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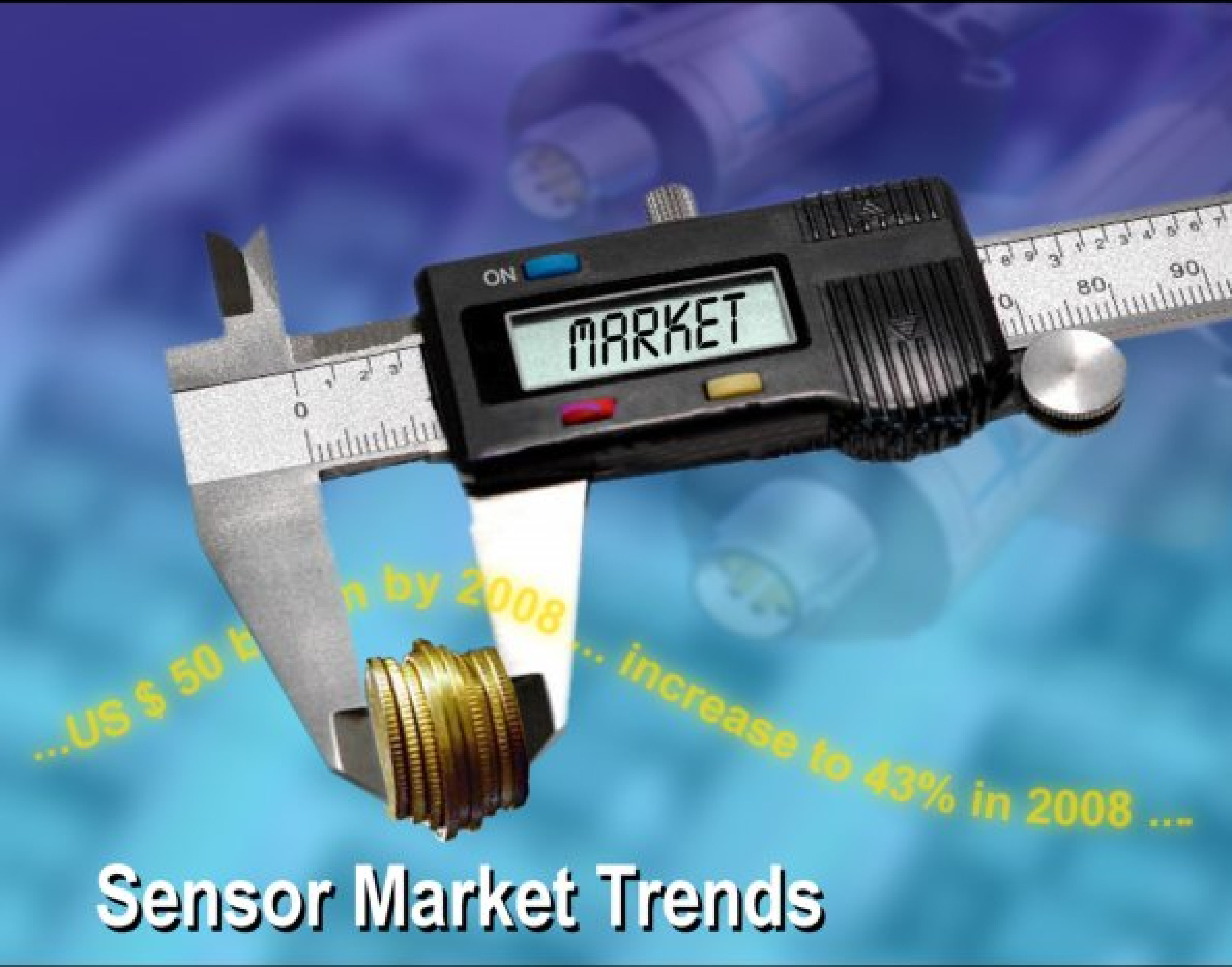

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Monitoring of High Pressure with Fiber Optic Sensor

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Abstract: Paper reports intensity modulated pressure sensor using microbending in the optical fiber embedded in the structural material. Pressure induced microbends have been created in silica clad graded index multimode optical fiber 50μm, plastic clad PCS200 and plastic clad PCS600 optical fibers embedded in the sample of araldite matrix. The samples have been tested separately with random microbending and periodic microbending of spatial periodicity Ë=5mm under high pressure cyclic loading conditions. The maximum pressure measured with PCS600 is 3.0 MPa, with PCS200 the maximum pressure measured is 1.8 MPa and that with silica clad 50μm maximum pressure measured is 1.6 MPa. The results with PCS600 optical fiber have been found to be linear and most reliable.

Keywords: Modulated pressure sensor; Fiber optic sensor; Optical fiber

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1. Introduction

There has been a need to develop a sensor to be used as a time monitoring device under cyclic loading conditions, which may be used for detection of dangerous strain levels in the structure and failure of materials as well. The concept of using optical fibers to sense the mechanical response of structure to applied load has been implemented in the so called form of smart skins [1-2]. An optical fiber embedded in a composite structure deforms together with the composite structure and modulates the light passing through the optical fiber when a physical parameter is changed in the surrounding environment. Work has been reported in the area of microbending sensors [3-4] and in the area of embedded sensors [5-6]. Work presented in this paper is advancement over the works in the field of embedded sensors and microbending sensors. The present work is a combination of the embedded sensor and microbending sensor. Pressure induced periodic microbends have been created in the sample having optical fiber embedded in it [7-10]. If high pressure is applied directly on optical fiber having microbends, it may break and if pressure is applied on embedded fiber in a solid structure without microbends, the sensitivity is less. The work presented in this paper is a combination of the embedded sensor and microbend sensor. This has the advantage of sensing high pressure on a structure with the sensitivity of a microbend sensor without breaking the optical fiber.

2. Principle of Operation

Microbending is carried by spatial variation in the lay of the optical fiber. This induces coupling between the modes of the fiber. Some of the coupling is to radiative modes. When a periodic micro bend is induced along the fibre axis, light power is coupled between modes with propagation constants $\hat{a}_p$ and $\hat{a}_q$ satisfying [11].

$$\hat{a}_p - \hat{a}_q = 2ð/\ddot{E} \tag{1}$$

Here $\ddot{E}$ is the spatial frequency of microbends. Power transfer will take place from the p^{th} to q^{th} mode. If q^{th} mode happens to be a radiation mode, this transfer of power will result in net transmission loss of the guided modes. Thus microbending produces loss. On application of pressure the losses are enhanced. Hence, by monitoring the decrease in guided optical power across the core as a function of the amount of microbending induced on the fiber the pressure sensor may be fabricated.

3. Experimental details

Samples of araldite with 30% hardener and 10% aniline have been prepared with optical fiber embedded in the sample. Ramp structure with spatial periodicity $\ddot{E}$ = 5.0mm has been created in the fiber during preparation and fiber inside the sample touches these ramps.

Experimental setup is shown in Fig.1. Light is launched in the optical fiber from a 15 mW He-Ne laser through a microscope objective of 10X. Pressure is applied on the sample by a hydraulic machine and the output is measured with a photodyne photometer/radiometer 88xLA model.

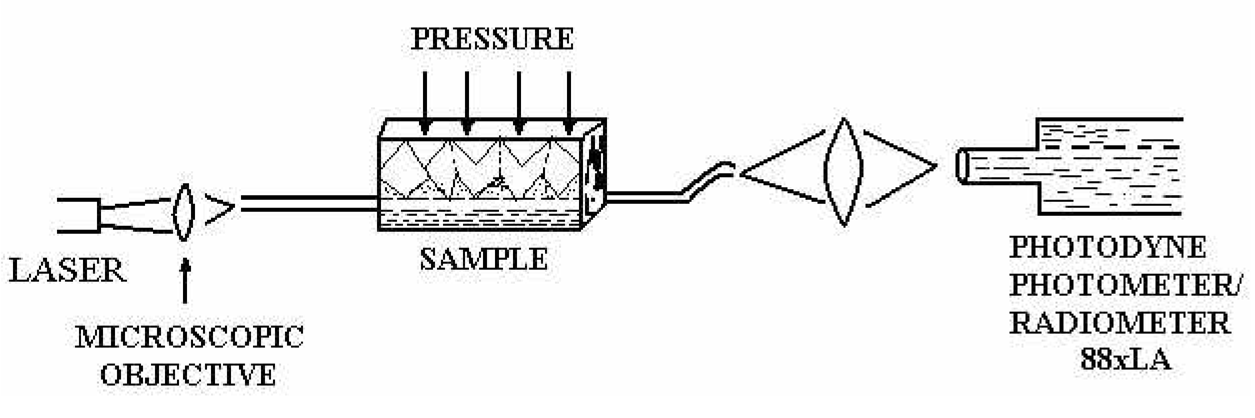

Fig.1. Experimental Layout.

4. Results and Discussion

Fig.2 shows graph between applied pressure and normalized output power for increasing cycle of operation for 50 µm silica clad graded index optical fiber with microbending periodicity Ë=5.0mm. The sample has been tested for many cycles of operation. The results have been found to be reproducible within ±5% of the measurand. It is observed that the rate of fall in the output power initially is large and then the fall is gradual. For an increase in pressure of 0.2 MPa the fall in the output power is nearly 40%.

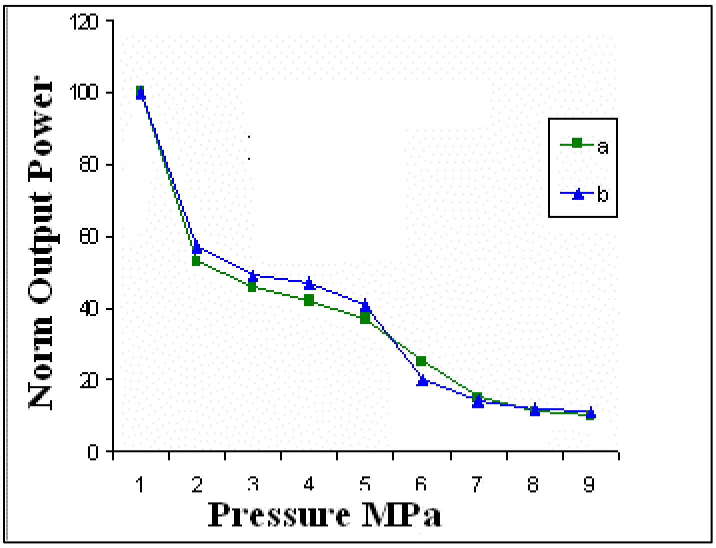

Fig.2. Variation of normalized output power with pressure (random microbending; PCS200).

Fig.3 shows the graph between pressure and output power for PCS200 with random microbending (the optical fiber is sandwiched between two sand papers). Fig.4 shows corresponding graph for PCS200 with microbending periodicity Ë=5.0mm. Results with periodic microbending are found to be reproducible within ±6% and that with random microbending within ± 5% of the measurand. For PCS200 with periodic microbending, for a pressure of 0.2 MPa the fall in the output power is more than 40% of the initial value. Comparing this with the fall in the output power for random microbending, it is observed that the fall for pressure of 0.2MPa is nearly 5% in the later case. Maximum pressure sensed before the fiber gets broken in the case of random microbending is 3.8 MPa whereas in case of periodic microbending it is 1.8MPa.

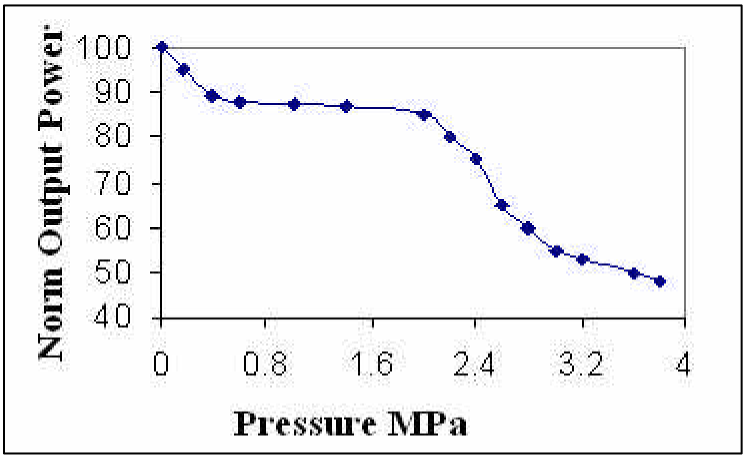

Fig.3. Variation of normalized output power with pressure (periodic microbending; PCS200).

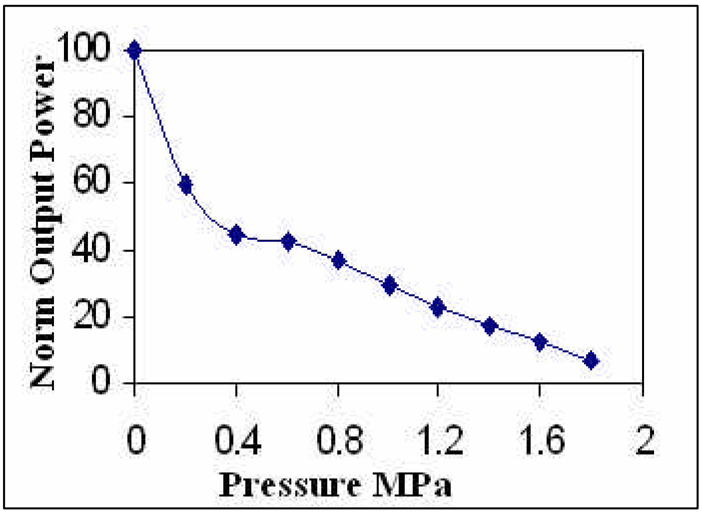

Fig.4. Variation of normalized output power with pressure (periodic microbending).

Fig.5 shows graph between pressure and normalized output power for first cyclic operation for PCS600 with spatial periodicity Ë=5.0mm.

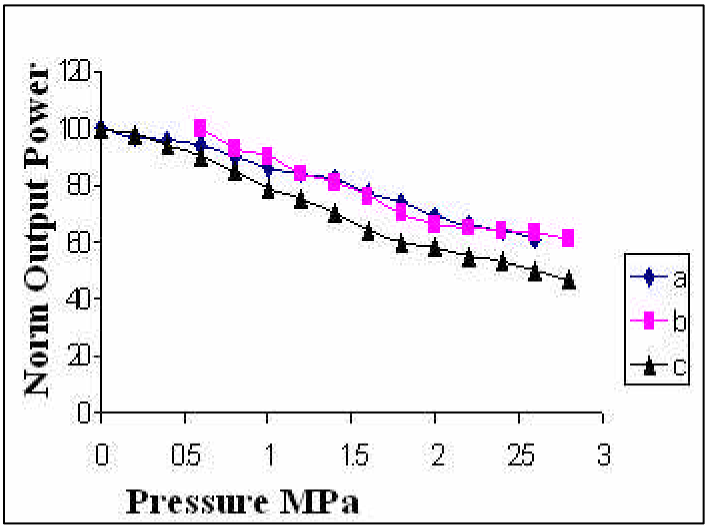

Fig. 5. Variation of normalized output power with pressure (periodic microbending; PCS600).

The results obtained are summarized in Table 1. Here the average sensitivity is defined as the average slope of the curve.

The average sensitivity in the case of 50µm silica clad graded index optical fiber is 94. However, the sensitivity all through the range of pressure applied is not uniform. The sensitivity in the pressure range of 0 to 0.2 MPa is 225 whereas it decreases drastically to 21 in the pressure range of 0.2 to 0.8 MPa, and increases to 34 in the pressure range 0.8 to 1.6 MPa. In the case of PCS200 with random microbending the average sensitivity is low at 15, the sensitivity falling to 5 in the pressure range of 0.6 to 2.2 MPa. For PCS200 with periodic microbending the sensitivity is again high at 140 in the pressure range of 0 to 0.4 MPa; then it falls to 26 in the pressure range 0.4 to 1.8 MPa. In the case of PCS600 the average sensitivity is 22, the graphs are almost linear and there is uniform sensitivity throughout the range of pressure applied from 0 to 3.0 MPa.

Table 1. Summarized Results.

Properties of sensors	PCS200 Random microbending	50mm (Silica) Ë=5.0mm	PCS 200 Ë=5.0mm	PCS 600 Ë=5.0mm
Reproducibility	± 2%	± 5%	± 6%	± 3.3%
Range	3.8 MPa	1.6 MPa	1.8 MPa	3.0 MPa
Average Sensitivity	15	94	83	22

5. Conclusions

Results described above show that plastic clad thick optical fiber PCS600 embedded in the sample with pressure induced periodic microbends induced in it is most suitable for monitoring of pressure and sensor application. This sensor is robust, cost effective and user-friendly.

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