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STRUCTURAL AND ACOUSTIC RESPONSE OF A FINITE STIFFENED CONICAL SHELL **

Xianzhong Wang[1,2*] **Weiguo Wu**[1,2] **Xiongliang Yao**[3]

([1] *Key Laboratory of High Performance Ship Technology of Ministry of Education, Wuhan University of Technology, Wuhan* 430063*, China*)
([2] *Departments of Naval Architecture, Ocean and Structural Engineering, School of Transportation, Wuhan University of Technology, Wuhan* 430063*, China*)
([3] *College of Shipbuilding Engineering, Harbin Engineering University, Harbin* 150001*, China*)

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ABSTRACT In this paper, a precise transfer matrix method is presented to calculate the structural and acoustic responses of the conical shell. The governing equations of conical shells are written as a coupled set of first order differential equations. The field transfer matrix of the shell and non-homogenous term resulting from the external excitation are obtained by precise integration method. After assembling the field transfer matrixes, the whole matrix describing dynamic behavior of the stiffened conical shell is obtained. Then the structural and acoustic responses of the shell are solved by obtaining unknown sound pressure coefficients. The natural frequencies of the shell are compared with the FEM results to test the validity. Furthermore, the effects of the semi-vertex angle, driving force directions and boundary conditions on the structural and acoustic responses are studied.

KEY WORDS conical shell, precise transfer matrix method, sound radiation, stiffener

I. INTRODUCTION

For the defense vessel, the acoustic stealth performance of the submarine depends on its vibration and sound radiation. Therefore, the vibro-acoustic response of the submarine is a significant topic that attracts many researchers' attention continuously. The middle cabin of the submarine can be modeled as a stiffened cylindrical shell, and the tail cone of the submarine can be modeled as a stiffened conical shell. Plenty of researches focus on the dynamic behavior of cylindrical shells, but it is not the case for conical shells. Internal mechanical equipment and external fluctuating propeller forces cause the structural and acoustic response of a submarine stern structure. The noise emitted by a submarine stern structure has been a key topic for naval research. The dynamic characteristics and responses of conical shells and in particular, of fluid loaded conical shells have not been widely reported in the literature. It is due to the existence of the vertex angle which increases the mathematical complexity. The equations will become variable coefficients after considering the effects of the variation of the radius along the length of the cone. So it's very difficult to obtain the analytic solution.

The free vibration of the conical shell has been studied by some researchers. Rayleigh-Ritz method was used by several authors[1–5] to solve the natural frequencies. Liew et al.[6] analyzed the free vibration

* Corresponding author. E-mail: xianzhongwang00@163.com
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of conical shells by the element-free kp-ritz method. Shu[7] analyzed the free vibration of composite laminated conical shells by the generalized differential quadrature method. Tong[8] presented the solution in the form of a power series to analyze the free vibration of composite laminated conical shells under arbitrary conditions. A transfer matrix method was employed by Irie et al.[9] to calculate the free vibration of a conical shell with variable thickness. Caresta and Kessissoglou[10] analyzed the vibration of a truncated conical shell under fluid loading in the low frequency range. Guo[11] used the multiple scale method to investigate the elastic wave propagation on conical shells with fluid loadings. Numerical results showed that the shear, compressional and flexural wave changed along the length of the conical shell, but the method is only an asymptotic analysis.

So far, little is done on the acoustic radiation of conical shells. Cao[12] investigated the acoustic radiation of cross-plied laminated conical shells. The displacements of conical shells were solved by using the wave propagation approach and Galerkin method. Caresta and Kessissoglou[13] analyzed the structural and acoustic responses of a submarine under harmonic force excitation. The structural response is obtained by solving the cylindrical shell equations of motion using a wave approach and the conical shell equations with a power series solution.

In this paper, the authors present a novel precise transfer matrix method to solve the acoustic radiation of a stiffened finite conical shell. The method is based on the transfer matrix method and precise integration method (PIM). The transfer matrix method of calculating the free vibration of the cone has also been used by Irie et al.[9], but the authors have never found that it is applied to the acoustic radiation of the conical shell. The transfer matrixes of the conical shell's section are assembled to an entire matrix and calculated by the precise integration method. The non-homogeneous term resulting from the sound pressure is obtained by the precise integration method and addition theorem. Then the unknown sound pressure coefficient is solved by using Moore-Penrose pseudoinverse method. Then the radiated noise of the conical shell can be obtained. A brief review of the ways of existing solution for the vibration analysis of conical shell is presented in §I. In §II, the dynamic responses under point force excitation and sound pressure excitation can be solved by the precise transfer matrix method. The sound pressure can be gained according to the boundary condition between the fluid and cylindrical shell. In §III, the natural frequencies of the conical shell are compared with computational results obtained from a finite element model. The convergence and availability analysis for the present method is carried out and the influences of vertex angle, boundary condition and driving forces are researched.

II. DYNAMIC MODEL OF A CONICAL SHELL

A thin conical shell is shown in Fig.1, in which α is the semivertex angle. L_{start} and L_{end} are the length of the small end and large end in the meridian direction, respectively. An arbitrary point on the surface can be described as the cylindrical co-ordinates (s, θ). s is the length in the meridian. θ is the angular value in the circumferential coordinate. R is the radius of the large edge.

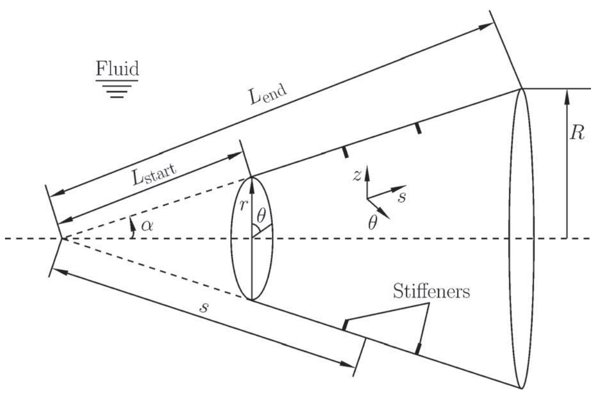

Fig. 1. Geometry and co-ordinate system for a truncated conical shell.