Dynamic Analysis of the Rotating Thin-walled Structure with Absolute Nodal Coordinate Formulation

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Abstract

Thin-walled structures are widely used in modern engineering, such as the solar panels, the vehicle bodies and the plane bodies. Large deformations are easy to occur in these structures due to their geometric features, especially when they experience high-speed rotation. The flexible deformations of the thin-walled structures have directly relation with the kinematic accuracy and the dynamic behavior of the whole mechanisms, which affects the dynamic stability of the system. Therefore it is necessary to establish a precise flexible dynamic model of the thin-walled structure to study its flexible deformation and dynamic behaviors during high-speed rotation.

The absolute nodal coordinate formulation (ANCF) was proposed by Shabana in 1996, which is always applied to solve the large deformation and large rotation problems with high-accuracy comparing with other methods such as the kineto-elasto dynamic method, the floating frame of reference method and the finite element method [1]. Some scholars have contributed to the theoretical and numerical advances in the dynamic modeling of the plated/shell element with the ANCF. These studies are mainly focused on the established of the new plate/shell elements, the description of the elastic forces of the plate element, the combination of the ANCF with CAD methods, the application of the plate/shell element to solve engineering problems, and et al [2-5]. However, the study on the dynamic behaviors of the thin-wall structures during high-speed revolution have not been reported in the previous literatures. Therefore it is the objective of this investigation to establish a dynamic model of the thin-walled structures based on the ANCF, and to analyze its dynamic behaviors during high-speed rotational motion.

A four-node ANCF thin plate element, as shown in Fig.1, is employed to discrete the thin-walled structure in this study. Since the thickness of this kind of structure is very small compared with its height and width, the deformation along the thickness direction can be neglected, which leads to a reduced order element with 36 degrees of freedom. To avoid the high numerical stiffness caused by the oscillation of some gradient components along the element, the Kirchhoff theory of thin plate is introduced here to describe the deformation in the thin-walled structure. The vector of the elastic forces of the element is derived by using the strain energy function. A thin-wall structure which rotates around the axis crossing its center with a constant rotational speed is used as example in the numerical simulation, as shown in Fig. 2. Firstly, the modal analysis of the rotating thin-walled structure is conducted by using a perturbation method, in which the frequencies and mode shapes are investigated and compared with the results of ABAQUS. Secondly, the dynamic behaviors of the rotating thin-walled structures with different rotational speeds and material parameters are studied based on the equations of motion. The flexible deformations of different structures are compared, by which the influences of the kinematic and material parameters on the dynamic behavior of the structure are studied. The simulation results are also compared with that of the ABAQUS.

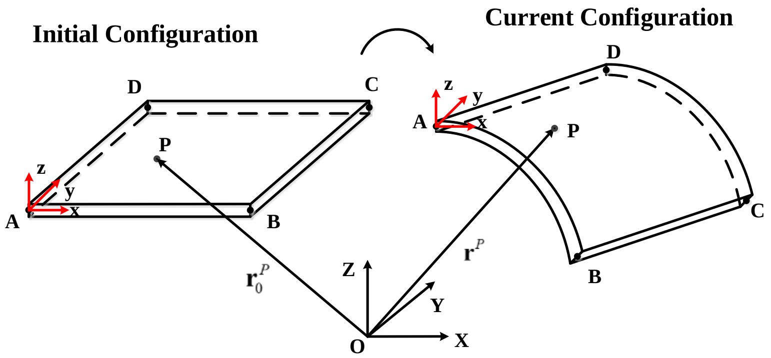

Figure 1: The four-node ANCF plate element.

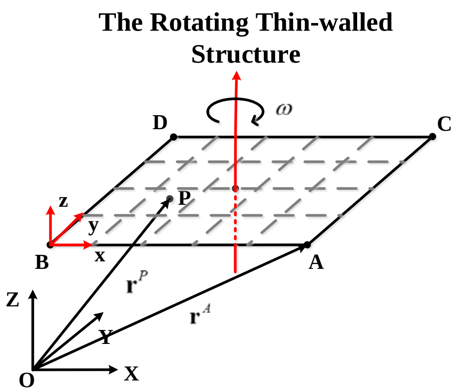

Figure 2: The rotating thin-walled structure.

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