Non-Invasive Human Breath Sensor

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***Abstract*— *In this paper, the design and development of a novel low-cost, non-invasive type sensor suitable for human breath sensing is reported. It can be used to detect respiratory disorders like bronchial asthma by analyzing the recorded breathing pattern. Though there are devices like spirometer to diagnose asthma, they are very inconvenient for patient's use because patients are made to exhale air through mouth forcefully. Presently developed sensor will overcome this limitation and is helpful in the diagnosis of respiratory related abnormalities. Polyvinylidene fluoride (PVDF) film in cantilever configuration is used as a sensing element to form the breath sensor. Two identical sensors are mounted on a spectacle frame, such that the tidal flow of inhaled and exhale air will impinge on sensor, for sensing the breathing patterns. These patterns are recorded, filtered, analyzed and displayed using CRO. Further the sensor is calibrated using a U-tube water manometer. The added advantage of piezoelectric type sensing element is that it is self powered without the need of any external power source.*

Keywords: Respiration rate, breathing pattern, Polyvinylidene fluoride (PVDF), bronchial asthma.

I. INTRODUCTION

Since ancient times breathing is believed to be the most important feature of life itself. In the human body, everything depends on the delivery of oxygen. We can survive without eating and drinking for days but we cannot survive without breathing for minutes. Hence respiration/breathing is the one of the very important physiological parameter of our body. There are many diseases that can harm and even destroy the respiratory system. Most people experience minor respiratory problems that can develop into major disease if proper diagnosis is not done at the initial stages. Therefore, the scientific study of the respiratory function becomes of paramount importance. In this paper we have reported the design and development of a sensor system suitable for the above purpose.

Bronchial asthma is one of the chronic inflammatory diseases of the respiratory airways that cause periodic "attacks" of coughing, wheezing, shortness of breath, and chest tightness. It is caused due to narrowing of airway in the bronchia. Since the air does not pass normally through the bronchia, the patient feels breathlessness. Asthma may be caused due to allergy, occupational, genetics, weather (especially extreme changes in temperature). The symptoms are chest tightness, difficulty of breathing, asthma attack, wheezing. Therefore asthma can harm or even sometime can destroy the respiratory system. Devices like spirometry are used to diagnose asthma, but as the patients are made to exhale air through the mouth forcefully, it makes slightly inconvenient for regular usage. Therefore the presently developed sensor system seems to be more ideal and convenient for routine clinical use, as it is made patient friendly.

II. METHODS AND MATERIALS

History

Ever since kawai [1] discovered in 1969 that PVDF (Polyvinylidene fluoride) material showed up several times higher piezoelectricity than its counterparts like quartz (after special treatments), many researchers attempted on the utility of PVDF for varied applications. PVDF is a bio-compatible polymer used for several applications. It is used as pulse sensor along with breath wave monitor [2] and as an airflow sensor for diagnosing sleep apnea [3].

Sensor Optimization: Analysis of a Cantilever Beam

In our work, we have used PVDF film as a sensing element in cantilever configuration for realizing the breath sensor as shown in fig. 1.

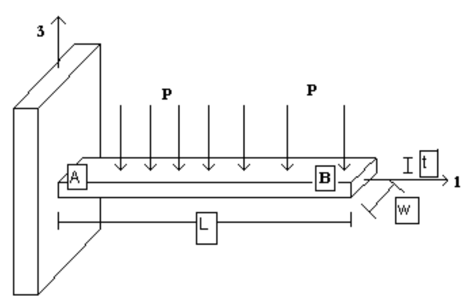

Fig 1: Cantilever beam with uniform loading

As can be seen in *fig. 1*, A is a fixed and end B is free for deflection. When a uniform load (air pressure during exhaling from the nostril) is applied on the beam, it will produce a

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corresponding deflection. Under these circumstances, a relationship between the applied load and the beam deflection can be derived [4]. Considering the Cartesian co-ordinate system, the length of the beam is aligned with the 1-axis, width is aligned with the 2-axis and thickness is aligned with the 3-axis.

The material properties of the beam are assumed to be homogeneous. The kinetic assumptions like there are no dimensional changes in 3-direction and that any section that is plane before deformation remains a plane section after deformation is made. Accordingly, following governing beam [5] equation (1) has been employed to find the deflection of cantilever beam for varying length, thickness and width.

$$Y = \frac{Pl^3}{8EI_{33}} \qquad (1)$$

Where, Y=Deflection (m), P=Total load (N/m), L=Length of cantilever beam (m), E=Young's Modulus (N/m^2), I=Moment of Inertia (m). *Fig. 2* shows the optimization of PVDF sensor parameters. For case 1, length of the cantilever is varied keeping the width and thickness constant. As the length is increased the deflection also increases. In 2nd case, keeping length and width constant, thickness is increased. As the thickness increases the deflection of the cantilever decreases, similarly, in 3rd case thickness and length are kept constant and width is increased. Deflection of the cantilever is decreased with the increase of cantilever width. After observing the geometry of human nose, we have assumed that the length of each nostril is 0.01m while the width is 0.005m. As a result, the dimensions of the cantilever cannot exceed these dimensions as the two sensors will touch each other and we might end up getting false signals. We get a good deflection 0.022m for 9μm thickness PVDF cantilever, but this thickness is very sensitive to very small movements of the body. So we have chosen the next best available thickness 28μm as PVDF cantilever thickness. We get a good deflection 0.006m for the dimensions: length(L)=0.01m, width(W)=0.005m and thickness(t)=28µm.

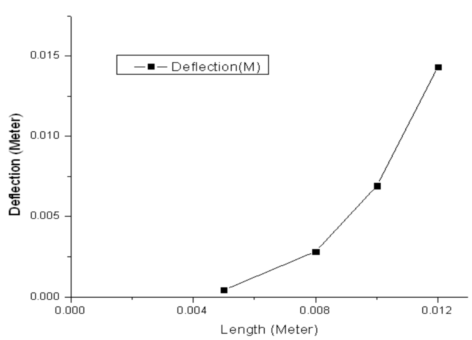

Fig:2(a) : Optimization of PVDF sensor parameters, Case 1: Keeping thickness and width constant

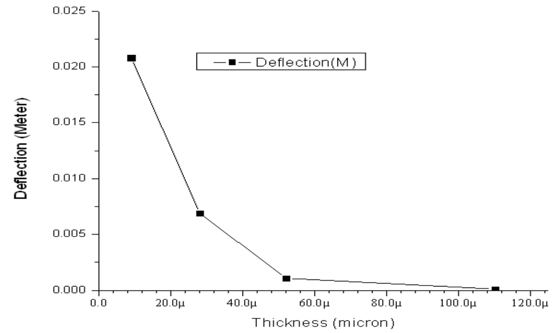

Fig:2(b): Optimization of PVDF sensor parameters, Case 2: Keeping length and width constant

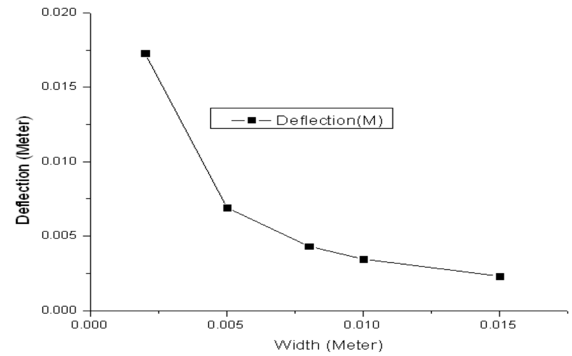

Fig:2(c): Optimization of PVDF sensor parameters, Case 3: Keeping thickness and length constant

III. Sensor Design

The schematic representation of PVDF sensing element is shown in *Fig. 3.* The PVDF sensing element used in the present work is coated with gold at top and bottom surfaces for electrode lead attachment. Double enameled copper wire (0.07mm diameter) is attached to the top and bottom surfaces of PVDF sensing element. Two similar PVDF sensing elements are mounted on a spectacle frame. The spectacle frame was worn by the subjects and their respective breathing patterns are recorded. The recorded signals are filtered using low pass filter with a cut-off frequency 5 Hz.

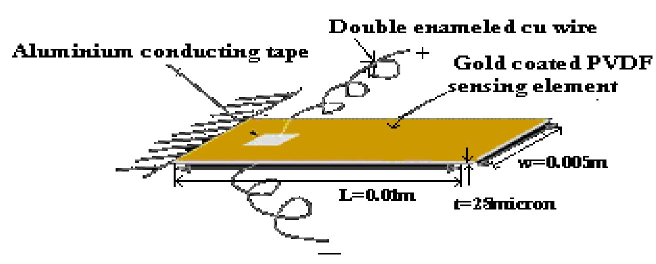

Fig 3: Schematic representation of PVDF Cantilever Sensing element

IV. *Sensor Calibration and Perfornace Study*

Since human breathing pressure is very low, gauge pressures, relative to atmosphere are usually used. Therefore, U-tube manometer is used as the primary standard for human breath pressure measurement and calibration purpose. The PVDF breath sensor is calibrated using this U-tube water manometer. The U-tube manometer calibration setup made is shown in fig. 4.

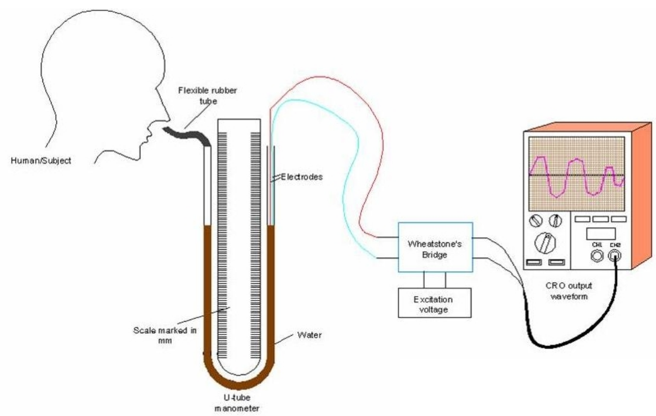

Fig 4: Schematic of the sensor calibration set-up.

U-tube manometer is filled with NaCl solution (Medical saline water), as it is used for better repeatability, conductivity. Also, it is safe for the subject in case if they inhale. Subject is made to breath in a relaxed position facing at one column of manometer and two thin copper electrodes are dipped in the other column. The top ends of copper electrodes are connected to the voltage sensitive Wheatstone Bridge. When a subject is breathing, the saline water level in the column changes thus changing the resistance of the copper electrode system. As the resistance of copper electrode system changes, the output of the bridge also changes and the corresponding voltages are measured in the CRO. The pressure of the normal human breathing is in the range of 0.5-1.2cmH_2O with the voltage range of 8-20mV at 1.5V DC excitation.

V. Results and Discussion

Various normal and asthmatic male subjects (volunteers) of age group 25-30years were made to wear spectacle frame mounted with PVDF cantilever sensing element. The subject was made to sit in a relaxed position. Further, the subject was asked to close the eyes and mouth and do quite breathing for few minutes. The respective breathing pattern signals are recorded for 60sec using CRO and analyzed with the help of Lab VIEW 8.0 version. Normal person breathing pattern is shown in Fig. 5(a). Breathing pattern of person with bronchial asthma is shown in fig. 5(b). By observing and comparing these breathing patterns carefully and analyzing, it is possible to detect the abnormalities. As can be seen, the normal breathing pattern is smooth while there are many jitters in the breathing pattern of the asthmatic person.

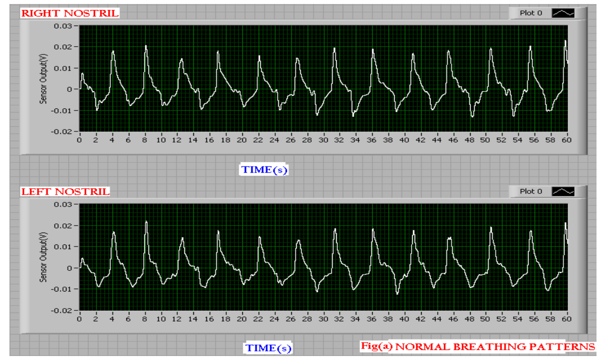

Fig: 5(a): Output from a breath sensor for the subject with a normal respiratory rate.

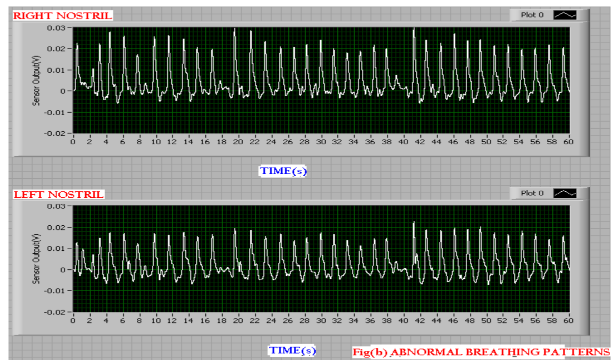

Fig 5(b): Output from a breath sensor for the subject with an abnormal (bronchial asthma) respiratory rate.

The respiration rate for normal male is 14(±2)/min [6] while the frequency is 0.2 Hz. The respiration period for a normal male is 5 sec [6] with 2 sec for inhaling and 3 sec for exhaling. The respiration rate of the normal person breathing pattern shown in Fig. 5(a) is 13/min while the frequency is 0.2 Hz and the average respiration period is 4.8 sec with 2.2 sec for inhaling and 2.6 sec for exhaling. While the respiration rate of the asthmatic person breathing pattern shown in Fig. 5(b) is 36/min while the frequency is 0.6 Hz and the average respiration period is 1.6 sec with 0.1 sec for inhaling and 1.5 sec for exhaling, which shows clearly that the respiration rate is higher than normal and the respiration period is very low. In bronchial asthma, due to high airway resistance in the bronchus, the subject cannot breathe normally. So the respiration rate of asthmatic patient is higher compared to normal person. Though there are devices like spirometer to diagnose asthma, it basically measures the lung capacity. And they are very inconvenient for the patient to use because patients are made to exhale air through mouth forcefully. The presently developed sensor overcomes this limitation, as the patient is made to inhale and exhale air through nose in a normal way.

Acknowledgment

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