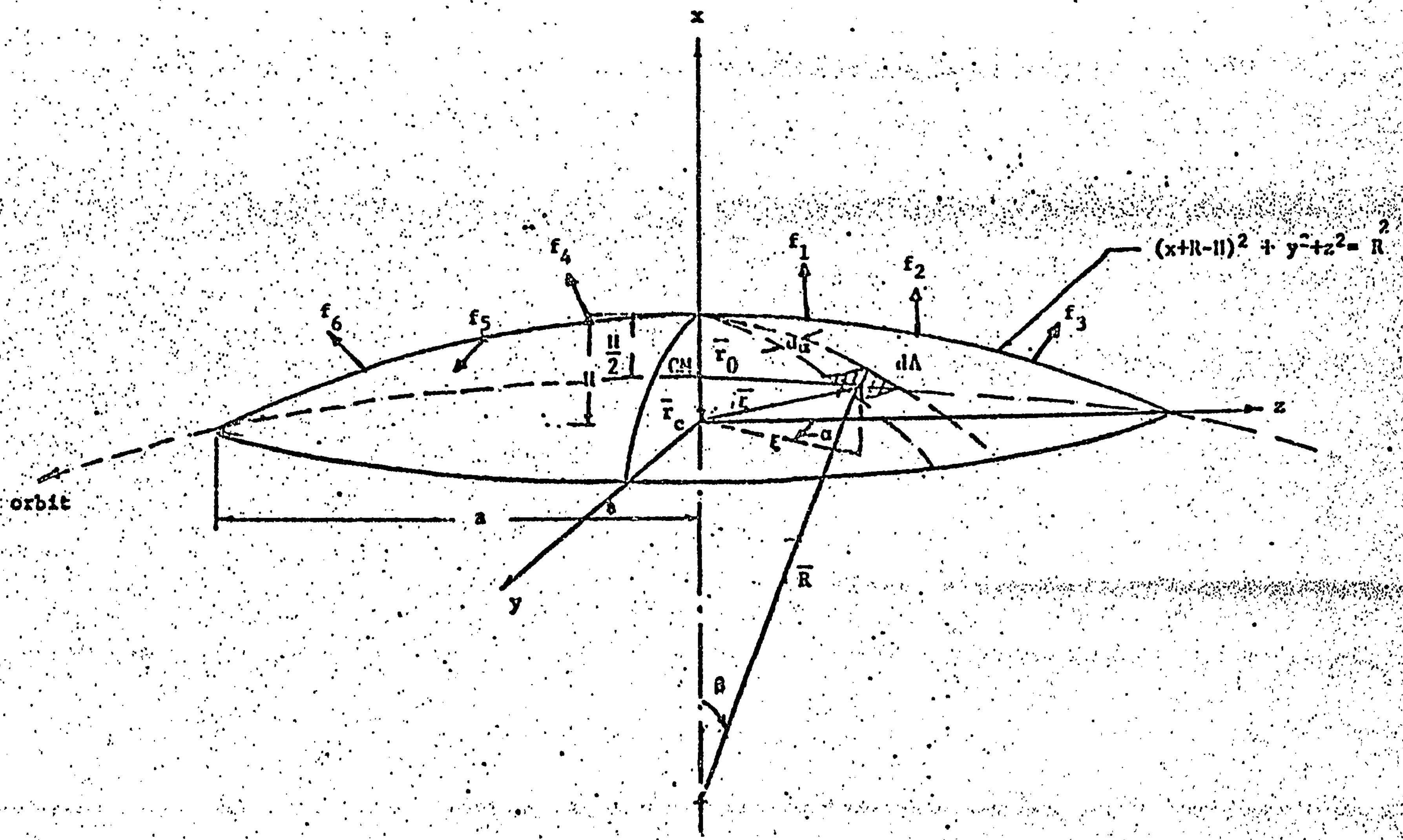
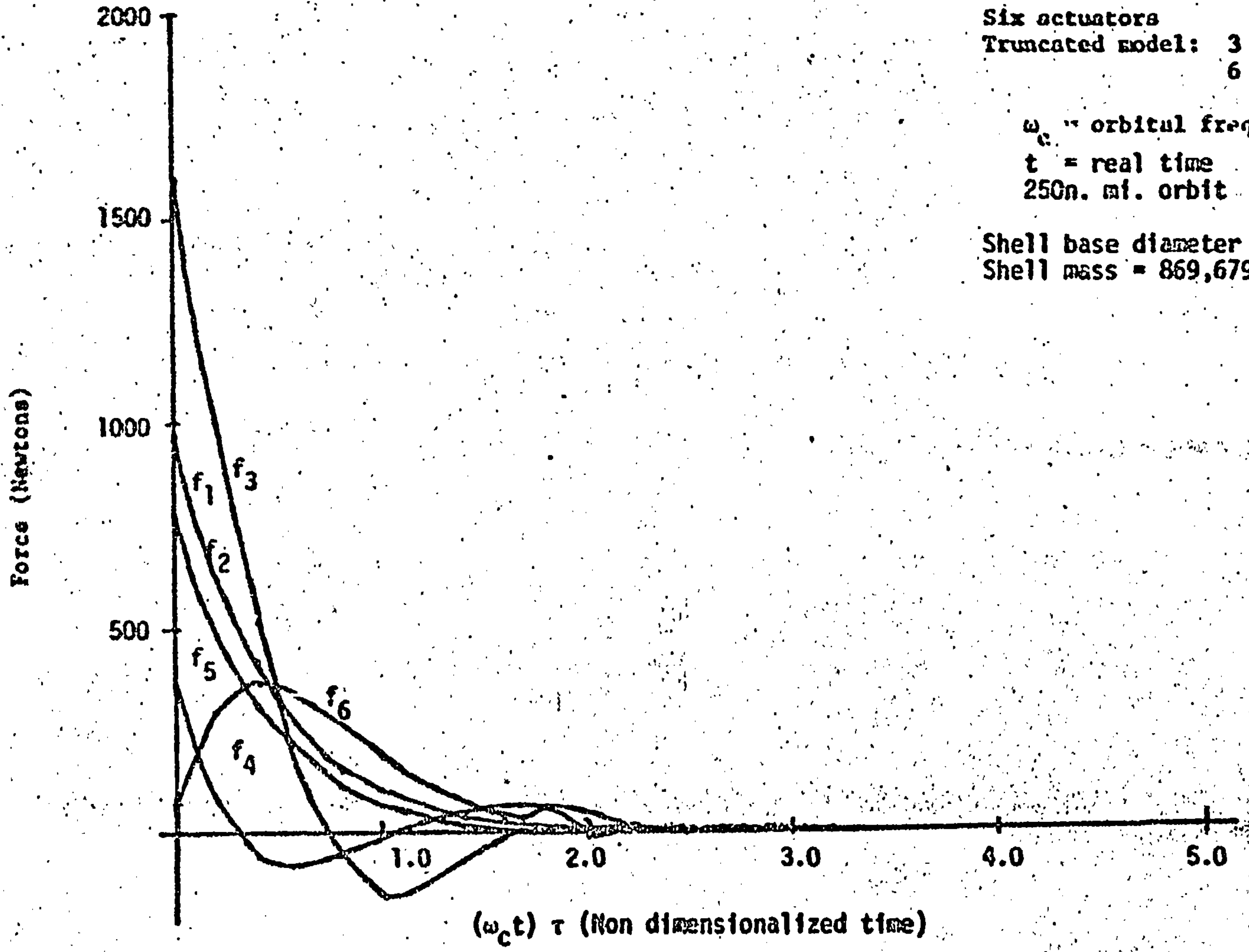


Fig. 2: Shallow Spherical Shell Showing Location of Actuators.



Control law base on pole placement
Six actuators
Truncated model: 3 rigid body modes
6 flexible modes

ω_c = orbital frequency
t = real time
250n. mi. orbit

Shell base diameter = 100m.
Shell mass = 869,679. 8058 kgs.

Fig. 3. Time History of Control Forces.

END

DATE

FILMED

JAN 7 1982