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Development of Fiber Optic Differential Pressure Sensor Used for BOD Measurement in Sugar and Allied Industry

M.L.Dongare

Abstract- An attempt has been made to develop prototype instruments with Fiber optic differential pressure sensor (FODPS) and its use for measuring Biological Oxygen Demand (BOD) in the effluent from sugar factories and distilleries. Design of fiber optic based differential pressure sensor (FODPS) using intensity modulation technique is reported in this paper. A corrugated diaphragm based differential pressure sensor with a fiber optic probe to record this deformation/displacement of the diaphragm is designed, optimized and fabricated. In FODPS, diaphragm act as a reflector. A flexible disc of plastic is used as a diaphragm to convert the measuring pressure to the deflection of diaphragm. Concentric corrugations are designed to linearise the deflections according to pressure. Reference and measuring pressures are applied to control and experimental headspaces respectively. As the pressure changes in the experimental head space, the diaphragm is deform and displaces, and distance between fiber tip and plane of diaphragm changes and thus resultant reading is proportional to the differential pressure.

An attempt has been made to develop prototype instruments with Fiber optic differential pressure sensor (FODPS) and its use for measuring Biological Oxygen Demand (BOD) in the effluent from sugar factories and distilleries.

Keywords :BOD, FODPS, Fiber, Distillery, Sensor

I. INTRODUCTION

This Paper describes development of optical fiber sensors for Biological Oxygen Demand (BOD) measurement. The commonly used BOD tests include respirometric, aeration flask test and continuous culture experiments. Respirometry is an established method for the
determination of BOD. This methods basically rely on the monitoring of the oxygen uptake of a biological system by observing the change in volume (constant pressure respirometry) or the change in pressure (constant volume respirometry) of the gas phase in contact with the respiring liquid [1]. Various configurations of fiber optic sensors are used for sensing physical, chemical, biochemical parameters. Fiber optics micro displacement sensors are largely reported in literature [2-4]. The FODPS is needed in physical, chemical, biochemical, analytical and biomedical applications [5-8]. Diaphragms are widely used as a sensing element for high accuracy and good dynamic response [9]. They can respond to pressure value ranging from a few mm of water column to several atmospheres. The main characteristics of the diaphragm are ruggedness, excellent stability and reliability, low hysterisis and creep, and good dynamic response. Sensing diaphragm are made up from elastic metal alloy, such as a phosphor bronze, beryllium copper, and stainless steel or from proprietary alloys.

Diaphragm type pressure gages are used for the measurements of difference of pressure [10,11]. Basically it is used for comparatively low pressure measurement amongst elastic pressure sensors. A load cell with optical fiber sensor based on differential pressure developed in our laboratory [12]. By applying different load in a pan, pressure on a diaphragm changes and finally readout through signal conditioning unit is taken [13]. In this work the same principle is extended to for differential pressure sensing. Design of this fiber optic based differential pressure sensor (FODPS) using intensity modulation technique and its use for the BOD measurement is reported .

II. PRINCIPLE OF FODPS

The optical fiber sensors are either intensity modulated or interferometer type. In intensity based sensors a measurand produces a change in the power of light propagating in the fiber or optical zone. The intensity-based systems are less sensitive compared to interferometer methods, however, they are much simpler to implement. The basic intensity modulated sensors consist of optical source used to launch the optical power in to the fiber, the optical fiber link used to carry the optical signal to and from the measurand zone. Optical fiber based displacement sensor consists of a light source, transmitter fiber, reflector, receiving fiber and a photo detector. Micro displacement sensor based on arrangement such as a transmitting fiber, a receiving fiber and a reflector is well studied [14-17].The light from the light source enters the transmitting fiber and then radiates conically to the surface of the target. A part of the reflected light enters the receiving fiber and is then detected by the photo detector. The response curve for the micro displacement sensor has three distinct regions – a blind region, linear region having positive slope and a nonlinear region having negative slope.

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***** Correspondence Author (s)
M. L. Dongare Department of Electronic Science Annasaheb Awate College Manchar ,Pune University of Pune, India.

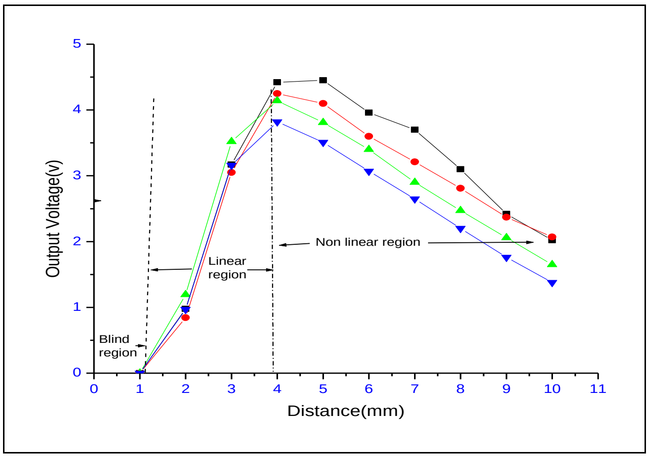

Fig. 1 Response of optical fiber sensors and various trials with distance.

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III. EXPERIMENTAL

In the present work intensity modulated fiber optic pressure sensor probe was designed. The diaphragm deformation due to change in pressure was sensed by FODPS. The change in output due change in pressure was measured in terms of voltage. The application of fiber optic sensors in pressure measurement has the advantage that there is no physical contact with the process parameter to be measured

Elastic element mechanical pressure gages consisting diaphragm are basically used for the differential pressure measurement. In FODPS, diaphragm act as a reflector. A flexible disc of plastic is used as a diaphragm to convert the measuring pressure to the deflection of diaphragm. Concentric corrugations are designed to linearise the deflections according to pressure. Reference and measuring pressures are applied to control and experimental headspaces respectively. As the pressure changes in the experimental head space, the diaphragm is deform and displaces, and distance between fiber tip and plane of diaphragm changes and thus resultant reading is proportional to the differential pressure.

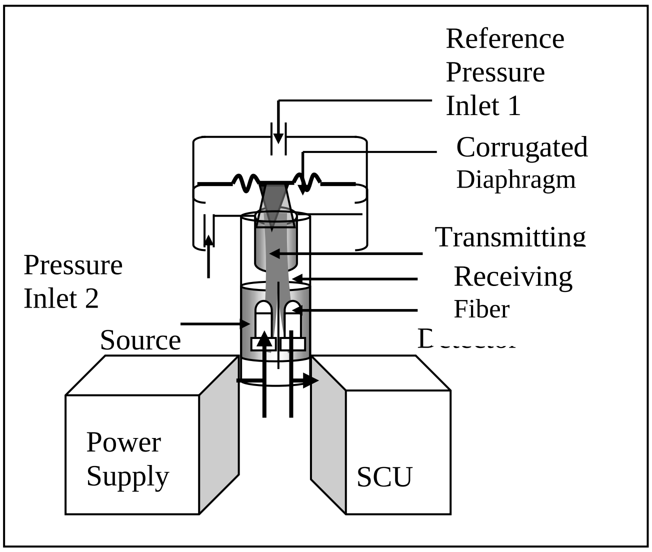

Fig.2: Principle of Fiber Optic Differential Pressure Sensor for BOD measurement

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By considering the simulation aspects, the FODPS was designed and then fabricated. The pressure sensor unit contains two parts, a sensor probe and an Electronic Readout. The probe contains sensor elements where as Electronic Readout Unit contains signal conditioning circuit and display unit. Figure shows the complete assembled fiber optic pressure probe. The fiber optic pressure sensor probe contains two plastic optical fibers with following specification i) length (L) = 25 mm. ii) numerical aperture (NA) = 0.47 iii) core radius (a) = 0.488 mm iv) fiber diameter (fd) = 2.2 mm. Transmitter source-high bright red Light Emitting Diode; Receiver- phototransistor (L14G 3).

A 3D model of the fiber optic differential pressure sensor (FODPS) is shown in figure 2 (a) and it's photograph is shown in figure 2.(b). The air pressure was varied above the atmospheric pressure and the corresponding variation in output was recorded. The distance between optical fiber probe tip and reflector decides the operating region of the sensor. The effect of this distance was studied by varying the distance from 1mm to 6mm in step of 1 mm.

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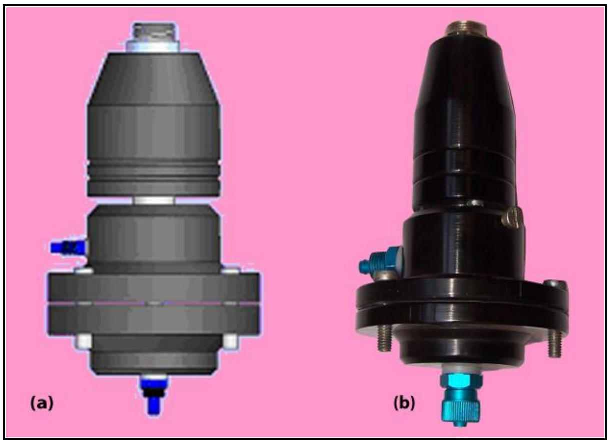

Fig. 2. (a) 3D model of (FODPS) (b photograph

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Figure 3 shows the response of FODPS with diaphragm of plastic having thickness 0.2 mm. Artificial pressure was applied on the diaphragm from one side and other side was kept open at atmospheric pressure. Initial output was adjusted to zero with the help of differential stage in the signal conditioning circuit. The output of FODPS increases with increase in pressureMeasurements are carried out with different spacing between the fiber tip and the back reflecting diaphragm. A distance of 3 mm, was optimized. for maximum sensitivity, is The effect of diaphragm thickness for differential pressure range of 0 to 30 mm of Hg indicates that as thickness of the diaphragm increases the sensitivity decreases.

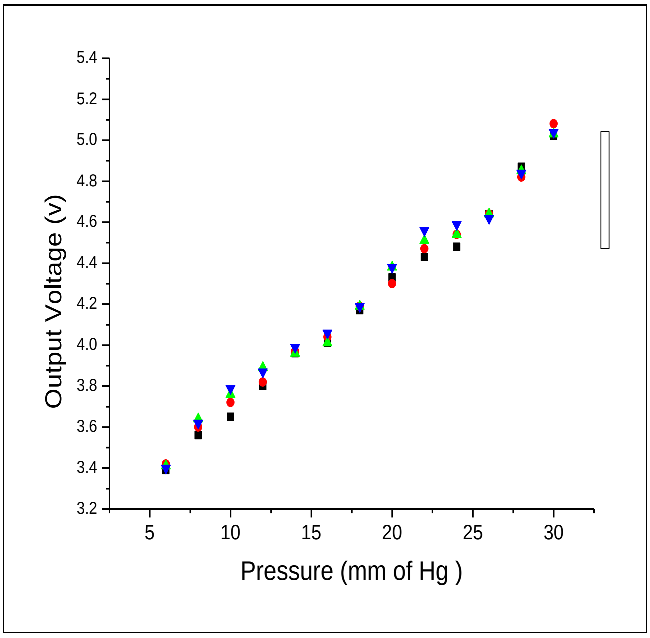

Fig.3. Response of pressure for various trials

IV. RESULTS AND DISCUSSION

The parameters regarding diaphragm ,such as thickness and radius of the diaphragm, position of transmitting and receiving fiber, and material constant for the metal diaphragm (i.e. modulus of elasticity and Poisson's ratio) decide the operational range. Considering the different aspects to perform the experiments using suitable material diaphragms of different thickness, a model can be designed and developed.

The selection of the diaphragm is crucial, linear relationship between a dimensional change and measured pressure have to be achieved before final experimentation. This is the prime requirement of it to be used as sensor. The selectivity of material should posses the following properties [10-14].

1. Linear stress strain relationship up to a fairly large elastic strain limit on corrugated and stiff area
2. Low strain hysteresis over repeated applied pressure
3. Very low creep over long periods for applied pressure
4. Very low plastic flow due to strain

V.CONCLUSION

The parameters regarding diaphragm, such as thickness and radius of the diaphragm, position of transmitting and receiving fiber, and material constant for the metal diaphragm (i.e. modulus of elasticity and Poisson's ratio) decide the operational range. Considering the different aspects to perform the experiments using suitable material diaphragms of different thickness, a model can be designed and developed. The experiential setup for BOD measurement is fabricated and initial tests are carried out.

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