ENERGY GENERATION FROM "**PIEZOELECTRIC**" MATERIALS

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Abstract: - **`Smart' materials like piezoelectric have the ability to perform both sensing and actuating functions. Passively piezoelectric materials respond to external change in a useful manner without assistance, while actively piezoelectric materials have a feedback loop which allows them to both recognize the change and initiate an appropriate response through an actuator circuit. One of the techniques used to impart intelligence into materials is `Biometrics', the imitation of biological functions in engineering materials. Composite ferroelectrics fashioned after the lateral line and swim bladders of fish are used to illustrate this idea. `Very smart' materials, in addition to sensing and actuating, have the ability to `learn' by altering their property coefficients in response to the environment. Field-induced changes in the nonlinear properties of relaxer ferroelectrics and soft rubber are utilized to construct tunable transducers. Integration of these different technologies into compact, multifunction packages is the ultimate goal of research in the area of smart materials.**

Keywords: - **biometrics, ferroelectrics, ferromagnetic, lead zirconate titanate (PZT).**

I. INTRODUCTION

Basically, there is no standard definition for smart materials, and the term smart material is generally defined as a material that can change one or more of its properties in response to an external stimulus. For example, the shape of the material will change in response to different temperature or application of electrical charge or presenting of magnetic field. Piezoelectric materials include shape memory alloys (thermo-to-mechanical), piezoelectric materials (electric-to-mechanical), magnetostrictive materials and ferromagnetic shape memory materials (magnetic-to-mechanical), etc. In the other hand, there are some materials which termed as "smart material" does not have the properties stated above, like the material with self-healing property is also termed as "smart material". Therefore, smart material can also be expressed as a material that can perform a special action in response to some specific condition such as very high/low temperature, high stress, very high/low pH value, even material failure.

Some natural minerals are piezoelectric, such as quartz. A vibrating quartz crystal in old radio sets used to generate and receive the radio signal. The Curie brothers discovered the piezoelectricity of minerals like this in 1880. In the late 1940s a robust piezoelectric ceramic material called barium titanate was discovered, and it became used as a sensor of mechanical vibrations in sonar devices. One of the most common and important piezoelectric in use today is a closely related material called lead zirconate titanate, which is abbreviated to PZT. Studying of the smart materials is a key to make the innovation of aerospace industry. The reason is the conventional automatic system has several limitations comparing to the smart system. The limitations are multiple energy conversions, large number of parts, high vulnerability (especially hydraulic network) and narrower frequency bandwidth (Yousefi-Koma A & Zimcik DG, 2003).

Accordingly, the conventional system has a larger weight, size and potential failure. In contrast, smart actuators, e.g. electrical-to-mechanical type, are much more efficient because the electricity is directly converse to actuation and transmitting speed of electricity is much higher. Moreover, the compact size and light weight of smart actuators will not give much loading or restriction to structure of aircraft, thus a higher freedom is given to the aircraft design. Therefore, studying smart material is necessary for improving aircrafts' performance.

II. PROPERTIES OF PIEZOELECTRIC MATERIALS

Among different types of smart material, piezoelectric material is widely used because of the fast electromechanical response, wide bandwidth, high generative force and relatively low power requirements. There are two main types of piezoelectric materials are applied as smart material, which are piezoelectric ceramic and polymer. The classic definition of piezoelectricity is the generation of electricity polarization in a material due to the mechanical stress. It is called as direct effect. Also, the piezoelectric material has a converse effect that a mechanical deformation will happen if an electrical charge or signal is applied. Accordingly, it can be a sensor to detect the mechanical stress by direct effect. Alternatively, a significant increase of size due to the electrical charge can be an actuator.

III. THEOREM OF PIEZOELECTRIC MATERIALS

Piezoelectric materials are a transducer between electricity and mechanical stress. The piezoelectric material has this effect because of its crystallized structure. For the crystal, each molecule has a polarization; it means one end is more negatively charged while the other end is more positively charged, and it is called dipole. Furthermore, it directly affects how the atoms make up the molecule and how the molecules are shaped. Therefore, the basic concept of piezoelectricity is to change the orientation of polarization of the molecules. To illustrate clearly, a polar axis is imaginatively set in a molecule that run through the center of two different charges. Regarding the orientation of polar axis, the crystal can be divided into two types which are mono crystal and poly crystal. The mono crystal means that all the molecules' polar axes are oriented in the same direction as shown in Figure 1 (a), and the poly crystal means that the polar axes of the molecules are randomly oriented as shown in Figure 1 (b).

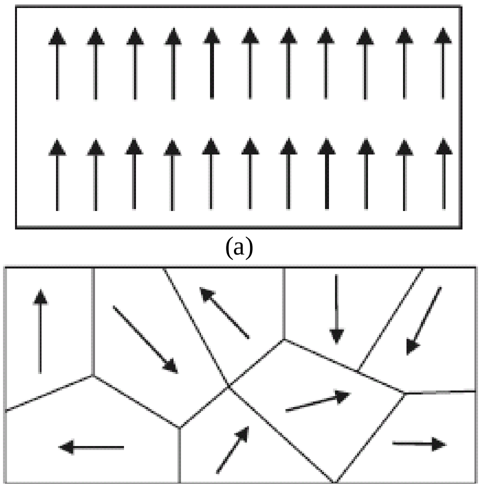
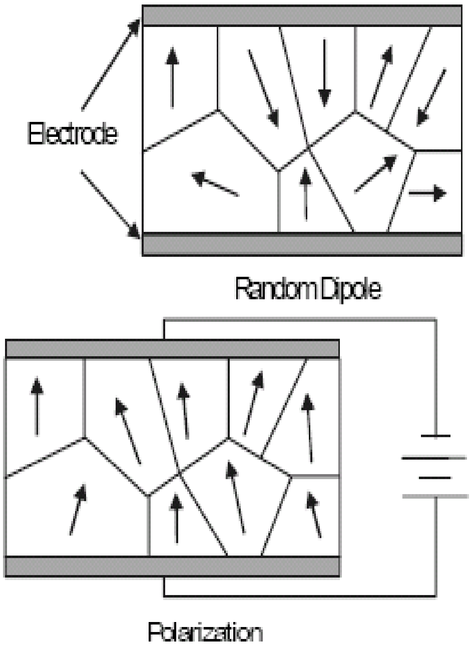


Figure 1. (a) Mono crystal (b) Poly crystal

For piezoelectric material, the crystal is in form of poly crystal initially and the crystal is connected with the electrodes. By applying the electric charge to the poly crystal, it almost become the mono crystal, accordingly the sharp will change which is shown as the converse piezoelectric effect (Figure 2).



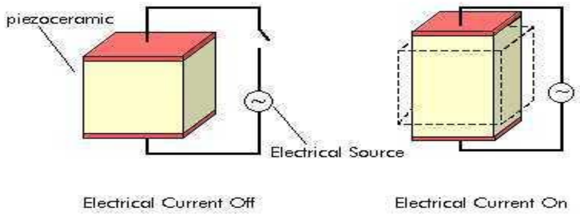


Figure 2. Piezoelectric Effect

In order to different direction of applied stress or charge, it will have different outcome which is shown in figure 3. In (a), it is the initial state of the piezoelectric material. For (b), a compressive force is applied to the material, and then the polarity current will flow in the same direction with polar axis. Conversely, it will have the opposite polarity current if it is in tension. In (c), it shown that the applied opposite polarity current will result in elongation. Also, the same direction of polarity voltage, (d), will result in compression. Finally, (e), a vibration will happen if the AC signal is applied, furthermore, their frequency will be the same.

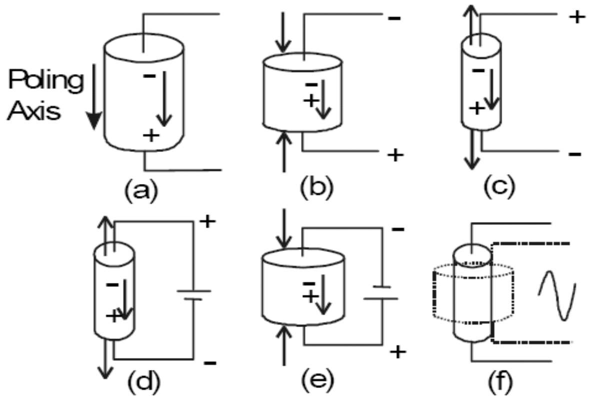


Figure 3. Stresses applied to piezoelectric materials

IV. APPLICATION OF PIEZOELECTRIC MATERIAL

The material always influences the weight, service life, function and strength of the aircraft. Hence discovery of new material is usually respecting an innovation in aerospace industry. Regarding the application of piezoelectric material, there are two main functions which are shape control and vibration control. In term of shape changing, it means the changing of aerodynamic feature. Conventionally, the aircrafts' control surface is still controlled indirectly and lack of flexibility. However, the piezoelectric actuator can perform an innovative mechanism of control system; it greatly increases the performance and maneuverability due to flexible, efficient and thin actuator. Regarding vibration, it is an unwanted effect in aircraft because it can contribute to stress concentration, material fatigue, shortening service life, efficiency reduction and noise. Obviously, these problems influence the safety and maintenance cost sharply. Besides, the noise problem is always considered, especially the passengers' aircraft, as the noise is a great annoyance.

Therefore, the engineers always want to minimize the vibration. By the piezoelectric material, it can be used as sensor and actuator at the same time, so it has a fast enough response to produce the anti-resonance vibration. Furthermore, it is flexible, small and thin to be applied in many parts of aircraft.

A. *Adaptive smart wing*

Conventionally, the flap, rudder and elevator are adjusted by electronic motor or mechanical control system like cable or hydraulic system. By applying piezoelectric actuator, no discrete surfaces are required because the control surface can be change the sharp itself in order to change the aerodynamic feature. Therefore, it creates a continuous surface which will not cause early airflow separation hence to reduce the drag, but also the lift is increased due to the delay airflow separation (Yousefi-Koma A & Zimcik DG 2003).

Accordingly, it increases the efficiency significantly. Basically, the concept of smart wing is to construct a continuous control surface embedded by a series of piezoelectric actuator. Furthermore, it is required to have a high strength-to-weight ratio; it means the actuator has to be placed strategically for optimizing a light weight design. Finally, it should have an ability to change the shape response to different flight condition, hence the performance of cruise flight can be improved that the conventional aircraft cannot achieve. In fact, this concept has started to be investigated since 1990. However, the smart wing system is mainly focus on military aircraft performance and maneuver improvement. Since 1994, this smart wing project has been started by many industries and research centers such as US Air Force, NASA, Northrop Grumman, Lockheed Martin, UCLA and the Georgia Institute of Technology (Yousefi-Koma A & Zimcik DG 2003).

B. *Helicopter blade application*

For the improvement of helicopter, most of engineers focus on the eliminating acoustic problem because it is the major problem and disadvantage. From the theoretical and experimental work both in Europe and USA, it shows that the BVI (Blade Vortex Interaction, shown in Figure 4) is the main source of noise, fortunately it can be dramatically reduced, 8 to 10dB, by an appropriate control of blades. (Monner HP & Wierach P) In order to solve this problem, there are two possible solutions. The first solution is to construct the blade that can perform a continuous twisting. The second solution is the servo-aerodynamic control surface like flap, tab, or blade-tip is installed on the blade to generate aerodynamic force (Giurgiutiu, V 2000).

Practically, it is difficult to install any conventional actuator in the blades of helicopter. However, the piezoelectric actuator seems to be suitable for the blades, so it receives an extensive attention (Giurgiutiu, V 2000).

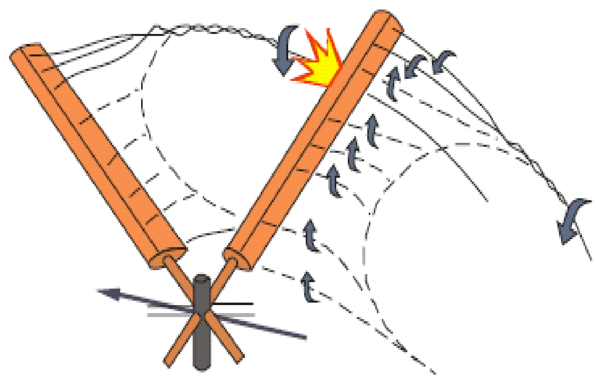


Figure 4. Blade Vortex Interaction

C. *Twist blades concept*

The twist blade is a more difficult concept and it needs many theoretical studies to find out the twist angle to optimize the vibration elimination. However, this concept receives many advantages such as smooth continuous deformed surface, high aerodynamic sensitivity, excellent structural and dynamic compatibility, minor influence of actuation forces on blade strength and no moving components involved (Monner HP & Wierach P).

To perform the twist blades, the simple way is to embed the PZT in the blades skin. In 1997, Chen and Chopra constructed a 1:8 Froude scale composite blade with diagonally oriented PZT wafers. The direct twist concept allows to directly controlling the twist of the helicopter blades by smart adaptive elements and through this to positively influence the main rotor area which is the primary source for helicopter noise and vibration. The concept is based upon the actively controlled tension-torsion-coupling of the structure. For this, an actuator is integrated within a helicopter blade that is made of anisotropic fiber composite material. Influencing the blade twist distribution finally results in a higher aerodynamic efficiency. Theory before a proof of principle demonstration structure was manufactured subsequently a Mach-scaled BolO5 model rotor blade with an integrated piezoelectric actuator was designed and successfully tested.

V. CONCLUSION

In the studying of piezoelectric materials, their properties in response to external condition such as temperature, stress, electrical charge, magnetic field, are understood and these unique properties receive a great attention from the airspace industry. The reason is that properties can be applied to different parts in the aircraft to improve the overall performance. Example, by using the piezoelectric material actuator, its performance is much more efficient than the conventional system since the electricity is directly converse to actuation, numbers of parts are greatly reduced and transmitting speed of electricity is much higher. Moreover, an innovative research is experiencing to make the adaptive wing or control surfaces which can greatly increase the maneuverability. In addition, piezoelectric material is usually light in weight and can be made in the compact size. At the same time, cost can be reduced and maintenance can be minimized by using vibration control piezoelectric material. Accordingly, the demand of piezoelectric structure constructed by smart materials is increase dramatically because it can improve the overall efficiency, maneuverability, safety, stability, light weighted structure of the aircrafts.

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