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AEROELASTIC ANALYSIS OF SPHERICAL SHELLS

A. A. Lakis[1], M. Menna[2] and M. Toorani[3]

[1] Ecole Polytechnique of Montreal (Quebec), aouni.laksi@polymtl.ca
[2] Ecole Polytechnqiue of Montreal (Quebec), mohamed.menna@polymtl.ca
[3] Conestoga College, Cambridge (Ontario), mtoorani@conestogac.on.ca

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Shells of revolution are one of the primary structural elements in the aerospace structures. Their applications include the propellant tank or gas-deployed skirt of spacecraft. Due to the aerodynamic shape combined with thin wall thicknesses, spherical shells are more disposed to dynamic instability or flutter induced by high Mach number gas flow. It is, therefore, important to understand the effect of different flow parameters and loadings on the dynamic response of these structures.

An analytical approach to the supersonic flutter of a spherical shell becomes very complicated if one wishes to include different parameters. Therefore, the efficiency of numerical methods such as the finite element method is an advantage for cases involving changes to all factors affecting flutter boundaries. The aim of the present study is to develop a hybrid finite element method in order to predict the aeroelastic behavior of isotropic spherical shells with different parameters such as boundary conditions, geometries, flow parameters, and radius to thickness ratios.

This paper addresses the aeroelastic analysis of a spherical shell subjected to external supersonic airflow. The structural model is based on a combination of the linear spherical shell theory and the classic finite element method. The finite element is a spherical frustum instead of the usual rectangular shell element. In this hybrid method, the nodal displacements are found from the exact solution of shell governing equations rather than approximated by polynomial functions. Therefore, the number of elements chosen is a function of the complexity of the structure. Linearized first-order potential (piston) theory with the curvature correction term is coupled with the structural model to account for pressure loading. The linear mass, stiffness, and damping matrices are found using the hybrid finite element formulation. The aeroelastic equations of motion are reduced to a standard eigenvalue problem. The flutter boundary is found by analyzing the real and imaginary parts of the eigenvalues as the freestream pressure is varied. The results are validated using the numerical and theoretical data available in literature. The analysis is accomplished for spherical shells with different boundary conditions, geometries, flow parameters, and radius to thickness ratios. The results show that the spherical shell loses its stability through coupled-mode flutter. The proposed hybrid finite element formulation can give the reliable results at less computational cost compared to commercial software.

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