# Wind Speed Signal Detection And Energy Capture System Design

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***Abstract*—Considering the shortcomings of existing wind signal detection equipment.a self-powered wind signal detection system is design.on the basis of its structural design analyzed the working principle and energy capture mechanism.The system can not only capture the wind energy, but also detect the wind signal.**

***Keywords-self-powered;energy harvesting;wind speed signal detection***

## I. INTRODUCTION

Green and sustainable self-powered testing equipment is an important development direction and research focus of the testing system.Wind energy is one of the most popular kind of clean and renewable energy. Effective conversion devices can not only convert wind energy in nature into electricity for human use, but also play a certain role in preventing typhoon natural disasters.

Wind energy is collected by wind turbine generator, micro - electromagnetic generator, wind - induced piezoelectric generator. Because of the small size, the swept area of the wind turbine generator is greatly reduced, so the energy collection efficiency is low. Although the performance of the micro-electromagnetic generator is reliable and the damping is small, the energy collection efficiency is not high under the condition of low wind speed. The common wind-induced piezoelectric energy collection system uses wind as the excitation source to drive the piezoelectric ceramics to generate energy. According to the form of incentive function, it is divided into direct type and indirect type. The direct type is that the wind acts directly on the piezoelectric plates, causing them to vibrate. The indirect type is that the wind acts on other mechanisms and then drives the piezoelectric sheet to deform and generate electricity through the corresponding transmission mechanism. Direct modes include vortex-induced resonance, flutter, galloping, resonance, etc. Indirect methods include collision, rotation,etc.

This paper studies on the base of the conventional wind energy detection device. Based on the principle of electromagnetic mutual repulsion, the piezoelectric sheet of the flexural tension structure is deformed by electromagnetic force. When the wind speed cup rotates, the rotor equipped with permanent magnets will rotate. Under the action of electromagnetic force, the piezoelectric sheet will be deformed to generate electric energy and output at the natural frequency.When the wind speed is accelerated, the speed of the spindle driven by anemometer cup will be accelerated, and the generated electricity and output frequency will be accelerated, so the wind energy capture and wind signal detection can be realized simultaneously in the same set of systems.

## II. STRUCTURAL DESIGN AND ANALYSIS

The typical piezoelectric vibrator includes cantilever beam structure, drum structure and ring structure et.al.piezoelectric device based on piezoelectric bending is the most common and the most studied piezoelectric capability collection structure it has simple structure and low resonant frequency.In the design process,we can adjusting the size of the mass block and the resonant frequency of the rotor can be adjusted.In this system the fixed end is driven by the rotor rotation of wind cup and then the periodic compression force is applied to the piezoelectric sheets of the curved structure to obtain electric energy.During the tested experimentally the shape,structure and connection mode of the piezoelectric sheet will affect its power generation performance.In this paper the energy capture and signal detection of piezoelectric cell structure is designed(fig2.1).In this structure, piezoelectric ceramics in the middle and metal platens are in the upper and lower layers,the metal pressure plate is bonded to the piezoelectric material.

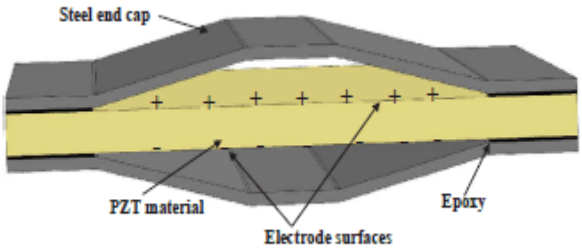


Figure 1. Energy capture and signal detection of piezoelectric units

The system is mainly composed of wind speed bar, piezoelectric element, support bar, bearing and rotating shaft.The working Principles is when the wind in one direction the anemometer rotates simultaneously with the rotating shaft the permanent magnet fixed on the axis of rotation also rotates together，when two magnets of the same class come together under the action of an electromagnetic force the piezoelectric sheet of a curved structure is compressed to produce electricity，When the wind speeds up，the rotor speed of the will increase the

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electricity generated and the output frequency will be accelerated,and wind energy capture and wind speed signal detection can be realized simultaneously in a system.

## III. WIND ENERGY CAPTURE AND WIND SPEED SIGNAL ACQUISITION

Mechanical energy collection has become one of the research hotspots at home and abroad, including vibration energy collection and rotational energy collection. There are three kinds of electromechanical energy acquisition modes: electrostatic type, electromagnetic type and piezoelectric type. Piezoelectric type is widely adopted because of its high energy density and flexible design. One of the most basic structures of piezoelectric energy acquisition is the piezoelectric beam. The resonant frequency of the piezoelectric beam is low, and it can produce large displacement under the low frequency weak excitation, so as to get high output power. However, the electromechanical coupling coefficient of the piezoelectric beam is relatively low, the deformation range is limited, and the piezoelectric ceramic sheet is easy to fracture under the bending stress. In order to improve the ability of wind energy capture and the accuracy of wind speed detection, this paper aims to obtain the energy and speed signal by driving the magnetic force in the permanent magnet to compress the flextensional piezoelectric sheet.

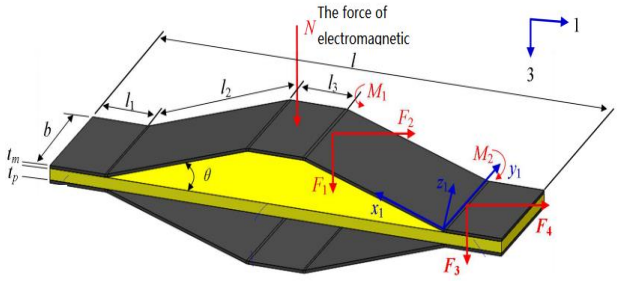


Figure 2. The Energy capture unit

### A. Mechanism analysis of energy capture elements

Flextensional piezoelectric elements are symmetric, the force analysis of a quarter of flextensional piezoelectric element is carried out. The force acting on the inclined plate direction 1 and 3 is equivalent to the concentrated force $F_1$ and $F_2$. The forces of direction 3 and direction 1 acted by inclined plate against the bonding site is equivalent to the force of the plate against the inclined plate, the moment of force is $M_1$, the moment of bonding to the inclined plate is $M_2$,it would be compatible with condition as follows:

$$\begin{cases} F_1 = F_3 = \dfrac{1}{2}N, F_2 = F_4 \\ M_1 = 0, M_2 = (F_1\cos\theta - F_2\cos\theta)l_2 \end{cases} \quad (1)$$

There is no load on the vertical and the $x-y$ plane, its immunity is $w_1$, the boundary conditions are as follows:

$$w_1|_{x1=0} = 0, \frac{\partial w_1}{\partial x_1}|_{x_{1=0}} = 0, -D\left(\frac{\partial^3 w_1}{\partial x_1^3}\right)|_{x_1=l_2} = \frac{F_1\cos\theta - F_2\sin\theta}{b} \quad (2)$$

As in the above formula (2), $D = E_m t_m^3/12(1-v_m^2)$ is flexural rigidity of the plate, $E_m$ is elasticity modulus, $v_m$ is poisson's ratio, $w_1$ can be solved.

$$w_1 = \frac{(F_1\cos\theta - F_2\sin\theta)l_2^3}{3Db} \quad (3)$$

It can draw a conclusion that both ends of this piezoelectric element and the bonded piezoelectric sheet are mainly subjected to pressure of direction 3. The piezoelectric direction of the inner region is subject to a pull in direction 1. The energy capture piezoelectric equation can be expressed as follows.

$$\begin{cases} D_{3end} = \varepsilon_{33}E_3 + d_{33}T_3 \\ S_3 = d_{33}E_3 + S_{33}T_3 \end{cases} \quad (4)$$

For the center section, the energy output equation can be expressed as follows.

$$\begin{cases} D_{3middle} = \varepsilon_{33}E_3 + d_{31}T_1 \\ S_1 = d_{31}E_3 + s_{11}T_1 \end{cases} \quad (5)$$

$T_1 = 2F_2/bt_p, T_3 = -F_1/(bl_1)$, $d_{31}$ and $d_{33}$ is piezoelectric coefficients, $s_{11}$ and $s_{33}$ is elasticity coefficient of piezoelectric materia, $\varepsilon_{33}$ is dielectric coefficient. The deformation of piezoelectricity in direction 1 satisfies the geometric relationship as follows.

$$S_1 l_c = 2w_1\sin\theta \quad (6)$$

So, electric charge quantity produced by the force on the piezoelectric sheet should satisfy relationship as follows.

$$Q_g = (D_3)_{ends}A_{ends} + (D_3)_{middle}A_{middle} = \left[-d_{33} + \frac{l_2^3 l_c\sin\theta\cos\theta}{t_p l_2^3\sin^2\theta + 3s_{11}}\right]N \quad (7)$$

open circuit capacitance is $C_p = bl\varepsilon_{33}/t_p$, and open-circuit voltage is $V_{open}$

$$V_{open} = \left[-d_{33} + \frac{l_2^3 l_c\sin\theta\cos\theta}{t_p l_2^3\sin^2\theta + 3s_{11}Dl_c}d_{31}\right]\frac{t_p}{bl\varepsilon_{33}^T}N \quad (8)$$

### B. Magnetic compression mechanism analysis

Piezoelectric ceramic piece is prone to fracture under bending stress, but its reliability and coupling coefficient are higher under compressive stress. In order to improve the working frequency domain and energy density of vibration energy collector, a method of magnetic pressure nonlinear wind energy acquisition is proposed. When the wind speed

cup is rotating, the end of the beam rotates with the shaft, causing the distance between the end of the beam and the flextensional piezoelectric element to change periodically.When the permanent magnet at the end of the beam is close to the flexural piezoelectric unit, magnetic repulsion pressure is generated under the action of it, then piezoelectric effect is produced.

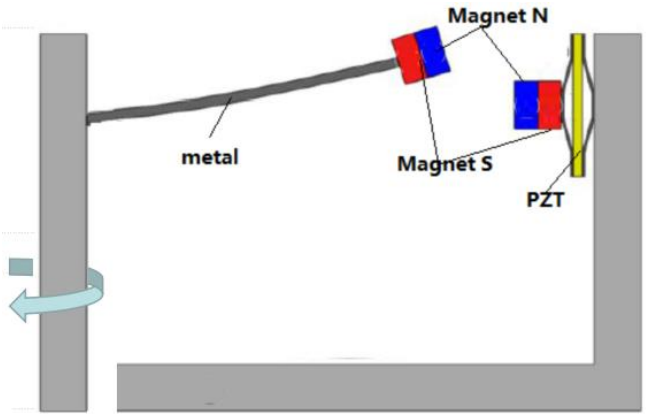


Figure 3. The Structural schematic of energy capture and wind signal detection

According to the above cograph, Permanent magnets attached to the free end of the cantilever beam and the curved piezoelectric elements are perpendicular to each other. When the rotation axis rotates, the free end permanent magnet fixed on the rotation axis produces an angular displacement $\varphi(\theta)$ magnetism repulsive force $x$ direction component is as follows.

$$F_x = \frac{3M_A V_A M_B V_B u_0}{4\pi\left\{[d+a(1-\cos\theta)]^2+(y+a\sin\theta)^2\right\}^{5/2}}\left(3[d+a(1-\cos\theta)]\cos\theta+\right. \\ \left.\frac{5\{-[d+a(1-\cos\theta)]\cos\theta+(y+a\sin\theta)\sin\theta\}[d+a(1-\cos\theta)]^2}{[d+a(1-\cos\theta)]^2+(y+a\sin\theta)^2}\right) \quad (9)$$

In the above formula, $M_A$ , $M_B$ are the magnetic moment vector of two permanent magnets, $V_A$ , $V_B$ are the The volume of two permanent magnets,, $u_0$ is the permeability of free space $u_0 = 1.256\times10^{-6} Hm^{-1}$ ,The rotation Angle of cantilever beam with length W can be estimated as $\theta(t) = w(t)$ . Tyler expansion of Formula (9) can done at the origin,the component of magnetic force in the $x$ direction can be approximately expressed as:

$$F_x = -a_x + b_x y^2 \quad (10)$$

$$a_x = 3M_A V_A M_B V_B u_0 / 2\pi d^4 \quad (11)$$

$$F_y = a_y y - b_y y^3 \quad (12)$$

$$a_y = 3M_A V_A M_B V_B u_0 (d+2L+4a) / 2\pi d^5 L \quad (13)$$

## IV. CONCLUSIONS

Mechanical energy collection has become one of the research hotspots at home and abroad, including vibration energy collection and rotational energy collection. There are three kinds of electromechanical energy acquisition modes: electrostatic type, electromagnetic type and piezoelectric type.Piezoelectric type is widely adopted because of its high energy density and flexible design.This paper is based on the principle of piezoelectric energy capture,design a wind speed signal detection and energy capture system,on the basis of its structural design analyzed the working principle and energy capture mechanism.The system can not only capture the wind energy, but also detect the wind signal.

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