Application Development of Piezoelectric Ultrasonic Transducer: A Descriptive Study

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ABSTRACT

Active and passive transducers are used in various engineering fields, including biomedical, environmental, and industrial applications. Piezoelectric materials, like single-diamond ceramics and polymer composites, offer properties like reduced mechanical damage, increased piezoelectric consistency, and improved coupling coefficient. This paper proposes a larger, advanced ultrasonic transducer with two-request twisting resonation modes for continuous cutting and welding movement. The design considers electromechanical closeness, helical vibrational execution, and resonation and reverberation generation conditions.

KEYWORDS

Radial vibration piezoelectric ultrasonic transducers; Radial oscillating piezoelectric transducer; Tubular transducers; Stepped Mental ring

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1 General View of Transducers

Transducers can be broadly classified into two categories: active and passive transducers. Active transducers are self-generating and do not require any external power source to perform their sensing function, while passive transducers require an external power source to work.

Active transducers can be further classified into two categories: mechanical and electrical transducers. Mechanical active transducers include electromechanical and piezoelectric transducers, while electrical active transducers include photoelectric and thermoelectric transducers. Passive transducers can also be classified into two categories: resistive and capacitive transducers. Resistive transducers include potentiometric, strain gauge, and thermistor transducers, while capacitive transducers include proximity, displacement, and humidity transducers. [1]

Furthermore, piezoelectric ultrasonic transducer application development research is regarded as cutting-edge and advanced for a number of reasons, including the following:

(1) A variety of applications

This study shows the meaning of these sensors in dealing with genuine issues by displaying their different rational applications. The study focuses on a variety of industries, including environmental monitoring, automotive, aerospace, consumer electronics, industrial, and medical.

(2) Look at numerous viewpoints

The piezoelectric ultrasonic transducers approach means quite a bit to address the mind-boggling difficulties and progress in this field. This review examines the materials science, hardware, physical science, and design aspects of the perplexing field of piezoelectric ultrasonic transducers.

(3) Innovations in Creativity

Recent advancements in the development of piezoelectric ultrasonic transducers, manufacturing techniques, and plans are the subject of this study. To maximize the potential of various applications, it is essential to keep up with these advancements.

2 Working Principles of Transducers

Various transducers work differently, but most of them use the basic principle of converting a physical quantity to an electrical signal, which can be processed for different purposes. For example, a piezoelectric transducer works by converting pressure into an electrical signal. Similarly, an accelerometer transducer works by converting acceleration into an electrical signal. In its most basic form, a transducer consists of a sensing element that detects the physical quantity to be measured and a signal processing element that converts the detected physical quantity to an electrical signal. [2] The sensing element can be based on various principles, including electrical, magnetic, optical, and mechanical.

Moreover, transducers have vast applications across different engineering fields, including mechanical, electrical, biomedical, and environmental engineering. A few common applications of transducers are discussed below.

(1) Biomedical applications

Transducers find various applications in the field of biomedical engineering. For example, a medical ultrasound scanner uses a piezoelectric transducer to generate high-frequency signals that bounce off an object and returns to the transducer, thereby generating an image of the object.

Similarly, a strain gauge transducer can be embedded into cardiac pacemakers to monitor the heart's pumping rate. Also, a differential pressure transducer can be used to monitor blood pressure, while a thermistor transducer can be used to measure body temperature.

(2) Environmental applications

Transducers find extensive applications in environmental engineering. They can be used to monitor various environmental parameters, such as temperature, humidity, wind speed, and air pollution.

For example, a thermocouple transducer can be used to measure the temperature of a body of water, which is crucial in determining the growth rate of aquatic organisms. Similarly, a humidity transducer can be used to measure the moisture content in soil, which is essential in agriculture.

(3) Industrial applications

Transducers also find extensive applications in the industrial sector. For example, a proximity transducer can be used to measure the precise location of a machine part, while a pressure transducer can be used to measure the pressure in hydraulic or pneumatic systems.

Similarly, a force transducer can be used to measure the force required to lift a load, while a torque transducer can be used to measure the amount of force a machine applies. [3]

3 History and Application of Radial Vibration Piezoelectric Ultrasonic Transducers

The disclosure of the piezoelectric impact and the usage of piezoelectric materials filled in as the establishment for the making of piezoelectric transducers. Piezoelectric materials are a kind of helpful materials that can directly figure out the change between mechanical energy and electrical energy. French specialists Jacques Curie and Pierre Curie have probably certified in view of speculative theories that some single-diamond materials are presented to a particular direction of strain. Lippmann expected the presence of the regressive piezoelectric effect which was insisted likely. An electric charge is made on the external layer of the diamond, or possibly, the piezoelectric effect. Piezoelectric materials are comprehensively used in the equipment field, for example, contraptions and military industry occupations. [4] Piezoelectric materials can be divided into a couple of orders, for instance, single-diamond Piezoelectric ceramics Polymer piezoelectric, and piezoelectric composites Quartz valuable stone is the most unmistakable piezoelectric single-jewel material. Right now, the piezoelectric fire is utilized the most. materials in light of strong electric fields and tremendous copious inspirations. Moreover, it can change execution in different ways by altering parts to meet the necessities of different applications.

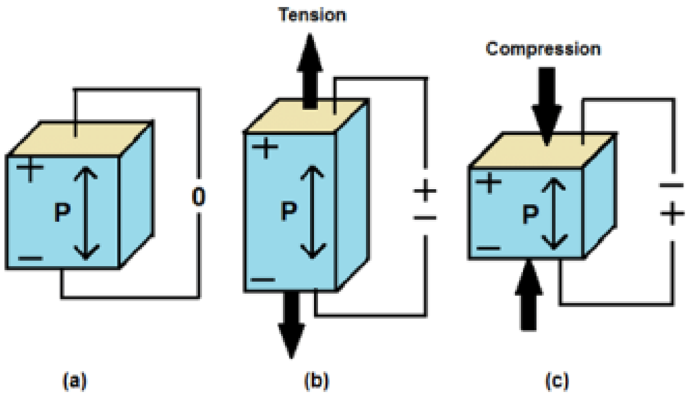

Fig. 1. Piezoelectric impact

Chipping away at the show of piezoelectric materials is huge in making piezoelectric ultrasonic transducers. Another advancement in piezoelectric materials is the unwinding ferroelectric single precious stone found in the last part of the 1990s. [5] Exactly when new piezoelectric materials are attempted It will fundamentally influence the improvement of piezoelectric ultrasonic transducers. Unwinding ferroelectric single precious stones are typical specialists of the first and later times of piezoelectric single-pearl materials. During the 1950s and 1960s, the disclosure and utilization of piezoelectric dirt materials. The unwinding of ferroelectric single gems was an accomplishment. The majority of artistic piezoelectric PZT's properties are piezoelectric. Less mechanical and dielectric mishaps More conspicuous piezoelectric consistency and the electromechanical coupling coefficient, It is especially sensible for PZT.

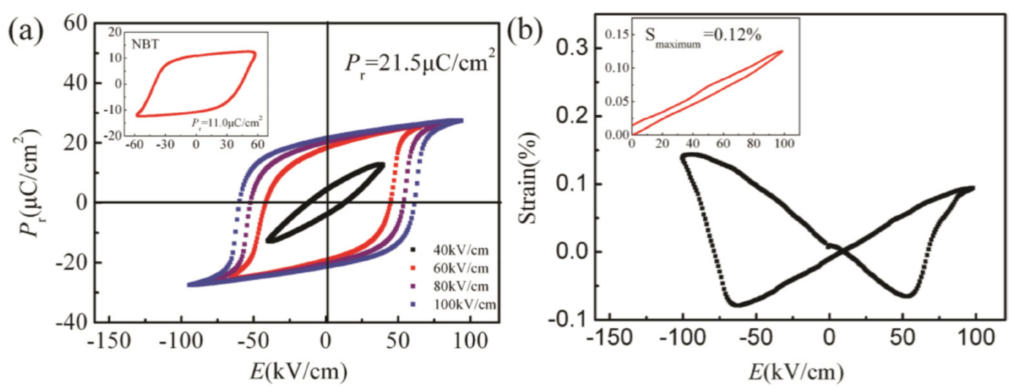

Fig. 2. After installing ferroelectric single gems, the compatibility of the transducer is significantly improved.

In the field of power ultrasound, in order to meet the needs of new technologies, in addition to the commonly used longitudinal vibration ultrasonic transducers, ultrasonic transducers with bending vibration, torsional vibration, longitudinal-torsional, and longitudinal-bend composite vibration modes have been gradually developed. And dual working frequency ultrasonic vibration system for ultrasonic welding. [6] In addition to several commonly used vibration modes such as longitudinal, torsional, and arc, radial vibration is also an important vibration mode. Piezoelectric radial vibration transducers have many unique advantages, such as a large radiation area. High radiation efficiency, uniform radial radiation direction, and diverse sound waves. It is used in the field of ultrasonic liquid treatment technology such as hydroacoustics, among which ultrasonic and sonochemical degradation are the most widely used. [7]

Fig. 3. Radial vibration

Ultrasonic transducers are common components for generating and receiving ultrasonic waves. Electrostatic, capacitive, and electromagnetic are the types widely used today. On the one hand, piezoelectric transducers are simple in structure and can be processed into various shapes. On the other hand, in order to meet different application requirements, piezoelectric materials have high electromechanical conversion efficiency. Sandwich piezoelectric transducer: High power density and stable performance, it is the earliest and most practical piezoelectric transducer. [8] The sandwich piezoelectric transducer is also the most widely used longitudinal vibration ultrasonic transducer in the field of power ultrasound.

Fig. 4. Ultrasonic transducer

4 The Role of Piezoelectric Ceramics

Piezoelectric ceramic composite transducers enjoy huge benefits like an enormous radiation region. Extended ferrules/chambers assemble ferrules/cylinders to additionally work with heat scattering from the piezoelectric ring. Increment the capacitance of the sensor. By changing the basic limit of the metal ring, the practical pattern of the sensor can be in this way acclimated to suit different use cases. High Radiation Productivity Uniform Expanded Radiation and High Helical Responsivity This transducer comprises of a piezoelectric earth ring/tube.

A large portion of the ongoing ultrasonic welding outlines acknowledge ultrasonic welding through the longitudinal vibration of the interlayer ultrasonic vibration outline. The size of the piezoelectric ultrasonic vibration outline is generally more noteworthy than or equivalent to 3 half frequencies. Sensors vibrate along the length of the ultrasonic horn and shaper to cut food or flexible. [9] Additionally, the vibrating outline is curiously large for continuous ultrasonic cutting with vibratory rolling. Hence, this paper proposes a plan with a bigger broadened ultrasonic transducer and more unassuming science. By choosing the transducer's two-request twisting resonation mode, the ultrasonic energy is locked in from the back to the front. The affiliation and fixation of sensors and outside equipment in the center point's twisting development. In this way, continuous cutting or ultrasonic welding movement can be affirmed by moving the transducer.

Meet the application necessities of ultrasonic roll cutting or ultrasonic twisting wrinkle welding. planned a helically vibrating ultrasonic transducer made of piezoceramic rings and unusual light metal rings. As per the rule of electromechanical closeness, a similar circuit as the helical vibration of the gutsy slim metal ring was laid out. Conditions for broadened resonation multiplication and annihilation improvement factors are found. Given the speculative model and restricted compositional reruns of experience metal. [10] The helical vibrational execution of a sensitive ring is recreated and examined. Furthermore, on this reason, a similar circuit as the Venturi ring piezoelectric ultrasonic transducer was moreover evolved. In light of beginning suspicions and limited component propagations, resonation and hostile to reverberation generation conditions are given, considering the hazardous piezoelectric ring ultrasonic transducer. [11]

5 Stepped Metal Ring

An electrical analogy is used to construct an equivalent circuit for the radial vibration of a stepped thin metal ring. In this circuit, the conditions of reverberation generation and protection are met. Also, it is important to check how the spiral vibration works. In this hypothesis, the Venturi piezoelectric ring ultrasonic transducer is located on the bottom layer, which can generate longer-lasting vibrations. [12] The influence of helical adequacy on the vibration characteristics of the adventitious annular piezoelectric ultrasonic transducer is discussed below with the assumptions and reproduced results:

As the thickness of the center of the inner ring of the adventure ring increases, the thickness of the pin of the adventure ring also increases. When the ratio of the inner ring hub thickness to the outer ring hub thickness is within 2.25, the adventure ring works the ability to eliminate the scope from the inner perception. [13] Increasing thickness causes both spiral and extended reverb reproductions to decrease over time. A stepped ring cannot tell how much space it has moved from inside to outside because the inner radial displacement of the ring is greater than its outer radial displacement.

As the radial thickness of the inner ring increases, the radial thickness of the outer ring decreases. Spiral reverberation decreases slowly, Extended reverb increases gradually, and Spiral reverb second reverb changes more. In the risk ring primary resonance approach, the sufficiency of elongation exits within the ring is of greater concern than the sufficiency of helical migration outside the ring.

The scanning speed of the sensitive ceramic piezoelectric ring of the unique piezoelectric ring ultrasonic transducer is improved. The anti-resonance frequency and first-order resonance frequency of the transducer decrease over time. The sensor bandwidth is reduced, the effective electromechanical conversion coefficient is usually zero, and the second-order resonant and antiresonant frequencies are usually close. The outer radius of the inner ring of the stepped ring is larger. The first-order antiresonance frequency and radial resonance frequency of the transducer gradually increase and decrease. [14]

6 Conclusions

Transducers are classified into active and passive types, with active transducers self-generating and requiring no external power. Mechanical active transducers include electromechanical and piezoelectric, while electrical active transducers include photoelectric and thermoelectric. Passive transducers are resistive and capacitive. They are used in various engineering fields, including biomedical, environmental, and industrial applications. Piezoelectric materials, such as single-diamond ceramics, polymer piezoelectric, and composites, are used in various applications, such as equipment and military. These transducers have properties such as reduced mechanical and dielectric damage, increased piezoelectric consistency, and improved electromechanical coupling coefficient. Piezoelectric ultrasonic transducers have evolved to meet new technologies, including longitudinal, torsional, and arc vibration modes, as well as radial vibration. These transducers are simple in structure and have high electromechanical conversion efficiency, making them suitable for various applications. This paper proposes a larger, more advanced ultrasonic transducer with two-request twisting resonation modes, enabling continuous cutting and welding movement. The design considers electromechanical closeness, helical vibrational execution, and resonation and reverberation generation conditions. The Venturi piezoelectric ring ultrasonic transducer generates longer-lasting vibrations, while the helical adequacy influences the vibration characteristics of the adventitious annular piezoelectric ultrasonic transducer.

About the Author

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