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A Simple Plastic Optical Fiber Force Sensor

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Abstract— **An inexpensive intensity modulated force sensor that used plastic optical fiber and a cantilever beam is demonstrated. The plastic optical fiber is bonded on the surface of metal beam made of spring-steel and subjected to force at the end of the cantilever. The performance of the sensor is evaluated during macro-bending of the beam for applied forces. The sensor is tested for both the upward and downward forces and negligible hysteresis is observed in the experimental results. The proposed sensor can replace stain gauges in structural bending applications.**

Keywords-Plastic Optical Fiber, Intensity modulation, Force, Canteliver

I. INTRODUCTION

Health monitoring of civil infrastructure systems has recently emerged as a powerful tool for condition assessment of structural performance. Such structures are capable of providing vital information concerning the integrity of engineering structures through the use of embedded or surface bond sensors. Amongst the various methods available, optical fiber sensing systems have attracted considerable attention [1–3]. Fiber optic sensors offer many advantages over conventional sensors; these include their insensitivity to electromagnetic fields, light weight, minimal intrusiveness, ease of termination and coupling, and their relatively high resistance to fracture. Many fiber optic bending sensors have been proposed to measure many physical quantities, such as voltage, strain, temperature, pressure, acoustic wave, liquid level, etc [4-6]. Although a number of optical fiber sensing schemes, such as fiber Bragg gratings (FBG) and optical fiber Fabry-Perot sensors offer excellent measurement capability, these systems require sophisticated and generally expensive signal processing hardware to acquire and analyze the optical signal [7-8].

This study reports, use of an inexpensive intensity based plastic optical fiber (POF) along with the cantilever beam to measure the force applied at the end of the cantilever. The cantilever consists of POF bonded on the surface of metal beam made of spring-steel. Force in terms of weight is applied at one end of the beam. The deflection of the beam causes macrobending in the POF. This sensor also can be used for weighing purposes.

I. EXPERIMENTAL PROCEDURE

The POF (Eska-Fiber) used in this study is of 1mm diameter multimode step index fiber. The buffer of the POF is stripped off exactly in the middle about 25cm of total length of 50cm and bonded on the top of the metal beam in "Dumbbell" shape using cynoacrylate adhesive. The metal beam with POF bonded is used as a force as sensor shown in Fig. 1.

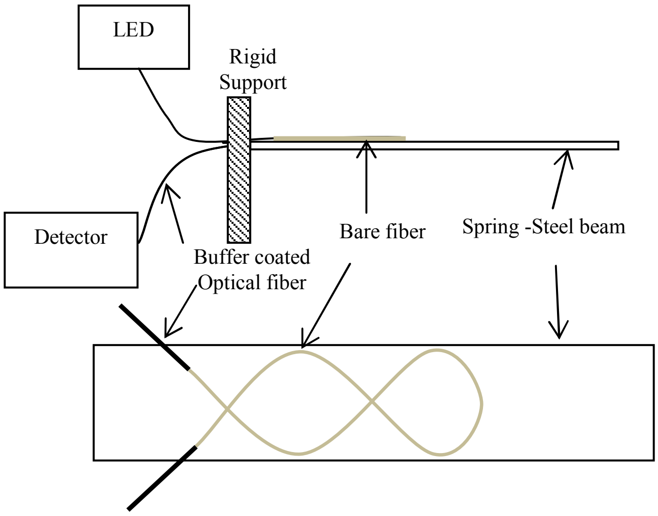

Figure 1.POF surface bonded cantilever metallic beam on upper surface in "Dumbbell" shapes.

In this experiment, the cantilever beam with length, width and thickness of dimensions 300 mm, 25 mm and 1.0 mm is considered for force sensing. A simple LED (IFE-93), photo detector (IFD-93) and a precession digital multi-meter were used to record the output of the detector.

The POF bonded beam is rigidly clamped at one end using fixed support as shown in Fig. 2. To bend the beam in downward direction due to applied force, a weighing pan is attached at the other end of the beam. To deflect the beam in upward direction, a pulley arrangement is used. A standard 5V dc power supply is used to power the LED and detector. The experiments were carried out at constant room temperature.

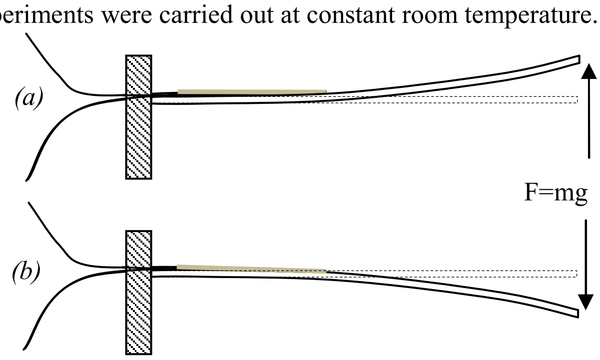

Figure 2. Schematic of cantilever beam with respect to *(a)* Upward force *(b)* Downward force.

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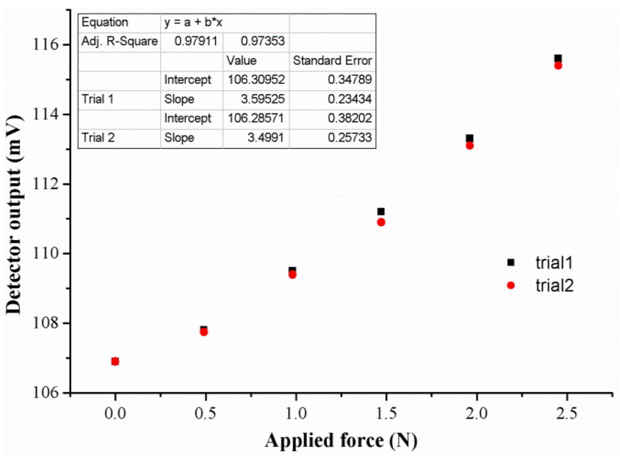
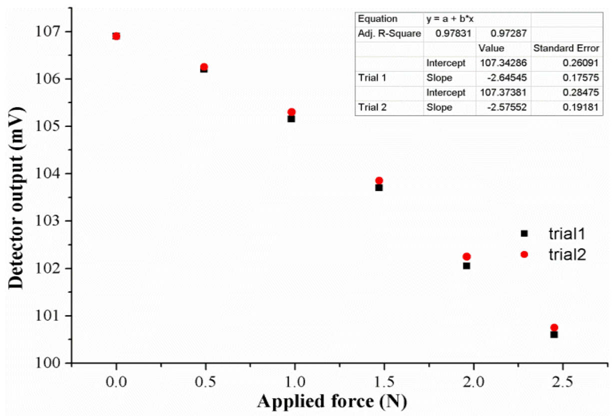
II. RESULTS AND DISCUSSION

The modulated light intensity of POF due to the macrobending caused by variation in applied force is plotted in Fig. 3. When the force is applied in upward direction, Fig. 2(a), the intensity of POF found to be increased linearly as shown in Fig. 3(a). In this condition, as the optical fiber is bonded on upper surface of the beam, it gets compressed during bending due to force. And in contrast, when the force is applied in downward direction, Fig. 2(b), the light intensity is found to be decreased as depicted in Fig. 3(b) where the optical fiber gets stretched. The change in intensity is due to the amount of optical power radiated out from a bent fiber, which in turn depends on the field strength at the critical distance and on the radius of curvature. Because higher order modes in the fiber are bound less tightly to the fiber core than lower order modes and will radiate out of the fiber first [9]. Thus, the total number of modes that can be supported by a curved fiber is less than in a straight fiber; hence there is change in intensity. The performance of the sensor is tested repeatedly and the measurements were shown in Fig. 3.



(a)



(b)

Figure 3. Variation of detector intensity in response to applied force *(a)* Upward direction and *(b)* Downward direction

From the Fig. 3, it is clear that the POF sensor exhibits a linear response with increasing beam bending in both directions in response to applied force and also it can be used to provide a direct measure of applied force. It is seen from above results that the weighing capacity of the designed force sensor is up to 250g (2.45 N) for a given dimensions of the beam specimen and till 250g there is no damage found in the optical fiber in spite of several repetitions of experiment. Hence, if we restrict the force constraints up to 2.45N, the life of the sensor may increase and will get repeated performance. The repeatability of the POF sensor under loading was found to be encouraging for both sets of directions of applied force. It has also seen that, with the force applied in both the directions for single end clamping (cantilever) has same weighing capacity. The sensor range of measurement can be varied by selecting suitable material and dimensions of the beam.

III. CONCLUSSION

A simple cantilever based intensity modulated POF force sensor was designed and demonstrated. The performance of the sensor was evaluated due to the macrobending caused because of applied forces in both upward and downward directions. The POF sensor response was also shown to be highly reproducible. Experimental results reveal that the sensor exhibits good sensitivity for bending loads in both directions of applied force. No hysteresis was observed for the sensor. The proper designing of this sensor can replace strain gauges up to certain extent in structural bending applications. This principle can be extended to make weighing machines up to some extent.

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