FLUID-STRUCTURE INTERACTION SIMULATION OF SIMPLY SUPPORTED PLATE WITH LARGE DEFORMATION SUBJECTED TO AXIAL FLOW

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Abstract. The dynamic behavior and flow field characteristics of freely supported structure elastic plates with large deformation subjected to axial flow are studied numerically. The structural dynamics equation is discretized by isoparametric displacement-based finite elements, and the motion of a continuous fluid domain is governed by two-dimensional incompressible viscous Navier-Stokes equations, which is discretized by finite volume method. The two-dimensional numerical model of two-way fluid-structure coupling is established combined with moving mesh technology, realizing the interaction of freely supported structure elastic plates and axial fluid. By using the numerical model for simply supported plate flow induced vibration characteristics are obtained. Studied the structure of the large deflection vibration stability .Pitchfork bifurcation curve have been obtained respectively and the structure of the nonlinear system Hopf bifurcation curve.

Introduction

Fluid and the fluid-structure coupling between elastic thin-walled structure is fluid-structure coupling research in the field of a prominent problem, Plate structure in the reactor fuel element structure integration design and has great application value in related engineering, In the aerospace, shipbuilding and biological organism simulation project also has a wide range of applications, Many scholars have conducted in-depth study in related field,The experimental research, theoretical calculation and numerical simulation on three aspects has achieved fruitful results. Recently, Michael and Zhang [1] in this respect, made a brief review of that system were introduced in recent years, research results and conclusions in this respect. LuLi [2] first use the Hopf bifurcation of the algebraic criterion research without viscous flow in the cantilever nonlinear slab structure of fluid-solid coupling vibration stability and bifurcation features. Bein [3], such as using nonlinear plate theory and nonlinear piston theory to study the dynamic characteristics of the simply supported plate. In the practical engineering problem of fluid-structure interaction in most cases, the elastic deformation of thin-walled components with geometric nonlinear, coupled with fluid flow equations of the nonlinear, will cause the interaction between fluid and elastomer on the interface of strongly nonlinear [4]. This article chooses the structure of the material as the ideal elastic material, do 2 d processing, using two-dimensional incompressible viscous fluid flow field, Two-way fluid-structure coupling method, and combined with dynamic grid control technology [5], Established a two-dimensional elastic thin plate under all kinds of bearing in the axial flow of several numerical model of fluid-solid coupling, so as to provide reference for relevant experimental study and theoretical calculation.

The numerical calculation method and its implementation

The fluid flow control equations. The fluid model in this paper for the air, Based on two-dimensional transient, viscous, incompressible navier-stokes equations with SIMPLEC algorithm is solved using the finite volume method.

$$\frac{\partial u_i}{\partial x_i} = 0 \qquad (1)$$

$$\frac{\partial u_i}{\partial t}+u_j\frac{\partial u_i}{\partial x_j}=-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\frac{\mu}{\rho}\frac{\partial u_i}{\partial x_j}\right) \quad (2)$$

where, ρ--fluid density, t--time, p--pressure, μ--dynamic viscosity (i =1, 2), u_i--velocity component, x_i--Coordinate component (i =1, 2).

Structure control equation. Using the finite element method to discrete elastic thin plate structure, Using Newmark numerical integral structural dynamics equation, the transient dynamic analysis (not considering the structure damping)

$$[M]\{\ddot{x}\}+[K]\{x\}=\{p\} \quad (3)$$

where, $[M]$−− mass matrix, $[K]$−− mass matrix, $\{\dot{x}\}$−−accelerated speed, $\{\ddot{x}\}$−−displacement, $\{p\}$−−Caused by the fluid motion load (stress)

Dynamic grid control. Considering structure for the nonlinear and the flow field grid deformation of the problems of large deformation, easy cause mesh distortion resulting in operation stop, In this paper, the mobile grid method is used to [5] to deal with large deformation of fluid-solid coupling interface grid, Interface using the arbitrary Lagrangian - eulerian method[4].

The coupling between fluid - structure. In scaled in adina.the structure model and the flow field model is set up. The structure model and fluid model with imported into the scaled - FSI adina.the solver for iterative calculation of fluid-structure interaction.

The calculation model and boundary conditions.

Model: The length of the elastic thin plate L = 100 mm,thickness h = 0.1 mm,width b per unit length, plate density ρ_b= 1.48Kg/m^3.elasticity modulus E = 3.5GPa, Poisson's ratio ν =0.25, fluid density ρ_b =1.226Kg/m^3, dynamic coefficient of viscosity μ =18×10^{-6} Pa, The flow field is highly H=800 mm,mass ratio α =0.78, Parallel to the flow load to a constant speed U, plates support form: Use the left end hinged and The right end directional support . Two dimensional modeling is shown in fig.1 The flow field area and boundary conditions: This study the flow field calculation of flow field area asshownin fig.1 Two dimensional modeling using quadrilateral structured grid and grid, On the left side being imported by velocity inlet boundary conditions.The right end as the boundary conditions using free exp-ort; Fluctuation trough for solid wall conditions,Thesurface of the plate fluid-solid interaction for interface.

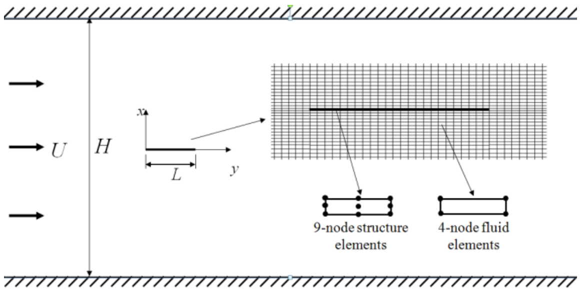

Fig. 1 two-dimensional numerical model diagram

Results and analysis

The vibration of the plate. When the flow rate is less than the critical flow velocity(about 2.85 m/s), fluid pressure difference of less than the effect of elastic restoring force of plate, Disturbance disappears, plates will restore linear equilibrium state, Linear equilibrium is stable.

When the velocity exceeds a certain value (critical velocity), the role of fluid pressure difference is greater than the plate elastic restoring force, Will produce a larger bending plate, linear equilibrium state is unstable. As the velocity increases more than the critical velocity when the plates structure produce certain static displacement, and remained stable in the basin.Velocity-deflection curve for the Pitchfork bifurcation curve as shown in fig.2 the plate deflection bifurcation curve (Ⅱ).

When the velocity is greater than 4.48 m/s, plate with velocity of 4.48 m/s velocity corresponds to the static displacement value of deflection vibration limit cycles for center. As shown in fig.4 velocity of 5 m/s plate midpoint time history curve. Limit cycle flutter with the increase of flow velocity, Deflection increases rapidly, the stiffness of the plate also increase, Hopf bifurcation curve as shown in fig.2 the plate deflection bifurcation curve (Ⅲ).

With the increase of flow velocity, In the initial position the upper(lower) part of the amplitude of vibration across the the initial position into lower (upper) part, Hopf bifurcation curve area cross . Two limit cycle vibration area overlap, Mutual influence were on board the initial position limit cycle vibration. In the process of vibration affected by the vibration of the region stable limit cycle oscillation influence equilibrium position, In the process of vibration with unilateral back to the vibration phenomenon. As shown in fig.5 velocity of 6 m/s midpoint time history curve of the work. Hopf bifurcation curve as shown in fig.2 the plate deflection bifurcation curve (Ⅳ).

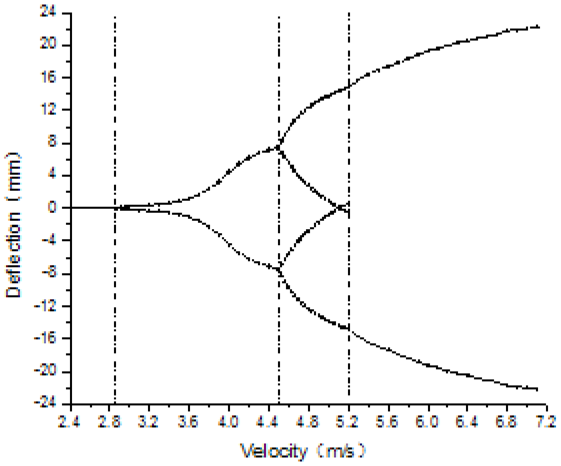

Fig. 2 the plate deflection bifurcation curve

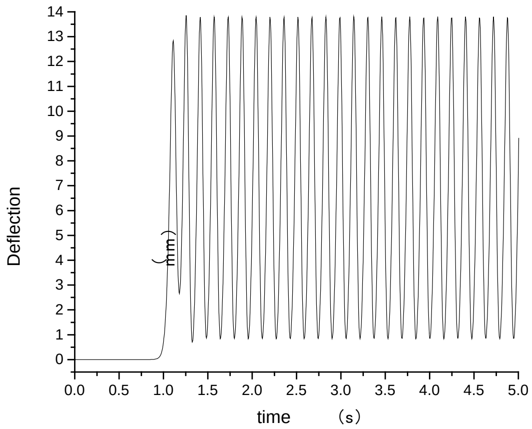

Fig. 3 velocity of 5 m/s plate midpoint time history curve

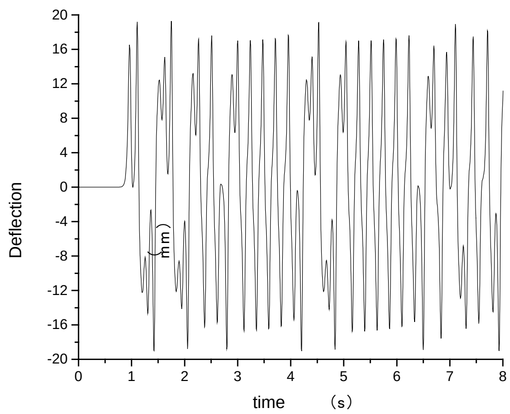

Fig. 4 velocity of 6 m/s plate midpoint time history curve

Flow field characteristics. Due to the speed and pressure is a fluid equations of two variables, vorticity is a function of flow rate, therefore, respectively, this paper emphatically analyzes the vorticity, the change of pressure and velocity. When the velocity increases to fig.2 the plate deflection bifurcation curve (Ⅲ) velocity range. The flow field of fluid from the fluid resistance on both sides of the stripping, both sides of the downstream of the flow field of the plate will produce two vortex in the symmetry, one of the upper vortex clockwise rotation, the other side of the spiral turn, in the opposite direction to form the karman vortex street. Velocity vortex plate strip is equivalent to a few times a long distance from region after region is more and more big, the spacing increases, trailing vortex increases with the increase of flow velocity. Velocity of 5 m/s under the flow field and vorticity contours as shown in fig.6 . With the increase of flow velocity, in fig.2 the plate deflection bifurcation curve (Ⅳ) velocity range, Both sides of the downstream of the flow field of the plate will produce two is not completely symmetric and parallel arrangement of the vortex, one of the upper vortex clockwise rotation, the other side of the vortex is the direction of rotation, the formation of karman vortex street. Velocity of 6 m/s under the flow field and vorticity contours as shown in fig.6. Under a given is greater than the critical velocity of flow, the flow field in the plate will eventually after a certain amount of time to do a certain amount of deflection amplitude of periodic vibration, such as law, the dynamic characteristics of the system and mechanism is the same.

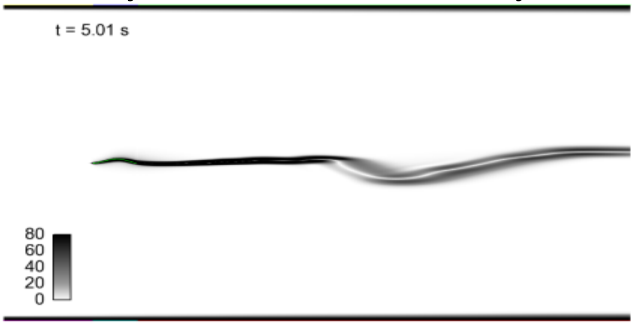

Fig.5 velocity of 5 m/s under the vorticity contours

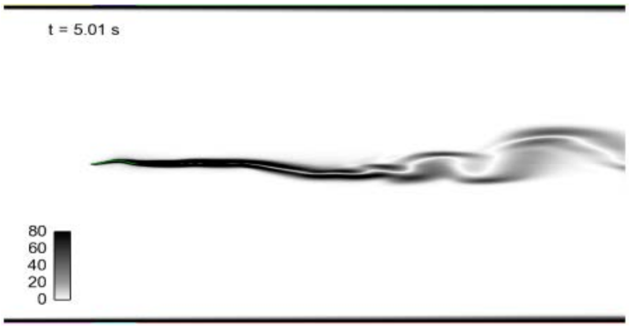

Fig.6 velocity of 6 m/s under the vorticity contours

Conclusion

In this paper, the axial flow in the large deflection of simply supported elastic thin plate fluid-structure coupling system is simulated. The following conclusions are drawn:

(1) in a simply supported plate system when the velocity is small, plate in the stable linear equilibrium state. When more than the critical velocity, the deflection of plate has a certain value, produce neutral equilibrium. As the velocity increases, the vibration of the limit cycle in the area of the single vibration, As well as across two balance vibration response of the vibration area.

(2)Respectively through to the vorticity, pressure and velocity analysis of the cloud. Formed in the downstream of the flow field in the karman vortex street. Vortex street based on the vibration of simply supported plate regional differences between existing parallel or dislocation arrangement. Intuitive image illustrates the interaction between fluid-structure interaction system.

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