Acoustic Characteristic Analysis of Prestressed Cylindrical Shells in Local Areas

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The influence of prestress on dynamic responses and acoustic radiation for thin cylindrical shells is analyzed in this study. The strain-displacement equation of cylindrical shells with prestress in local areas is established based on the Flügge theory. The structural-acoustic radiation formulation for prestressed cylindrical shells in local areas is instituted by using the variational principle. A numerical analysis is then carried out. The numerical results are validated by comparing the influence of prestress on acoustic radiation power and directivity. This study shows that prestress significantly affects the dynamic characteristics of cylindrical shells.

1. INTRODUCTION

Prestress (initial stress) exists in complex structures because of welding residual stress, structural manufacturing defects, material thermal effects, and static external loading. Prestress resists or aids structural deformation and alters the static and dynamic characteristics of complex structures. For example, the natural frequencies of a structure increase or decrease with prestress distribution. Several studies have demonstrated the influence of prestress on structural-acoustic radiation. A previous study analyzed the structure buckling and vibration problem of composite sandwich plates with initial stress through the higher-order finite element theory.[1] The influence of prestress on the vibration frequency of concrete bridges was also investigated using the prestress stiffness matrix.[2] Regarding uniform Euler-Bernoulli beams under linearly varying fully tensile, the structure natural frequencies may be increased or decreased, and parameters change the forbidden frequencies of the mechanical system, considering the pre-stress force.[3] The influence of temperature was also determined by specifying the arbitrary high temperature on the outer surface and the ambient temperature on the inner surface of cylindrical shells. In this case, the prestressed state was induced by thermal loading.[4] The potential influence of prestress on resonance frequencies was also assessed, and the results showed that prestress depended on water depth.[5] Moreover, prestress can be used as a parameter to change the natural frequencies of a mechanical system in a proposed model of the prestressed structure.[6]

Thin cylindrical shells are widely used in complex structures, such as aerospace, marine, mechanical, and civil constructs. Research on the vibration and acoustic radiation of cylindrical shells has been a hot topic these past few years. A non-linear finite element model based on Murnaghan third-order elastic theory was applied to analyze the resonance structure, and the results showed that natural frequencies increased with increasing compressive stress.[7] The free-vibration characteristics of cylindrical shells were also investigated for a general class of elastic-support boundary conditions which considered depth-water pressure.[8] Moreover, several studies have investigated cylindrical shell dynamic problems with prestress distribution. A previous study reported the output power flow for an infinite ring-stiffened cylindrical shell submerged in fluid induced by a cosine harmonic circumferential line force under a uniform external hydrostatic pressure field and compared the influence of depth-water pressure.[9] The effect of variation in flow velocities and hydrostatic pressures on the dynamic behavior of fluid-conveying shells, as well as that of support conditions on free vibration, were further studied; a 3D method for prestress distribution was also established.[10,11] Simultaneous effects of a prestress condition, including its linear and nonlinear parts and the elastic foundation on natural frequencies of shells under various boundary conditions, were extensively examined.[12] The structure dynamic response of cylindrical shells subjected to harmonic excitation at low natural frequencies was discussed by comparing five different nonlinear cylindrical shell theories.[13] The free vibration and instability characteristics of a ring-stiffened cylindrical shell that conveys internal fluid was analyzed using motion equations based on the Flügge theory. The effects of fluid velocity and ring stiffener parameters on the natural frequency and stability characteristics of the shell were also assessed.[14] The effect of prestress on dynamic responses of fluid and initial stresses for the pipeline were further investigated using the integral equation; the result showed that the influence of prestress at high frequencies is essential.[15] The vibration problem of cylindrical shells was also evaluated using the differential quadrature method to resolve the prestressed structure problem.[16]

However, most studies focused on models of uniformly distributed prestress, such as hydrostatic pressure or water pressure, although fluid velocity deduces pressure. To the best of the author's knowledge, few results have investigated the prestress problem of local area distribution, despite its wide existence in engineering design and manufacturing. With this reason, to analyze the dynamic response and acoustic radiation characteristics of a prestressed complex structure in local areas is necessary. This study aimed to describe the low-frequency dynamic and acoustic responses of a prestressed cylindrical shell structure. The basic equations of structural-acoustic characteristics for cylindrical shells were established using the classical Flügge theory. The developed model was used to determine the influence of prestress on the local area. A general mathematical model capable of analyzing the dynamic behav-