# Vibration Characteristics of Piezoelectric Ceramic Elements with Large Anisotropy and Its Application in Ultrasonic Probe

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***Abstract:*** With the development of ultrasonic machining technology, meeting the needs of modern industrial production, improving product quality and efficiency and reducing cost have become one of the urgent problems to be solved. Using piezoelectric ceramics to study the vibration characteristics of materials has become the most important and effective means. Piezoelectric ceramics is a new type of composite material. It has high power density, low loss, dielectric constant and good mechanical properties. It can obtain good machining effect in ultrasonic machining. Therefore, in this paper, the application of piezoelectric ceramic materials in ultrasonic probe is studied according to the vibration characteristics of piezoelectric ceramic materials. Firstly, this paper introduces the research status of piezoelectric ceramic materials, summarizes the characteristics of different piezoelectric ceramic materials, analyzes and summarizes their characteristics under different parameters, and then compares various parameters. Finally, the experimental results are as follows: PMN-PT raw materials have very good properties and have been commercialized in recent years. If it can be used in this field, it will have superior properties that other raw materials can't compare. Under the same structure and voltage, the maximum output displacement of piezoelectric laminate is larger than pzt5a, which also verifies that pzt4 is a transmitting piezoelectric ceramic and pzt5a is a receiving piezoelectric ceramic. When the stress is applied at the centroid of the fractal piezoelectric ceramic vibrator, the strain degree of the whole structure will increase with the increase of the distance from the centroid. According to the forward piezoelectric effect of piezoelectric materials, the greater the degree of deformation, the greater the voltage generated on the surface of piezoelectric materials.

## 1. Introduction

With the rapid development of Chinese economy, energy shortage has become a major problem

restricting social stability and sustainable utilization. Piezoelectric materials are needed in the exploration, exploitation and use of petroleum resources. However, due to the shortcomings of traditional process methods, such as processing difficulties, it is particularly important to design a new technology to replace manual work in order to meet the needs of modern industrial production. Piezoelectric ceramics are widely used in modern industry and national defense. They have high working frequency and low energy conversion efficiency. At present, some progress has been made in ultrasonic vibration, piezoelectric crystallization and dielectric impedance substrate in China and applied to practical engineering fields.

Many scholars have studied the vibration characteristics of piezoelectric ceramics with large anisotropy. Chunguang studied the vibration characteristics of an ultrasonic transducer composed of two piezoelectric rings. This study is necessary for the design of ultrasonic sensors and actuators composed of piezoelectric ring laminations. Theoretically, the natural frequencies and modes of the radial and axial modes of the transducer are obtained from the motion equation and boundary conditions. Through finite element analysis, we get the impedance curve of natural frequency and the amplitude of supplementary three-dimensional vibration mode. In the experiment, the natural frequency is measured by impedance analyzer, and the radial in-plane vibration mode is obtained from the amplitude measured by laser in-plane vibration meter. The theoretical analysis is verified by comparing the three results, and the variation of vibration characteristics with the thickness of piezoelectric ring is determined [1]. Jeon, J. Y. studied the spray characteristics of piezoceramic sprayer. Pzw-pmn-pzt and other piezoelectric ceramics containing $MnO_2$ were prepared, and the physical, dielectric and piezoelectric properties of the samples were studied according to the molar ratio, sintering temperature, accessories and substitutes. A theoretical equation for the atomization of aerosolized particles with a piezoelectric ceramic sprayer is derived. The length of the nozzle is changed to control the atomization amount and atomization particle size of the liquid (including water, diesel and mixed oil) passing through the nozzle [2]. C Piao studied the vibration characteristics of multilayer piezoelectric transducers. The sensor is composed of a plurality of piezoelectric layers for excitation, a piezoelectric layer for sensing and an insulating layer. Theoretically, based on the motion equation and boundary conditions, the natural frequencies and modes of the radial in-plane modes of the piezoelectric transducer are obtained. Through finite element modal analysis, the natural frequency is obtained from the calculated impedance curve, and the amplitude is calculated to supplement the three-dimensional vibration mode [3]. YM Han proposed the performance evaluation of an ultrasonic vibrator for uniform atomization, which can be used for conformal coating control in the manufacturing process of light-emitting diodes or wall wetting control in fuel injection of vehicle engines [4]. J Wang derived the theoretical solutions of three radial layered piezoelectric ceramic/epoxy resin cylindrical composite transducers, which are composed of a solid epoxy resin disk, two axially polarized piezoelectric ceramic rings and two epoxy resin rings. Two piezoelectric ceramic rings are functional components that can drive and adjust the properties of the composite. According to different functions, three typical sensors are developed. The first involves two piezoelectric ceramic rings, which are electrically connected in parallel as actuators. The other two involve only one piezoelectric ceramic ring as the actuator and the other ring connected to the resistor as the sensing element to adjust the electromechanical characteristics [5]. HQ tran gives an analytical solution of the free vibration characteristics of functionally graded carbon nanotube reinforced composite (fg-cntrc) hyperbolic shallow shells with integrated piezoelectric layer [6]. Shan Shengyu measured the transverse piezoelectric coefficient d31 of piezoelectric ceramics by using Lloyd mirror interference, and installed the flat reflector on the same side of the piezoelectric ceramics. When the piezoelectric ceramics have a longitudinal

change of micron scale under the influence of external transverse charge. The distance between it and the interference fringe of laue mirror changes accordingly. Thus, the micro changes of piezoelectric ceramics are amplified. By using the camera, the moving direction of interference fringes and the change of fringe spacing can be obtained, and analyzed by MATLAB program, the corresponding shape variables of piezoelectric ceramics under different driving currents can be obtained. Thus, the piezoelectric coefficient of the material is calculated [7]. The piezoelectric and ferroelectric properties of Sha B were studied. All samples have tetragonal structure at normal temperature. There was no significant change with the increase of Ba concentration. Ba doping significantly improves the piezoelectric properties of PSN PZT. When x = 0.05, the maximum is d33 ~ 560 PC/N, Tc ~ 317 ℃ [8]. The purpose of the P mangaiyarkarasi study is to determine the maximum power that piezoelectric harvesters can be used to provide energy to medical devices such as prosthetic hands. Structural and material analysis shows that the maximum power generated by e structure with ceramic material (PZT-5H) and rectangular anti vibration mass ensures the effective power of IMD [9]. M arefi analyzed and studied the electroelastic analysis of cylindrical sandwich pressure vessel with porous core and two integrated piezoelectric panels. The displacement field along the thickness direction is described by using the third-order shear deformation theory [10]. In recent years, researchers have put forward a lot of related work. However, the existing research work does not consider the influence of large anisotropy on piezoelectric ceramic materials at the same time, that is, in ceramic materials, the effect of piezoelectric with large anisotropy on ceramic materials.

With the development of ultrasonic machining technology, piezoelectric ceramics have shown great advantages in aerospace, aviation and military fields. The innovations of this paper are as follows: (1) Take a certain type of piezoelectric crystal (STM) as the research object, and its vibration characteristic parameters are analyzed. (2) The frequency and power are meshed by ANSYS software. (3) The corresponding vibration mode diagram and spectrum distribution diagram are obtained to characterize the change of formant position and instantaneous attenuation with time under different parameters. It is compared that the isotropic structure can significantly improve the amplitude and voltage amplitude under certain conditions.

## 2. Experiments and Methods

### 2.1. Research Content

In the use of ultrasonic probe, piezoelectric material is widely used and has relatively good performance, but it also has some defects. Therefore, this paper takes a anisotropic large metal thin-walled steel pipe as the research object. The simulation calculation and experimental verification are carried out by using the finite element analysis method. The vibration characteristics of materials are tested and analyzed under different loading parameters, and the stress-strain curve and dynamic time-varying and transient response characteristics are obtained. At the same time, the anisotropy in the ultrasonic probe can be calculated, which is one of the methods to provide reference basis and ideas for the optimal design of piezoelectric ceramic structure [11-12].

### 2.2. Piezoelectric Ceramic Materials

### 2.2.1. Piezoelectric Materials

Piezoelectric materials are dielectric materials with piezoelectric effect. Piezoelectric effect can

be divided into positive piezoelectric effect and inverse piezoelectric effect. The deformation of dielectrics under the action of mechanical force leads to the charge phenomenon proportional to the force on some end faces, which is called positive piezoelectric effect. On the contrary, under the action of electric field, the dielectric becomes a phenomenon with linear relationship between electric field intensity, which is called inverse piezoelectric effect. Piezoelectric effect is closely related to crystal symmetry. Among the thirty-two point groups of seven crystal systems, twenty-one point groups have no symmetry center, while twenty point groups have piezoelectric effect. There must be positive and inverse piezoelectric effect in crystals with positive piezoelectric effect, and vice versa. It should be noted that any dielectric will expand when exposed to a strong electric field. Therefore, only when the stress is linear with the electric field intensity, it corresponds to the inverse piezoelectric effect. If the stress has a quadratic relationship with the electric field strength, it is called the electric expansion effect [13-14].

Piezoelectric raw materials can be divided into several types according to different classification methods. According to the properties of raw materials, they can be divided into single crystal, polycrystalline (piezoelectric ceramics), piezoelectric polymer and piezoelectric composite raw materials. This is our main category. Another classification is that according to the shape of raw materials, they can be divided into two categories, namely block raw materials and piezoelectric films [15-16]. Piezoelectric expansion constant D, dielectric constant and electromechanical coupling coefficient K determine the piezoelectric properties of piezoelectric materials. The piezoelectric strain constant reflects the coupling strength of each force point of raw materials. It is the ratio of potential shift to voltage. It mainly indicates the quality of electromechanical conversion performance. The higher the value, the better the conversion performance. For the energy recovery device, the larger the dielectric constant of piezoelectric material, the more charge or electric energy can be stored, which can effectively reduce the resistance of the device and reduce the internal energy loss of the device.

### 2.2.2. Selection of Piezoelectric Ceramics

Piezoelectric ceramics is a kind of functional ceramics that can realize mutual energy conversion in different physical fields. A typical example is the conversion of mechanical energy and electrical energy. In the field of material science, piezoelectric ceramics is a non-metallic inorganic material. Due to the excitation of external mechanical stress or electric field, charges with opposite polarity are generated on the surface of piezoelectric crystal. The movement of charges causes piezoelectric crystal to produce displacement voltage or ceramic effect. It is mainly used in the fields of medicine and health, underwater communication, nondestructive testing, electroacoustics and so on. Piezoelectric ceramic products range from signal processing filter, frequency converter, acousto-optic spectrum analyzer to transmission field, ultrasonic measuring device and sonar, from piezoelectric motor to piezoelectric resonator, from high-precision instrument in the industrial age to electric lighter and fan used in people's daily life. As a component of electric ceramics, piezoelectric ceramics have certain influence and can measure the progress and development speed of any human civilization [17-18].

Piezoelectric ceramic plates also have circular, square, fan-shaped and other shapes. The ceramic material constituting the piezoelectric ceramic plate is thin and brittle, so it should be handled with care during high-altitude transportation or use, with strong impact or impact, otherwise the ceramic material may crack and cause product damage. It should pay attention to the specific technical use. Do not let the tip of the multimeter and other hard objects scratch the surface of the piezoelectric

ceramic plate, because the electrode of the piezoelectric ceramic plate is easy to be oxidized. Be careful to keep the surface clean and store it in a closed container as far as possible to prevent the electrode oxidation from affecting its performance. In this paper, PZT piezoelectric ceramics are used as piezoelectric materials. PZT piezoelectric ceramics mainly include the following series: PZT-4, PZT-5A, PZT-5H, PZT-8, etc. With large relative dielectric constant and fast charge and discharge, PZT-5 is suitable for high-frequency converter material, while PZT-5 has large dielectric constant and slow charge and discharge speed [19-20].

## 2.3. Piezoelectric Ceramic Sensing Principle

When piezoelectric ceramics are combined with structures similar to cantilever beams, the one-dimensional sensing and driving equations applied to piezoelectric ceramics only need to consider the deformation and tension of piezoelectric ceramics in one direction. If it is adhered to the probe like structure, it shall be applicable to the two-dimensional equation of detection and motion, that is, it is necessary to consider the elongation and stress of the piezoelectric ceramic material in two directions on the plane. When the piezoelectric ceramic material is adhered to the conical cylinder as the sensor and actuator, it can be roughly regarded as the glue on the plane structure [21].

The piezoelectric ceramic sensor and driving equation can be derived from the composition equation of piezoelectric ceramics. In order to facilitate theoretical analysis, the following assumptions should be made for piezoelectric ceramic sensors and actuators:

(1) The piezoelectric ceramic sheet and the base material are isotropic in the X-Y plane;

(2) The piezoelectric ceramic sensor and actuator are ideally adhered to the substrate surface of the damping object, and the thickness of the adhesion layer is zero;

(3) The stress on piezoelectric ceramics and damping objects is continuous in the whole structure;

For piezoelectric ceramic sensors, if an ideal charge amplifier is connected externally, it can be obtained from $\sigma_3 = 0$ and $E_3 = 0$:

$$D_3 = d_{31}\left(\sigma_1 + \sigma_2\right) \tag{1}$$

From formula (1):

$$\varepsilon_1 = S_{11}\sigma_1 + S_{11}\sigma_2 \tag{2}$$

$$\varepsilon_2 = S_{12}\sigma_1 + S_{12}\sigma_2 \tag{3}$$

The young's modulus and Poisson's ratio of piezoelectric ceramic sensor are taken as:

$$E_{\mathrm{p}} = \frac{1}{S_{11}}, \mu_P = -\frac{S_{12}}{S_{11}} \tag{4}$$

From formula (4):

$$\sigma_1 = \frac{E_{\mathrm{p}}}{1 - \mu_p^2}\left(\varepsilon_1 + \mu_p\varepsilon_2\right) \tag{5}$$

$$\sigma_2 = \frac{E_p}{1-\mu_p^2}\left(\varepsilon_2 + \mu_p\varepsilon_1\right) \tag{6}$$

Then the relationship between the amount of charge generated by the sensor and the strain can be approximately expressed as:

$$Q = D_3 A_3 = l_1 l_2 d_{31}\frac{E_p\left(\varepsilon_1 + \varepsilon_2\right)}{1-\mu_p} \tag{7}$$

Where L1 and L2 are the length and width of the sensor, the relationship between the output voltage of the two-dimensional piezoelectric ceramic sensor and the strain of X and Y axes is as follows:

$$V_s = \frac{Q}{C_p} \tag{8}$$

Where $C_p$ is the capacitance of piezoelectric ceramic sensor. It can be calculated from (9):

$$C_p = \frac{l_1 l_2 e_{33}^\sigma}{t_p} \tag{9}$$

Where $t_p$ is the thickness of piezoelectric ceramic sensor. According to the sensing equation, piezoelectric ceramics can be used as a sensor in vibration experiments to measure the magnitude of strain, and the voltage generated by the sensor is linear with the magnitude of strain, so the magnitude of vibration strain can be judged according to the magnitude of output voltage.

## 3. Results and Analysis

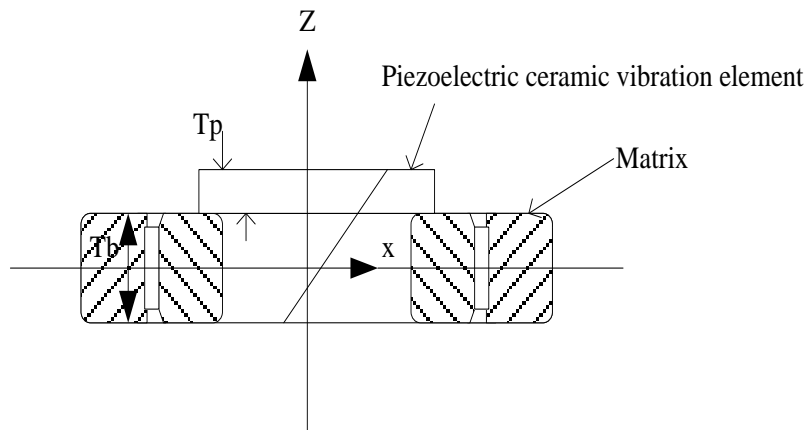### 3.1. Vibration Principle of Piezoelectric Ceramic Elements



*Figure 1. Schematic diagram of piezoelectric ceramic vibration elements*

As shown in Figure 1, the piezoelectric ceramic plate is adhered to the surface of the ultrasonic probe, that is, the actuator is only adhered to one side of the substrate. The purpose of combining

the vibration element is to reduce the vibration of the substrate. In order to reduce vibration, torque opposite to vibration is generated. If the piezoelectric ceramic is bonded to the surface of the ultrasonic probe, the vibration can be reduced by generating a local torque opposite to the vibration direction, and the generated torque value has a linear relationship with the output voltage. Therefore, it is convenient and feasible to use piezoelectric ceramics in active vibration control system.
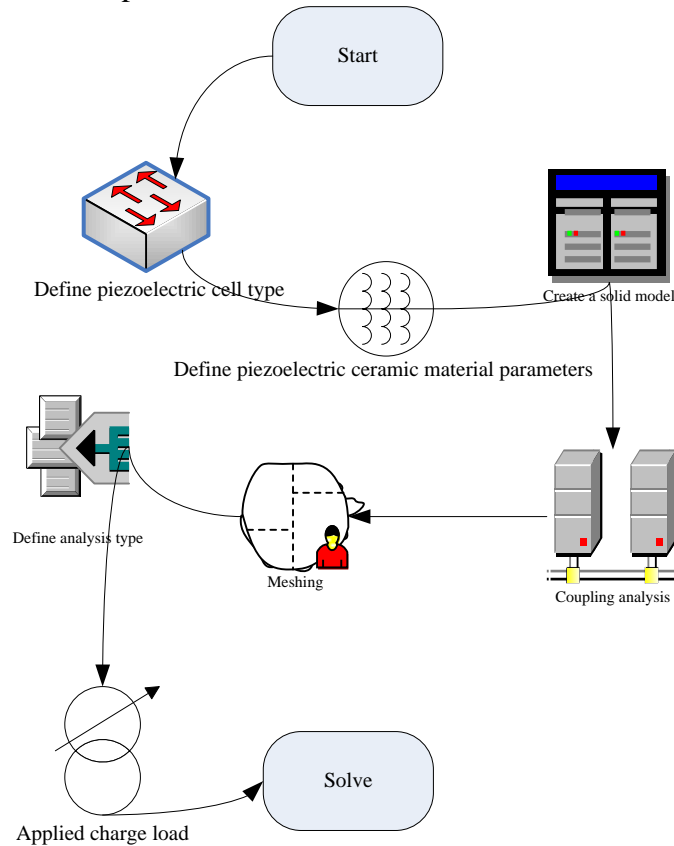


*Figure 2. Calculation process of vibration parameters of piezoelectric ceramic element*

This paper uses ANSYS finite element analysis software, which can carry out structural analysis, thermal analysis, fluid analysis, electromagnetic field analysis and multi physical field analysis. It is the only CAE software that really carries out multi field coupling at present. With the help of ANSYS finite element calculation software, not only the piezoelectric layered model can be established by using three-dimensional solid-state elements, but also the constitutive relationship of the structure can be satisfied. Considering the efficiency of the solution, the results obtained by analyzing the finite element software are more intuitive than those obtained by solving differential equations. It can be seen from Figure 2 that the direct coupling method is adopted in this item. The piezoelectric layer adopts solid5 element. Solid5 is 8 node elements, and each node has 6 degrees of freedom, which can be displacement, temperature, voltage and magnetic scalar positions. Because solid5 is a unit and a 3D entity, creating a solid model is more intuitive and convenient. The solid 5 unit can be directly used for thermoelectric coupling unit or electromagnetic coupling unit. In the case of piezoelectric analysis, it can directly couple the output structure by applying voltage, and the displacement changes without transferring charge.

*Table 1. Material performance data of piezoelectric ceramics*

| Pressor ceramic raw material | KP% | K33% | Kt% | K31% | d31 (pm/V) |
|---|---|---|---|---|---|
| PZT4 | 58 | 70 | 52 | 42 | -256 |
| PZT5A | 60 | 70.5 | 49 | 44 | -310 |
| PMN-PT | 51 | 56 | 42 | / | -1000 |
| PVDF | 56 | 69 | 51 | 12 | -23 |

Table 1 shows that although piezoelectric polymer (PVDF) shows excellent properties in many aspects, such as light weight, good flexibility and high voltage constant, it is very suitable for long-term application environment and high resistance. One of the obstacles to its application is its low piezoelectric strain constant, easy to change size and difficult to burn, which is difficult to be used in MEMS process. MFC is made of piezoelectric ceramic fiber mixed with epoxy resin. Although it has excellent performance in several aspects, it is difficult to be compatible with MEMS technology. AlN, ZnO and PZT films can be easily integrated into semiconductor materials, making them common piezoelectric thin film materials in the field of MEMS. In addition, PMN-PT raw material has very good performance and has been commercialized in recent years. If it can be used in this field, it will have superior performance unmatched by other raw materials.

## 3.2. Vibration Performance Analysis of Piezoelectric Ceramic Components

*Table 2. The front fifth-order resonant frequency of the piezoelectric ceramic oscillators*

| First order resonant frequency(Hz) | Second order resonant frequency (Hz) | Third order resonant frequency(Hz) | Fourth order resonant frequency(Hz) | Fifth order resonant frequency (Hz) |
|---|---|---|---|---|
| 38.25 | 105.36 | 214.3 | 268.10 | 325.34 |

It can be seen from Table 2 that the piezoelectric ceramic vibrator vibrates after absorbing the mechanical vibration energy in the environment, and the vibration causes the deformation of the fractal piezoelectric ceramic vibrator. In the actual experiment, it is important to ensure that the piezoelectric ceramic plate will not crack during vibration, so static analysis is needed. The purpose of static analysis is to understand the undamaged maximum displacement of fractal piezoelectric ceramic vibrator. The static analysis shows that when the centroid of the fractal piezoelectric ceramic vibrator is charged, the elongation of the whole structure increases with the increase of the distance from the centroid. According to the positive piezoelectric effect of piezoelectric materials, the higher the degree of deformation, the higher the voltage generated on the surface of piezoelectric materials.
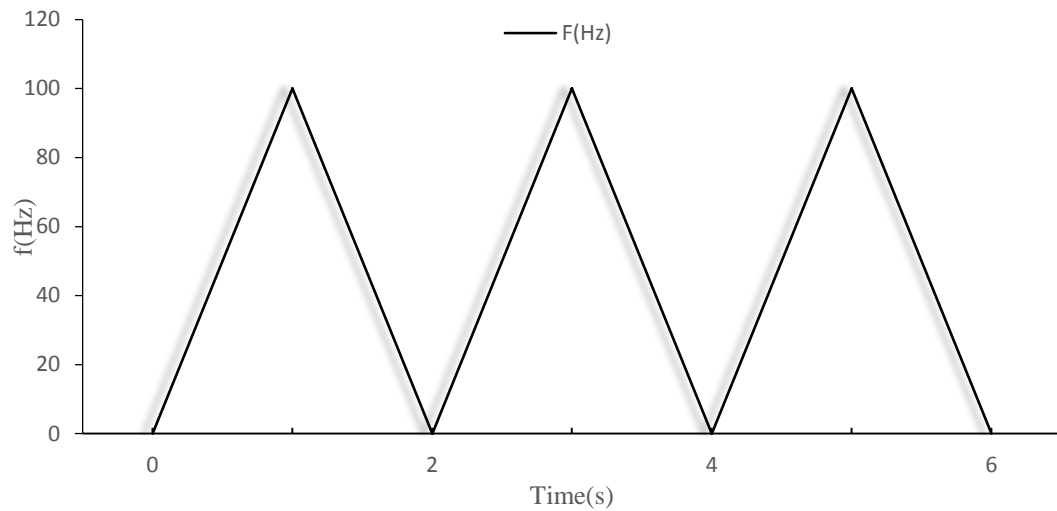
*Figure 3. Relationship between periodic sweep frequency and time*

In order to more comprehensively test the output voltage in the frequency range of 0 ~ 100Hz, detect the resonant frequency of piezoelectric vibration sensor and the energy conversion density of fractal piezoelectric ceramic vibration sensor in low frequency environment, we designed the periodic scanning frequency experiment of piezoelectric vibration transducer in the range of 0 ~ 100Hz. Periodic frequency sweep test is used to test the change of output voltage of vibration sensor under periodically changing vibration frequency. The scanning period is fixed at 2 seconds, which means that the oscillation frequency of the exciter increases from 0 Hz to 100 Hz in a period of 0 to 2 seconds. As shown in Figure 3, it shows the evolution of the oscillation frequency of the exciter in one cycle.
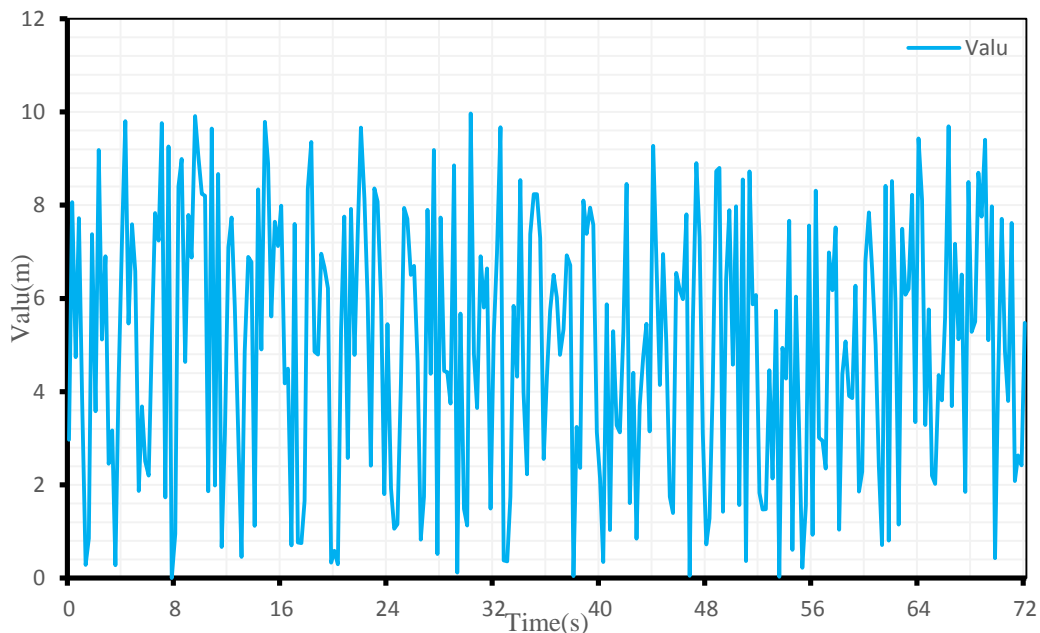


*Figure 4. Piezo electric ceramic materials show a displacement response in the Z direction*

As can be seen from Figure 4, the maximum displacement in Z direction of piezoelectric ceramic

node at 0.60s is 7.467*10-7m. From the comparative analysis of the above vibration response characteristics, the actuation effect of PMN-PT piezoelectric sheet on the middle beam of rigid frame is more obvious than that of PVDF piezoelectric sheet on the middle beam of rigid frame, which is consistent with the static analysis results and verifies the regularity of selecting piezoelectric sheet in this paper.

Generally, isotropic material means that the material composition and properties in all directions are uniform, and the response to electromagnetic wave does not change with the polarization mode and

propagation direction of incident wave. Then, anisotropic materials have different electromagnetic response values in different directions.
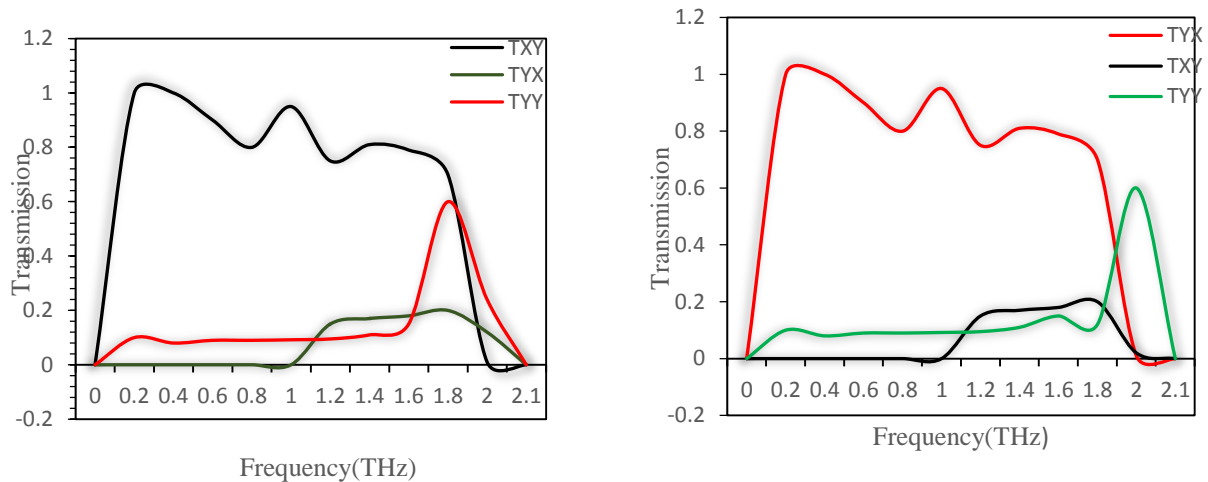


(a)Transmission spectrum diagram of the electromagnetic waves along the -Z direction
(b)Transmission spectrum diagram of the electromagnetic waves along the + Z direction

*Figure 5. Simulation transmission spectrum for (a) backward (+Z to –Z) and (b) forward (-Z to +Z) incident direction*

It is obvious from Figure 5 (a) that when the incident light is incident along the - Z direction, the minimum value of the cross transmission coefficient (TXY) is greater than 0.8 when the frequency is 0.38th to about 1.89thz, while it can be seen from Figure 5 (b) that when the incident y polarization is incident along the + Z direction, the cross transmission coefficient is very low and its value is just equal to the cross transmission coefficient of the incident x-polarized light along the - Z direction. This forms the characteristic of asymmetric transmission.

*Table 3. Distribution of SR measurements of different materials on ultrasound probes*

| Pressor ceramic raw material | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| PZT4 | 1.92±0.17 | 1.85±0.11 | 1.92±0.10 |
| PZT5A | 2.25±0.30 | 2.16±0.12 | 2.04±0.12 |
| PMN-PT | 1.86±0.16 | 1.98±0.15 | 2.03±0.15 |
| PVDF | 1.98±0.17 | 2.01±0.17 | 2.02±0.13 |

It can be seen from table 3 that the four piezoelectric ceramics were tested by RTE under three groups of experimental conditions, and the ROI of the ultrasonic phantom and the SR value of the surrounding reference plane were measured. CV was one of the values of groups 1, 2 and 3, and the

difference was statistically significant (F = 15.853, P < 0.001). There was no significant difference in CV values between group 2 and group 3 (q = 0.625, P = 0.685). The CV values of group 2 and group 3 were lower than those of group 1 (q = 4.732, P < 0.001; q = 5.038, P < 0.001), that is, the measurement data of group 2 and group 3 were more stable and reproducible than those of group 1.
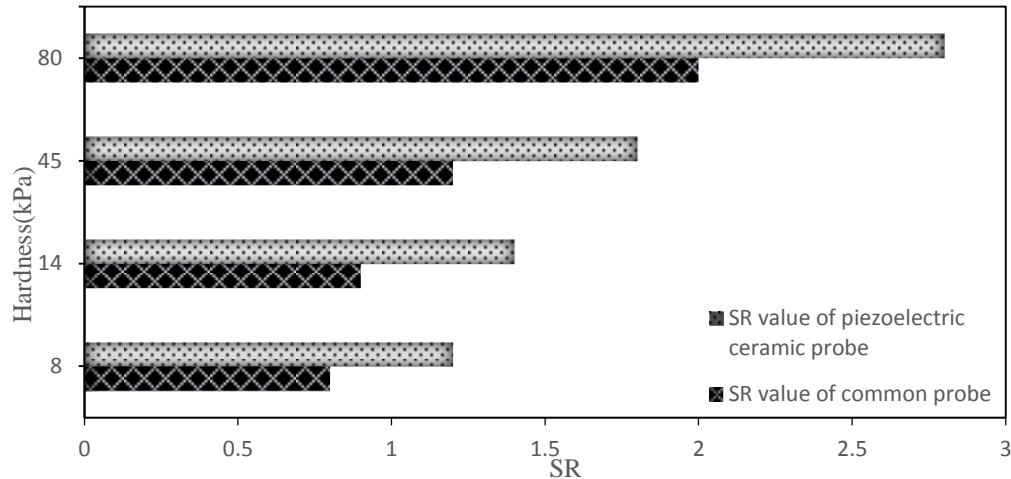


*Figure 6. Distributions of SR measuring values of different elastic modulus ultrasonic phantoms*

The SR values of four kinds of hardness ultrasonic elastic imaging models with elastic modulus of 8, 14, 45 and 80 kPa, diameter of 10.4 mm and center depth of 3 cm were measured respectively. The four elastic modulus data were divided into three levels: group I (80 kPa vs 45.14.8 kPa) and group II (80.45 kPa vs 14.8 kPa) III (80.45, 14 kPa vs 8 kPa). There are three groups. As can be seen from Figure 6, there is no statistically significant difference in SR values between 8KPa and 14kpa groups (P = 0.258), SR of ordinary material probe is between 8.45 and 80kPa, Sr is between 14, and the difference between 45 and 80 kPa values is statistically significant (F = 426.013, P < 0.001; F = 543.084, P < 0.001). The piezoelectric ceramic probe performed elastic imaging on four elastic modulus analogues through pressure feedback information. The SR values of ultrasonic probes with different hardness were statistically different (F = 992.627, P < 0.001).

## 4. Discussion

At present, vibration exists all the time in the environment we live in, and mechanical vibration is the most common one, whether in road traffic, industrial production, military, aircraft and other equipment, or in the daily movement of various life bodies such as human beings and animals, blood flow in blood vessels, heart beating and other processes. The occasions mentioned above, such as production and life, are important application fields of wireless sensors and electronic components. The power density of mechanical vibration energy is very high, which can reach 100 μW/cm3 or even higher. The micro vibration energy density applied to large mechanical vibration can reach about 800 μW/cm3. When the human body walks, the energy output of the impact between the heel and the ground can reach the order of 1W. Because of the above advantages, mechanical vibration energy has become the main research direction of many scientific researchers. Mechanical vibration energy has high power density and a wide range of sources. Compared with other acquisition methods, it can not be affected by weather, location and other lighting conditions, and has no impact on the environment. International research has been carried out in this field, and it is generally recognized that it is promising to solve the power supply problem of microelectronic

components.

Piezoelectric ceramics have many excellent characteristics, such as high-resolution characteristics, it can produce continuous output displacement under small input voltage, and it has high-frequency characteristics, and can respond quickly at high frequency of 100kHz. It has large output characteristics and can output large force and torque under the condition of small input voltage. In addition, the energy consumption and noise of piezoelectric ceramics are very small. These advantages of piezoelectric ceramics make it more and more widely used in engineering, especially in various sensor and actuator materials. Therefore, it has a good application prospect in the field of vibration reduction.

At present, the research and analysis of piezoelectric ceramic laminated structure, research field and research results are mainly at the laboratory level, and the research on the physical properties of piezoelectric materials is at the advanced stage. However, the combination of different layers uses piezoelectric effect and physical coupling to study the vibration law of piezoelectric layered structure, and there is a lot of room for improvement in the research of piezoelectric layered structure. The structural style is complex, but the basic components such as rods, plates, beams and so on. The research also focuses on some basic components of these structures, and there is less research on the overall vibration of space. Therefore, the piezoelectric effect activation analysis method is applied to the damage detection of rigid space frame and piezoelectric plate, because the influence law of actuator on the damage of space frame has certain practical significance. Because piezoelectric analysis often involves multi physical field coupling analysis, the transformation between different physical fields in piezoelectric effect can be visualized through computer simulation to more accurately express the actual situation between different physical fields.

## 5. Conclusion

With the development of society, energy problem has become one of the important challenges facing mankind. In the development and utilization of new energy and energy conservation and emission reduction, it also depends on piezoelectric ceramics to a great extent. For piezoelectric crystals, the inverse relationship between resistivity and material natural frequency is very complex, and it is difficult to directly calculate its vibration characteristics. This situation can be considered when forming a good energy conduction band with the metal contact surface. When the metal is under pressure, it will produce large deformation or bending stress, and then be broken. This is the most widely used and important commutation effect in ultrasonic probe. However, due to the limited experimental field and research capacity, this study needs to be improved.

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## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

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