



Experimental validation of the vibro-acoustic model of a pressurized membrane

Pablo A. Tarazaga^{a,*}, Marty E. Johnson^a, Daniel J. Inman^b

^a Department of Mechanical Engineering, Virginia Tech, 310 Durham Hall, Blacksburg, VA 24061-0261, USA

^b Department of Aerospace Engineering, University of Michigan, Ann Arbor, MI 48109-2140, USA

ARTICLE INFO

Article history:

Received 7 April 2012

Received in revised form

19 November 2013

Accepted 23 November 2013

Available online 17 December 2013

Keywords:

Structural acoustic coupling

Gossamer

Acoustic radiation

Impedance modeling

Validation

Experiment

ABSTRACT

In the odyssey of achieving further lightweight space structures and systems, optical-quality membrane mirrors are expected to replace the conventional, metal-based and glass-based, rigid mirrors. These thin film membranes offer an order of magnitude size increase in apertures and in weight reduction. Some of these membrane mirrors are coupled to a pressurized cavity with the end goal of using the pressure in the chamber for shape control. The replacement of rigid mirrors for optical quality membrane mirrors is still a large area of research with many questions thus far requiring further investigation. These areas include modeling, material properties, fabrication due to high tolerances required for imaging, storage, and deployability. The ability to accurately model and predict the dynamics of these space-based membrane mirrors is of great importance. This will lead to more adequate design and manufacturing processes and optimized performance of such systems.

The work presented here focuses on the validation of an impedance-based model of a membrane in air and of a coupled membrane–cavity system using experimental results. The impedance based model takes into account sound radiation and energy loss to the far field. This is crucial in earth-based telescopes and also very important when testing and validating these systems on earth before being launched into space.

Published by Elsevier Ltd.

1. Introduction

The testing of membranes is not a trivial process by any means, and requires a considerable amount of work to achieve accurate and representative results. In [1], Jenkins et al. provide a concise review on membrane testing. They address their history and their peculiarities and difficulties associated with testing and how these, as a consequence, have led to the low number of experiments reported in the literature. An example of these is seen in [2] by Bales et al. They address methods to dynamically characterize thin membrane surfaces with discrete attachment points. They state, “while apparently theoretically simple, the behavior of real membrane flats offers a wide range of significant challenges that complicated test/model validation.” They then proceed to address some of these complications such as point instead of uniformly distributed edge loads, variations in achievable preload at corners, wrinkling and variations in preload caused by gravity induced sag.

Although challenging, the use of membranes to replace conventional rigid mirrors, either space-based or earth-based, comes with a list of favorable advantages [3]. These include, but are not limited to, weight reduction, cost reduction, higher

* Corresponding author. Tel.: +1 540 231 2906; fax: +1 540 231 2903.

E-mail addresses: ptarazag@vt.edu (P.A. Tarazaga), martyj@vt.edu (M.E. Johnson), daninman@umich.edu (D.J. Inman).

packaging efficiency, lower life-cycle costs, lower parts counts, and higher deployment reliability. The proposition of using membranes as the optical component in telescopes and other imaging type devices was proposed in [4]. These thin film membranes offer an order of magnitude size increase in apertures and in weight reduction [5]. Consequently, these advantages do not come without cost. Given the low density of these thin film membranes, the lower end dynamics play a more significant role than their rigid plate-like counterparts in achieving functional mirrors [5–7]. The replacement of rigid mirrors for optical quality membrane mirrors is still a large area of research with many questions thus far requiring further investigation. These areas include, but are not limited to, modeling, material properties, fabrication due to high tolerances required for imaging, storage, control, and deployability. Also, problems such as wrinkling, local defects, boundary conditions, ambient temperature, and moisture can greatly affect the dynamics of these systems. Thus, being able to model the dynamics appropriately is essential for the adequate performance of thin-film membrane mirrors. Validation of a circular membrane has proven to be quite challenging. As stated before, although theoretically simple, constructing an experimental setup capable of representing the theory proved difficult. The most challenging aspect of the experimental setup has been producing a uniformly tensioned circular membrane. After countless iterations, a dependable method to obtain an acceptable uniform tension has been developed and is explained here in detail. Besides the aforementioned problem of producing a uniformly tensioned membrane, other important considerations need to be taken into account when testing a membrane. Some of the most critical challenges are appropriate and representative boundary conditions, portability of the membrane, measurements technique, preparation of membrane surface for measurement, excitation technique, and isolation of membrane from surroundings. Each of these challenges will be addressed in the following sections.

The work herein focuses mainly on the experimental validation of a pressurized optical membrane setup with an impedance-based model. The impedance based model, previously developed by the authors in [8], takes into account sound radiation and energy loss to the far field as this is crucial in earth based telescopes and also very important when testing these systems on earth before being launched in space. First, the experimental setup is discussed in great detail in order to obtain a representative system of what is being modeled. Some of the construction concerns are addressed, such as providing a uniform tension to the membrane and use of adequate sensors as to not mass load the system. Second, experimental results are compared and correlated to an impedance-based model in order to validate such a model. This is carried out in parts by first testing a membrane by itself and then coupling such membrane to a cavity for the final results.

2. Modeling

The model used for validation in this work is taken from [8] and is briefly presented here. The systems are modeled using an impedance-based modeling approach [9]. The multiple subsystems can be modeled independently and then coupled at the interface where appropriate.

2.1. Circular membrane in air

The response of a baffled thin membrane immersed in air will be considerably influenced by the surrounding air. In this case, where the system is defined by the membrane and surrounding air, the restoring forces are not only given by the tension as in the case of a membrane in vacuum [10]. This can be accounted for by coupling the two subsystems, membrane and air, at the interface.

Initially, the membrane is discretized with the condition of obtaining similar areas for every point on the grid. The schematics of such a membrane can be seen in Fig. 1, where the subscript i indicates the i th discrete point with coordinates and area (r_i, θ_i, s_i) , and respective velocity v_i . In the same manner, the subscript j indicates the j th point where the actuation

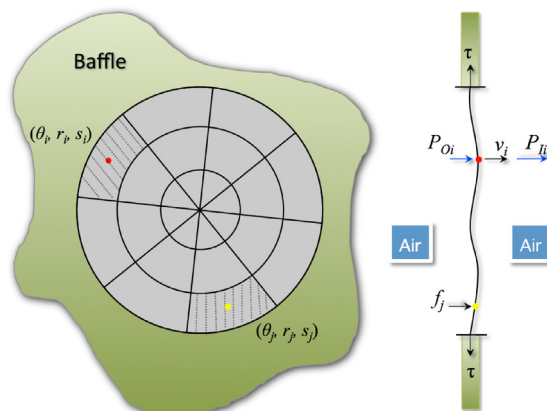


Fig. 1. Schematic of discretized membrane immersed in air with a point force (actual discretization is much finer).

Download English Version:

<https://daneshyari.com/en/article/560491>

Download Persian Version:

<https://daneshyari.com/article/560491>

[Daneshyari.com](https://daneshyari.com)