Piezoelectric structure optimization analysis

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Abstract

In order to provide a sustainable power source for ocean-going detection sensors, a small amount of power generated by a piezoelectric effect power generation device is combined with a wave collection model to assemble an ideal energy supply device, and the piezoelectric film structure is optimized for analysis in order to increase the piezoelectric power generation efficiency. Based on piezoelectric constitutive equations and boundary equations, the application of APDL analysis results shows that under the condition that concentrated force and variable load are applied to the piezoelectric film, the law of the piezoelectric film's power generation changes with the force, and the voltage change is presented in the time domain. With a certain periodicity, the circular piezoelectric slice model has the highest power generation efficiency of the piezoelectric sheet structure when the center hole opening is 0.001 m.

Keywords

Piezoelectric effect; power generation efficiency; APDL; simulation analysis.

1. Introduction

The research of piezoelectric power generation efficiency is mainly based on the optimization of the piezoelectric type and material size. The K.F. Wang [1] et al. analysis of the flexural electrical effect of the single-crystal piezoelectric energy harvester based on the Hamiltonian principle shows that the smaller thickness deflection of the piezoelectric layer has an effect on the output voltage and power. Hajhosseini M [2] used the generalized differential orthogonal method to calculate the voltage output of a periodically variable cross-section bimorph and compared it with a common piezoelectric beam to produce a voltage over a wide frequency range. SZ Li [3] studied the energy harvesting performance of piezoelectric transducers under different prestressed mechanical vibrations. The results showed that the energy of the transducer increases with the increase of prestress when the resonant frequency shifts to a lower value. . Hyeoung Woo Kim [4] conducted a comparative study of the performance of the helium sensor under AC power of 70N through simulations and experiments and found that higher piezoelectric voltage constant ceramics provide higher output power.

In this paper, a three-dimensional circular piezoelectric slice structure is designed and simulated for analysis. The concentrated force and variable load force are applied to the midpoint of the bottom surface of the piezoelectric slice respectively, and the center hole diameter and thickness of the model are changed to optimize the results.

2. Modeling and Meshing

In the process of modeling the piezoelectric effect, the single piezoelectric slice in the piezoelectric stack commonly used in piezoelectric experiments is selected as the modeling object, so that the effects of multiple piezoelectric effects generated in the stack gap and the middle electrode can be eliminated. The model is shown in Figure 1. The APDL module is used for modeling and material unit definition. The APDL instruction is used for modeling and simulation for the convenience of operation modification. The overall Cartesian coordinate system's axial direction (z direction) is the thickness direction of the wafer piezoelectric film model. A circular piezoelectric piece with a radius of 0.05 m and a thickness of 0.001 m is provided with a SOLID5 element type, a material density of 7600, a piezoelectric matrix, an elastic coefficient matrix, and a dielectric constant matrix. The APDL is modeled as follows.

In accordance with the physical modeling of the data in the piezoelectric quartz chip table, the axis of the overall Cartesian coordinate system is selected as the thickness direction of the wafer model. The finite element calculation of the piezoelectric quartz slice uses six faces, eight nodes, and each node has four degrees of freedom. In the finite element simulation, the meshing is more difficult for the volume object, and the unreasonable division will seriously affect the calculation accuracy. Here, the mesh is divided by the sweeping mesh method. The components of the sweeping division are mainly wedge-shaped and hexahedral elements. The division also takes into account the symmetry of the model, and the resulting elements also have a certain degree of symmetry. The mesh is shown in Figure 2.

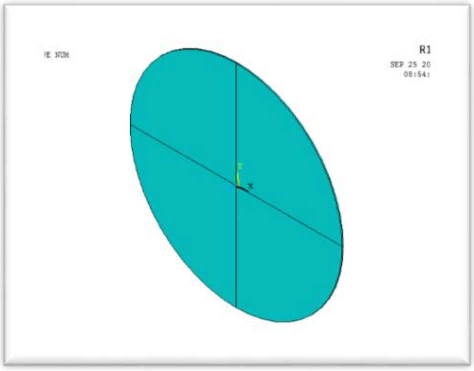

Fig.1 Piezoelectric model

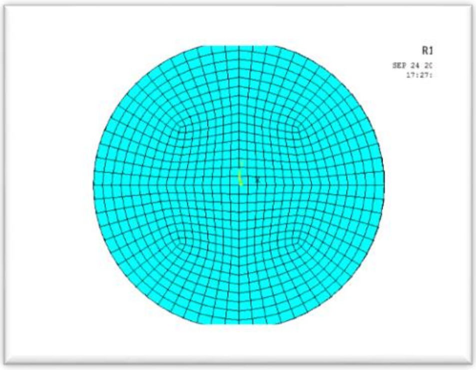

Fig. 2 Piezoelectric grid mesh

3. Piezoelectric Plate Force Numerical Simulation Settings

The piezoelectric disk force output energy simulation analysis needs to consider its thickness and radius. The effective area of the air intake hole is the power generation part of the piezoelectric film. A 3-D piezoelectric film model is established in APDL with a radius of 0.1 m and a thickness of 0.001 m. , choose unit type Solid5, set KEYOPT(1)=3 to activate piezoelectric freedom, displacement and voltage, piezoelectric material density is 7600 kg/m3, elastic modulus is 1.69×105, Poisson's ratio is 0.066, piezoelectric film The edges are fixed and restrained. The dielectric matrix, piezoelectric stress matrix, and elastic coefficient matrix of the piezoelectric functional material are as follows. The solution method is a complete transient solution analysis method. The load is set as a ramp load, and the automatic time step control is turned off. Provincial steps and time steps.

4. Piezoelectric Sheet Center Hole Parameter Optimization

Since the outlet of the air chamber sink air chamber has been determined, the piezoelectric area is determined by the area of force at the outlet of the air chamber, that is, the size of the piezoelectric patch remains unchanged. In order to reasonably set the parameters of the center hole of the piezoelectric film, taking into account the air chamber outlet size, the air chamber air pressure change rule and the reference literature, the center hole radius of the piezoelectric film is divided into 0, 0.005, 0.01, 0.015, 0.02 with an interval of 0.005. Five dimensions for optimal analysis.

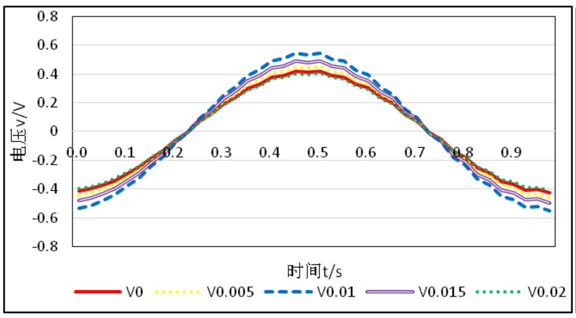

Fig. 3 Piezoelectric deformation curves of different center hole radius

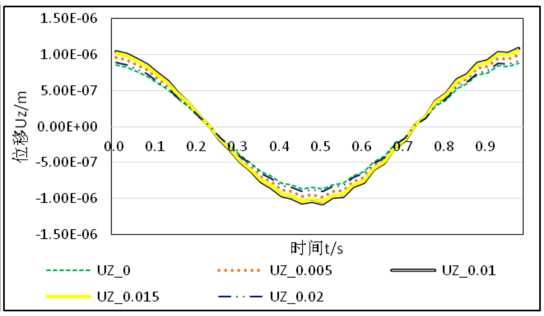

Fig. 4 Piezoelectric deformation curves of different center hole radius

The comparison of the force deformation curves of the five different center hole size radius piezoelectric films is shown in Fig. 3. It can be seen that when the opening radius of the piezoelectric film is 0.01, the deformation difference is the largest, and the maximum downward deformation amount is -1.15E-6m. The maximum upward deformation is 1.1E-6m. When there is no hole, the deformation of the piezoelectric sheet is the smallest. The deformation of the two kinds of piezoelectric slices is about 2.5E-7m. The total deformation from large to small is UZ0.01> UZ0.015> UZ0.005> UZ0.02> UZ0.

The comparison of the force deformation curves of the piezoceramic sheets with five different center hole sizes and radii is shown in Fig. 4. It can be seen that the voltage generated when the opening radius of the piezoelectric film is 0.01 is the maximum, and the maximum voltage is about 0.56 V. When the maximum downward deformation is achieved, the reverse voltage is about -0.55 V. The piezoelectric element with a hole radius of 0.02 has the smallest deformation, and the generated voltage is also the smallest, about -0.4V. The voltage difference between the two sizes of piezoelectric films is nearly 0.2V. The total amount of generated voltage is V0.01>V0.015>V0.005>V0>V0.02.

5. Conclusion

From the simulation and comparison of five different center hole radii with different piezoelectric radii, it can be known that the radius dimension parameter of the center hole of the piezoelectric film has a greater influence on the piezoelectric film, and the deformation of the piezoelectric film is proportional to the amount of generated voltage. The larger the voltage is; the larger the opening of the piezoelectric film compared to the piezoelectric film without the opening of the larger deformation but the power difference is not large; the center of the hole in the larger piezoelectric film and the center of the hole The piezoelectric films are more densely distributed with respect to the other three types of bottom voltages. The piezoelectric film with a central hole radius of 0.01m generates a deformation and a larger amount of voltage, which are caused by the force of the piezoelectric films of the other four sizes, and is the optimum radius of the center hole of the piezoelectric film.

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