IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 20, Issue 4 Ser. III (July. – August. 2023), PP 01-09
www.iosrjournals.org

Simulation Analysis Of Piezoelectric Oscillator Displacement Characteristics

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Abstract: *With the improvement of scientific and technological level, digital printing technology has achieved great development. Among them, piezoelectric inkjet printing technology has the characteristics of high precision, good stability and strong adaptability. Because of its remarkable characteristics, piezoelectric drive jet liquid technology is also widely used in large-scale inkjet painting, biomedicine, 3D printing and other fields. The drive input in piezoelectric inkjet technology is provided by piezoelectric ceramics, so the driving performance of piezoelectric ceramics determines the accuracy and stability of inkjet. For the needs of jet fluids and liquid cavities, ANSYS software is used to perform modal analysis, static analysis, harmonic response analysis, transient response analysis and vibration displacement analysis of single piezoelectric circular membrane ceramic oscillator drivers, For this series of simulation analysis, the relationship between the natural frequency and elastic substrate of the piezoelectric sheet, voltage and size can be obtained. The simulation results are optimized for material selection, structural design and its parameters for piezoelectric injection.*

Keyword: *Droplet; Finite element analysis; Piezoelectric ceramics; Transient analysis*

Date of Submission: 06-08-2023 Date of Acceptance: 16-08-2023

I.Introduction

The most representative of traditional microdrop spraying technology is inkjet printing technology. As a fully digital control process, microdroplet injection technology is operable and real-time, and the droplets are ejected out of the nozzle under the action of the actuator through the spray time and time interval of the control device. This non-contact printing method has the superior characteristics, such as wide substrate and strong adhesion. Therefore, it is widely used in microelectronics, biomedical manufacturing and other fields,[Error! Reference source not found.]and also brings new vitality to the field of 3D printing.[Error! Reference source not found.]

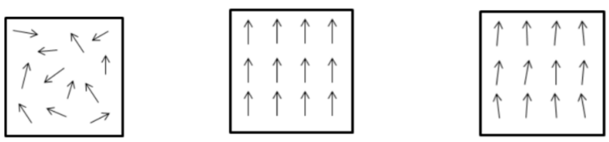
With the rapid rise of piezoelectric spraying technology, piezoelectric pump driver as the core driving device of piezoelectric inkjet printer, not only requires low power consumption, small volume, easy integration processing, but also requires fast response speed, high action frequency, accurate and controllable. The piezoelectric injection device is a complex multi-physical field coupling system, so the shape, size, material composition of the piezoelectric ceramic have a great influence on the performance of the piezoelectric drive. At present, there are many studies on rectangular piezoelectric sheets, and most of the research is from the perspective of transducers.[Error! Reference source not found.] Lou Lifei[Error! Reference source not found.] studied the physical properties of a rectangular piezoelectric film fixed at one end and the influence of external load on the output voltage according to the relationship between electric field-potential and strain-displacement of piezoelectric materials. Zhang Dongzhi[Error! Reference source not found.] optimized the structure of the double piezoelectric circular membrane by command flow, and simulated the static, modal and harmonic response of the material. Yazhou M[Error! Reference source not found.] Applying axial electric field to a single piezoelectric sheet and analyzing the effect of physical parameters of piezoelectric ceramics on resonance frequency by harmonic response. Pan Xiaojuan[Error! Reference source not found.] analyzed the vibration of double iterative piezoelectric ceramics, without considering the transsubsistence, studied the bending vibration of piezoelectric ceramic oscillator about the free boundary conditions, and proposed a general solution of the vibration displacement of circular thin plate piezoelectric ceramics and resonance frequency equations. Saxena[Error! Reference source not found.] studied the effect of the length and thickness of the piezoelectric layer on the von-Mises stress of the structure. Kamel[Error! Reference source not found.] optimized the model by finite element modeling and then compared the results obtained by the model under different control methods. Terzi[Error! Reference source not found.] presented the equations of control for cantilever beams at three levels of beam theory, establishing the eigenfrequencies and eigenfunctions for two boundary conditions. Yu Dong[Error! Reference source not found.] used the audio signal modulated by the Hanning window to perform harmonic response analysis and transient analysis of the rectangular piezoelectric oscillator, and clarified that the modulated audio signal can make the piezoelectric oscillator vibrate, but will show hysteresis. Hu Shijun[Error! Reference source not found.] studied the power generation characteristics of cantilever piezoelectric ceramic plates under different conditions, analyzed the relationship between output voltage and excitation size, piezoelectric plate and substrate thickness, and added fixed support constraints compared with previous studies, but the effect of fixed constraint on the characteristics of piezoelectric sheet was not analyzed. Guo Xinyuan[Error! Reference source not found.] interpreted elucidated the relationship between the voltage output of the piezoelectric cantilever beam and different structures, frequencies and sizes by modal analysis and harmonious response analysis of single-crystal piezoelectric cantilever beams. The fixed support was set as the boundary condition of the rectangular cantilever beam in the text, and by default one side of the end face of the piezoelectric cantilever beam was fixed, in fact, when the piezoelectric sheet was installed, it was not just a simple fixed face, and the effect of the fixed support on the frequency of the structural member was not discussed in this paper. Lian Wei[Error! Reference source not found.] studied the influence of the support method on the composite foam sandwich structure, and the results showed that the different support methods would affect the response time of the structure itself to the load.

In summary, scholars mainly focus on the simulation analysis of rectangular piezoelectric transducer direction, for microdrop injection, the liquid cavity is mostly cylindrical, so the driving source is mostly circular piezoelectric sheet, and there is relatively little research on the influence of circular piezoelectric sheet and fixed support on piezoelectric sheets, while the influence of round piezoelectric sheets and fixed supports on piezoelectric sheets is relatively rare, this paper uses software ANSYS to simulate the modal, transient and harmonic response of single-piezoelectric circular membrane ceramic structures, explores the relationship between the natural frequency and maximum displacement of piezoelectric structures and the structure and fixed support distance of piezoelectric cells, and analyzes piezoelectric ceramics of different materials, which provides theoretical basis and application support for subsequent research.

II.Working principle

In 1880, the Curie brothers discovered that due to the asymmetry of the atomic structure of some crystalline materials, the relative displacement of charged particles caused by external loads leads to the non-coincidence of the centers of positive and negative charges, and the two opposite surfaces of the crystal will have a different number of charges, and this phenomenon is called the piezoelectric effect, and the materials with the piezoelectric effect are called piezoelectric materials. Whether a material is piezoelectric or not is determined by its own structural properties, where a material with a center of symmetry in its structure is never piezoelectric.[Error! Reference source not found.]

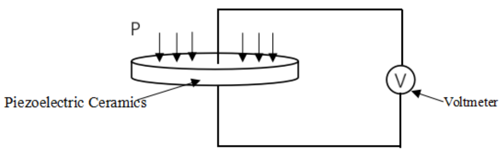
Piezoelectric materials exhibit an isotropic structure before they are subjected to external loads. Due to the nature of their symmetric structure, the spontaneous polarization direction of each internal electric domain is haphazard, and the material exhibits negligible piezoelectric effects when loads are applied. Therefore, it is particularly important that the polarization process changes the orientation of each electric domain. During the polarization process, the strong DC electric field applied to the material keeps the orientation of all dipoles in line with the electric field direction. By removing the polarization electric field, most of the dipoles do not return to their initial orientation due to the effect of the pegging effect caused by microscopic defects in the lattice,[Error! Reference source not found.] we obtain a material composed of a large number of microscopic dipoles with approximately the same orientation. In contrast, depolarization treatment involves applying a strong DC electric field to the material in the opposite direction of the original polarization or placing the material in an environment where the temperature is higher than the Curie temperature and the material will undergo depolarization, as shown in Figure 1.



(a)Pre-polarization (b) Polarization processing (c)Removal field
Fig. 1. Polarization process

The piezoelectric effect is divided into positive piezoelectric effect and inverse piezoelectric effect according to the way of energy conversion.

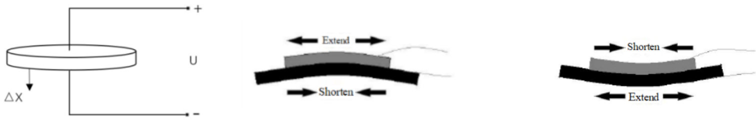
The positive piezoelectric effect refers to the deformation of a piezoelectric material by applying an external force in a certain direction, which causes the charged particles inside the piezoelectric material to shift, resulting in a change in the total electric moment of the material and thus a charged state on the two opposite surfaces of the material, as shown in Figure 2. The positive piezoelectric effect converts mechanical energy into electrical energy, when the applied external force disappears, the piezoelectric material quickly returns to uncharged state, and when the direction of the external force changes, the polarity of the charge changes as well.



DOI: 10.9790/1684-2004030101

Fig. 2. Positive piezoelectric effect

The inverse piezoelectric effect means that when an electric field is applied to a piezoelectric material, it causes a relative displacement of the positive and negative charges inside the material, as shown in Figure 3(b), thus deforming the piezoelectric material. The inverse piezoelectric effect is the conversion of electrical energy into mechanical energy, and the deformation produced by the piezoelectric material is proportional to the strength of the applied electric field. The inverse piezoelectric effect is also called the electrostriction effect, as shown in Figure 3(a).



(a)Inverse piezoelectric effect **(b) Transformation**
Fig. 3. Inverse piezoelectric effect and deformation diagram

The structure of the single piezoelectric ceramic drive injection device is shown in Figure 4, with fixed supports at both ends of the elastic substrate, the elastic substrate diameter and thickness D2 and H2, the radius and thickness of the piezoelectric sheet aret D1 and H1. This paper analyzes the influence of the elastic substrate material on the drive performance. The piezoelectric sheet material is PZT-5, and the elastic substrate material is aluminum, copper, silicon and 65M

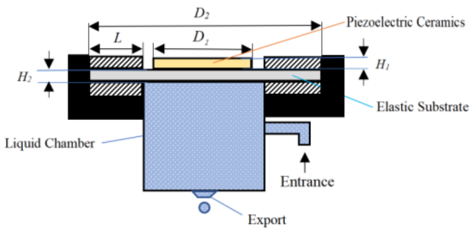


Fig. 4. Piezoelectric microdrop injection device

The piezoelectric drive element is bent and deformed by the bonded piezoelectric substrate, which is bounded by the piezoelectric ceramic PZT-5A with the same polarity on the upper and lower surfaces of the substrate. When the upper piezoelectric sheet contracts and the lower piezoelectric sheet expands, the volume of the cavity expands and fluid is drawn in by the inlet. When the upper piezoelectric sheet expands and the lower piezoelectric sheet contracts, the volume of the cavity compresses and fluid is extruded by the outlet. The drive element produces periodic vibration of the circular membrane under the excitation of periodic electric field, which makes the piezoelectric injection device with fluid self-priming and discharge capability, controlling the movement of the piezoelectric actuator to creates a controllable jet.

III.The Simulation Method and Results Analysis

Material Definition

Material properties and parameters are shown in Table 1.

Table 1. Materia

Material	Density/kg*m-3	Modulus of Elasticity	Poisson's Ratio
Aluminum	Fi2700	7.2E+10	0.32
Copper	8960	1.11E+11	0.36
Silicon	2330	1.9E+11	0.278
65Mn	7850	1.97E+11	0.282
PZT-5A	7750	6.756E+10	0.31

The stiffness matrix, piezoelectric matrix and dielectric matrix of the piezoelectric ceramic chip PZT-5A are as follows:

Stiffness Matrix: $[C^E]$ = parameters

$$\begin{bmatrix} 12.03 & 7.52 & 7.51 & 0 & 0 & 0 \\ 7.52 & 12.03 & 7.51 & 0 & 0 & 0 \\ 7.51 & 7.51 & 11.09 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2.26 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2.11 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.11 \end{bmatrix} \times 10^{10}\ \mathrm{N/m^2}$$

Piezoelectric Matrix: [d] =

$$\begin{bmatrix} 0 & 0 & -1.71 \\ 0 & 0 & -1.71 \\ 0 & 0 & 3.74 \\ 0 & 0 & 0 \\ 0 & 5.84 & 0 \\ 5.84 & 0 & 0 \end{bmatrix} \times 10^{10}\ \mathrm{C/N}$$

Dielectric Matrix: $[\varepsilon^S]$ =

$$\begin{bmatrix} 8.137 & 0 & 0 \\ 0 & 8.137 & 0 \\ 0 & 0 & 7.319 \end{bmatrix} \times 10^{-8}\ \mathrm{F/m}$$

The relative permittivity is:

$KS = \frac{\varepsilon S}{\varepsilon 0}$, $\varepsilon 0 = 8.854\mathrm{e}{-12}$ F/m;

$$KS = \begin{bmatrix} 919 & 0 & 0 \\ 0 & 919 & 0 \\ 0 & 0 & 827 \end{bmatrix}$$

The structural and quasi-electrostatic fields are coupled by the piezoelectric constant e in the piezoelectric analysis. For the analysis of piezoelectric coupled fields in piezoelectric ceramics, the second type of piezoelectric equation is used**Error! Reference source not found.**:

$$T = c^E S - e_t E \quad (1)$$

$$D = S + \varepsilon_S E \quad (2)$$

where S is the mechanical strain vector; e is the piezoelectric stress matrix; E is the electric field intensity vector; T is the mechanical stress vector; D is the potential shift vector; c^E is the stiffness matrix of the piezoelectric ceramic measured under the condition of constant electric field strength; ε_S is the dielectric matrix of the piezoelectric ceramic measured under the condition of constant mechanical strain.

Differential equation of vibration for circular oscillator

The analysis of forces and dimensions of the piezoelectric oscillator are shown in Figure. The diameter of the piezoelectric ceramic is d1, the diameter of the metal substrate is d2, the bending moment is M2, the excitation force is F, and the elastic displacement is W.

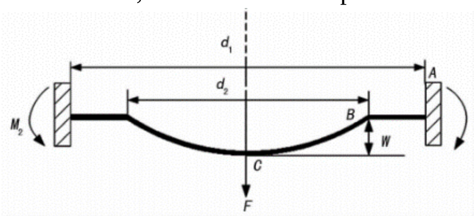


Fig. 5. Force diagram of piezoelectric oscillator

The deflection of parts A-B:

$$W_{11} = \frac{F}{8\pi D}\left[\frac{d_1^{\,2}}{4} - r^2\left(1 + \frac{1-\nu}{2(1+\nu)}\frac{d_1^{\,2} - d_2^{\,2}}{d_1^{\,2}}\right)\right] + \frac{F}{8\pi D}\left(\frac{d_2^{\,2}}{4} + r^2\right)\log\frac{2r}{d_1} \quad (3)$$

where: r is the distance to the center of the piezoelectric oscillator; D is the bending stiffness.
The deflection of the piezoceramic edge-to-center(B-C)portion is.

$$W_{11}=\frac{F}{8\pi D}\left[\frac{d_1^2}{4}-r^2\left(1+\frac{1-v}{2(1+v)}\frac{d_1^2-d_2^2}{d_1^2}\right)+\left(\frac{d_2^2}{4}+r^2\right)\log\frac{2r}{d_1}\right]+$$

$$\frac{d_2^2-4r^2}{8D(1+v)}\left[\frac{(1-v)F\left(d_1^2-d_2^2\right)}{8\pi d_1^2}-\frac{(1+v)P\log\frac{d_2}{d_1}}{4\pi}\right]=$$

$$\frac{F}{8\pi D}\left[\left(\frac{d_2^2}{4}+r^2\right)\log\frac{d_2}{d_1}+\left(\frac{d_1^2-d_2^2}{4}\right)\frac{(3+v)d_1^2-4(1-v)r^2}{2(1+v)d_1^2}\right] \quad (4)$$

Iterate the outer edge deflection with the bending moment M_2, making it be 0 there:

$$-\frac{F\left(d_1^2-d_2^2\right)}{8\pi d_1 D(1+v)}+\frac{M_2 d_1}{2D(1+v)}=0 \quad (5)$$

The above equation is available:

$$M_2=\frac{F\left(d_1^2-d_2^2\right)}{4\pi d_1^2} \quad (6)$$

The deflection generated by the bending moment M_2 is:

$$w=\frac{M_2}{D(1+v)}\frac{4r^2-d_1^2}{8} \quad (7)$$

From formula (6) and (7), the deflection of the A-B part of the circular piezoelectric oscillator is:

$$w_{A-B}=\frac{F}{8\pi D}\left[\left(\frac{d_1^2-4r^2}{4}\right)\frac{d_1^2+d_2^2}{2d_1^2}+\left(\frac{d_2^2+4r^2}{4}\right)\log\frac{2r}{d_1}\right] \quad (8)$$

The deflections of parts B-C is:

$$W_{A-B}=\frac{F}{8\pi D}\left[\left(\frac{d_1^2-4r^2}{4}\right)\frac{d_1^2+d_2^2}{2d_1^2}+\left(\frac{d_2^2+4r^2}{4}\right)\log\frac{d_2}{d_1}\right] \quad (9)$$

From the above theoretical analysis, it can be seen that the vibration displacement of the piezoelectric vibrator is related to the driving force, material parameters and dimensional parameters.

This paper focuses on the effect between the maximum displacement generated by the piezoelectric sheet at the excitation voltage and the physical properties of the structure itself when the intrinsic frequency of the piezoelectric drive structure is close to the frequency of the use scenario.Transient analysis is a method used to determine the dynamic response of a structure subjected to arbitrary time-varying loads. It can be used to determine the variation of displacement, stress, strain and other response values of a structure under steady state load, transient load or a combination of simple harmonic load with time.

Model & Meshing

A single piezoelectric circular membrane actuator model is established, in which the elastic substrate has a radius of 30 mm and a thickness of 0.1 mm, and the piezoelectric diaphragm has a radius of 12.5 mm and a thickness of 0.2 mm. The piezoelectric analysis cell solid226 is selected to mesh the model with a mesh size of 6e-4 m, as shown in Figure 6.

Fig 6. Modeling and Meshing

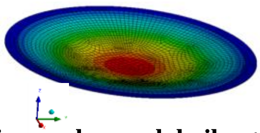
Modal Analysis

Modal analysis refers to the study of the dynamic properties of a structure. Among them, modal refers to the inherent vibration characteristics of a mechanical structure, each of which has a specific inherent frequency, damping ratio and modal vibration mode. Vibration modes, as inherent characteristics of elastic structures, play an important role in analyzing the stability of structures under dynamic loads and certain frequency responses, and the method of modal analysis is also widely used in the field of fault diagnosis.

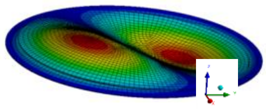
POST1:Allows the results of the entire model to be examined at a particular load step and sub-step (or for a particular time point or frequency).

POST26:The change of a result item of a specified node of the model with respect to time, frequency or other result items can be checked.

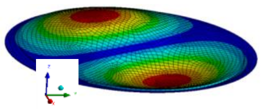
The results are analyzed and processed using POST1 in this paper. The piezoelectric sheet has a diameter of 25 mm and a thickness of 0.2 mm, and the elastic substrate has a diameter of 30 mm and a thickness of 0.1 mm. The modal vibration pattern of the first four orders of the piezoelectric actuator is obtained by modal analysis, as shown in Figure 7.



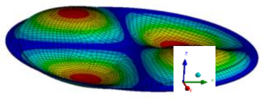
(a) First-order modal vibrations



(b) Second-order modal vibrations



(c) Third-order modal vibrations



(d) Fourth-order modal vibrations

Fig. 7. First four orders of modal vibrations

Figure 7 shows that the drive source of the piezoelectric injection device only needs the piezoelectric sheet to produce vibration in the direction of fixed thickness, so only the first-order vibration root meets the actual demand, therefore the study is conducted for the first-order vibration type and frequency.

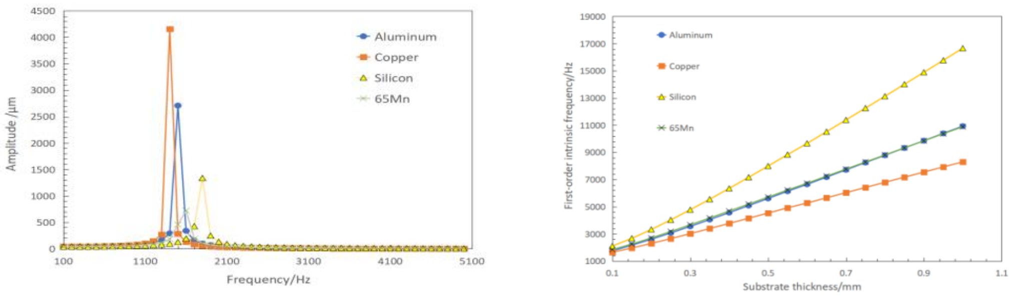
IV. Harmonic Response Analysis

Harmonic response analysis as a technique for determining the steady-state response of a linear structure subjected to a load that varies sinusoidally (simple harmonic) with time. The purpose of the analysis is to calculate the response of the structure at several frequencies and to obtain some curves of the response values (usually displacements) versus frequency so that the designer can predict the continuing dynamic properties of the structure and verify that the design can overcome resonance, fatigue, and other harmful effects caused by forced vibrations. The radius and thickness of the piezoelectric sheet are selected as 13.5 mm and 0.2 mm, respectively, and the radius and thickness of the elastic substrate are 15 mm and 0.1 mm, respectively, and the fixed support is the radial surface of the substrate. The harmonic response analysis is performed for the driving structures of different piezoelectric materials, and only the first-order intrinsic frequency is analyzed since the first-order vibration pattern is required to satisfy the piezoelectric injection device.A sinusoidal voltage of 200 V is applied to the upper and lower surfaces of the piezoelectric sheet, and the harmonic response curve of the system is shown in Figure 8. According to the curves, it can be seen that the structures all resonate near the first-order intrinsic frequency with a maximum amplitude. The first four orders of intrinsic frequencies are shown in Table 2.

Table. 2. First-order inherent frequency

Material	Aluminum	Copper	Silicon	65Mn
First-order frequency/Hz	1756.8	1653.5	2102.9	1849.9

Fig. 8. Frequency response curve



Analysis of the effect of piezoelectric sheet radius on the first-order intrinsic frequency

The relationship between the radius and the first-order intrinsic frequency is analyzed for different piezoelectric sheet radii with constant thickness, as shown in Figure 9. It can be seen that the first-order intrinsic frequency increases nonlinearly with the gradual increase of the radius. When the radius of the piezoelectric sheet is around 13 mm, the change of the first-order intrinsic frequency is relatively small.

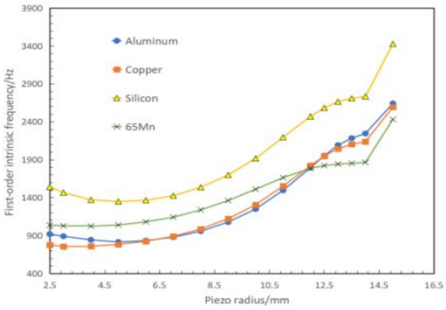
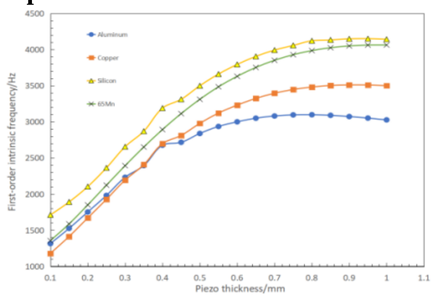


Fig. 9. Radius of piezoelectric sheet versus first-order intrinsic frequency

Analysis of the effect of piezoelectric sheet thickness on the first-order intrinsic frequency

The substrate radius is 15 mm and the piezo radius is 13.5 mm. For different piezo thicknesses, the relationship between displacement and thickness is analyzed when the thickness varies from 0.1 mm to 1 mm, as shown in Figure 10. It can be seen that as the thickness of the piezoelectric sheet gradually increases, the first-order inherent frequency of the system tends to increase more obviously; when the thickness increases to about 0.7 mm, the change trend is relatively flat; when the thickness increases to about 0.95 mm, the first-order inherent frequency of all four materials decreases.

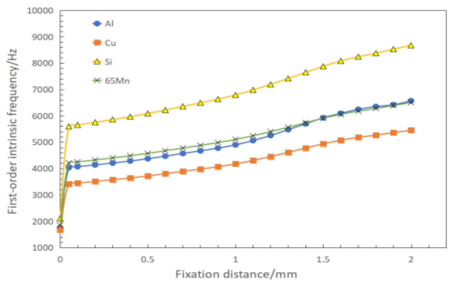
Fig. 10. Relationship between piezoelectric sheet thickness and first-order intrinsic frequency



Analysis of the effect of substrate thickness on the first-order intrinsic frequency

The relationship between the first-order intrinsic frequency of the system and the thickness of the substrate is analyzed for different substrate thicknesses in the range of 0.1 mm to 1 mm, as shown in Fig. 11, for a radius of 13.5 mm, a thickness of 0.2 mm, and an elastic substrate radius of 30 mm. It can be seen that as the substrate thickness increases, the first-order intrinsic frequency gradually increases; it can be clearly seen that the first-order intrinsic frequency versus thickness curves are relatively similar when Si and 65Mn are chosen as the piezoelectric sheet materials.

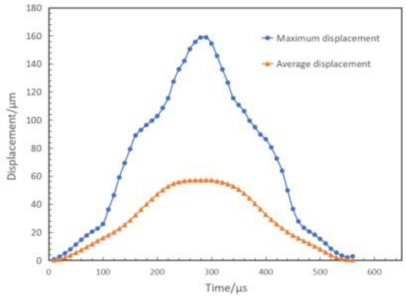
Fig. 11. Baseboard thickness versus first-order geo frequency



Analysis of the effect of fixed support distance on the first-order inherent frequency

From the piezoelectric microdrop injection device in Fig. 4, it can be found that the elastic substrate needs to have fixed constraints at both ends to prevent the piezoelectric sheet from vibrating too much when it is subjected to the excitation voltage; therefore, the effect of the fixed support distance fixed support distance L on the driving characteristics of the device needs to be investigated. The relationship between the first-order intrinsic frequency and the fixation distance is analyzed for different fixation support distances L. The relationship between the first-order intrinsic frequency and the fixation distance is shown in Fig. 12 for different fixation support distances L. The substrate radius is 15 mm and the thickness is 0.1 mm, and the piezoelectric sheet radius is 13.5 mm and the thickness is 0.2 mm. It can be seen that when only the radial outer surface of the substrate is fixed, the first-order inherent frequency of the system is the smallest; the inherent frequency increases gradually with the increase of the fixed support distance.

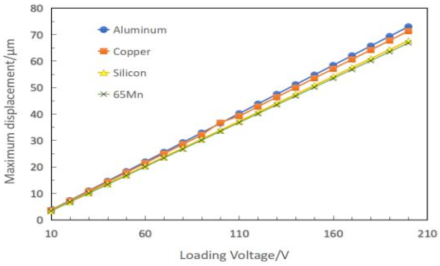
Fig. 12. The relationship between the solid support distance and the first-order inherent frequency



Transient Analysis

This paper only uses aluminum as the piezoelectric material for transient analysis, the radius and thickness of the piezoelectric sheet are 13.5 mm, 0.2 mm, and the radius and thickness of the elastic substrate are 15 mm, 0.1 mm, respectively. the displacement versus time is shown in Fig. 13, which takes the displacement curve of the structure under 200V excitation in one cycle with time, it can be seen that as the time increases, the displacement generated by the piezoelectric sheet tends to increase and then decrease. It can be seen that with the increase of time, the displacement generated by the piezoelectric sheet shows a trend of increasing and then decreasing, and the curve exhibits symmetrical characteristics.

Fig. 13. Load loading time versus displacement



Static Analysis

According to Figure 13, it can be seen that the displacement has a maximum value when the excitation voltage is maximum. In the piezoelectric microjet device, the piezoelectric sheet is used as the power source, and the size of the sprayed microdroplets as well as the forming accuracy are related to the maximum displacement; therefore, the relationship between the maximum displacement of the piezoelectric sheet and the physical characteristics of the structure itself needs to be studied through static analysis.

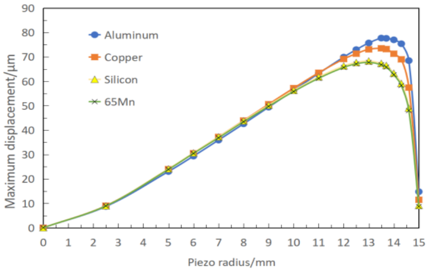
Analysis of the effect of piezoelectric sheet radius on maximum displacement

The piezoelectric sheet is excited with a voltage difference of 200 V. The elastic substrate is restrained by fixed supports around it with a radius of 15 mm and a thickness of 0.1 mm, and the piezoelectric diaphragm has a radius of 0 ~ 12.5 mm and a thickness of 0.2 mm.

The simulation results are shown in Fig. 14. Under the constant substrate structure parameters and loading voltage, the piezoelectric diaphragm shortens and deforms, and the displacement generated by the elastic substrate shows a trend of increasing and then decreasing with the increase of the piezoelectric diaphragm radius.

According to the relationship curve between radius and displacement, it can be seen that the maximum displacement is achieved when the ratio of piezoelectric diaphragm radius to elastic substrate radius is around 0.9. Under the same conditions, the maximum displacement is greater when the piezoelectric sheet material is aluminum than the rest of the materials; the radius-displacement relationship curves for silicon and 65Mn materials have similar trends.

Fig. 14. Radius of piezoelectric sheet versus maximum displacement



Analysis of the effect of piezoelectric sheet thickness on maximum displacement

The excitation voltage difference of the piezoelectric sheet is 200 V, the fixed support constraint around the elastic substrate, the radius of the elastic substrate is 15 mm, the thickness is taken as 0.1 mm, the radius of the piezoelectric diaphragm is 13.5 mm, and the relationship curve between the maximum displacement of the system and the thickness of the piezoelectric sheet is discussed in the range of 0.1 mm ~ 1 mm, as shown in Figure 15. From the figure, it can be seen that the maximum displacement of the system decreases gradually with the increase of the piezoelectric sheet thickness.

V.Conclusion

Simulation analysis of the modal, transient and static displacements of single piezoelectric ceramics is carried out by ANSYS Workbench in this paper in conjunction with the design of piezoelectric micro-jet device. The effects of the intrinsic frequency and maximum displacement of the piezoelectric structure with respect to radius, thickness and fixed support distance are investigated and analyzed for different materials of piezoelectric ceramics, which provide theoretical basis and application support for the subsequent research. The analysis shows that the displacement of the piezoelectric sheet increases linearly with the increase of the excitation voltage; the maximum displacement of the structure is influenced by the radius and thickness of the piezoelectric sheet and the elastic substrate; according to the harmonic response analysis, it is known that the distance of the fixed support and the thickness of the substrate have the greatest influence on the inherent frequency of the system. Therefore, the substrate thickness and the distance of the fixed support can be reduced appropriately to obtain the required displacement output of the piezoelectric microjet as long as the structure space allow.

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