Fiber Optic Liquid Level Sensor using multimode fused coupler

[1,2] D.Sengupta, [1]M.Sai Shankar, [1]K.Srimannarayana, [1]R.L.N.Sai Prasad
[1]National Institute of Technology, Warangal, India
[2]Vidya Jyothi Institute of Technology, Hyderabad, India
guuptasengupta@gmail.com

ABSTRACT

An intensity based fiber optic liquid level sensor for continuous measurement is described. The sensing principle is based on intensity of reflected light which is disturbed by the change in proximity of the fiber probe and the reflector. A Mechanical CAM is used in the sensing arrangement. It converts the rotatory motion into a linear displacement. As the liquid level raises, rotation of the CAM takes place and the CAM follower connected to it moves linearly. A reflector which is attached to the end of the CAM follower reflect the incident light. As the displacement of reflector occur the intensity of reflected light also changes and is a measure of change in liquid level. The prototype designed sensor can sense liquid level upto 17cm. The proposed sensor can find potential applications in transportation and process industries.
Key words: Liquid level sensor, Fused coupler, Plastic optic fiber, CAM, Float

1. INTRODUCTION

Liquid-level sensing is a requirement in many applications in which knowledge of the volume of a liquid is necessary, for example, in fuel storage systems and chemical processing. A wide range of liquid-level sensing techniques based around mechanical, electrical and optical methods has been reported [1-3]. Electrical liquid-level sensors are widely employed, but their applicability is compromised if the liquid to be monitored is conductive or if the environment is potentially explosive. Optical fiber sensors offer well-established advantages under these conditions. The optical fiber is a dielectric, and thus is non-conducting, and the sensor may be configured such that the light is confined within the fiber, reducing the likelihood of ignition of a flammable environment. The reported fiber-optic liquid-level sensing techniques generally rely on the interaction of the tip of the sensor with the surface of the liquid or on transmitting light to and receiving the reflected light from the surface of the liquid[4-7].

A float based fiber optic level sensors that works on reflection of light can be realized with either glass or plastic optical fiber. But the system has small range of level measurement. A non contact static liquid level measurement using PMMA fiber was demonstrated and can be useful for the measurement of level in micro scale [8]. The sensor has also some limitation because of its extrinsic sensing that also depends on involvement of stray light and reflectivity of the reflector.

In this paper we describe a fiber optic liquid level sensor which can be classified as non intrusive float based level sensor. The sensing range is enhanced by taking different connecting rod joining the float and the sensor head. The sensitivity and repeatability of the sensor was studied. The sensor head is encapsulated to avoid the effect of stray light and dust on reflector and on the cross section of the fiber.

2. PRINCIPLE AND DESIGN DETAILS

The sensor works on the principle of fiber optic displacement sensor using a plastic multimode 50:50 (2X1) fused fiber coupler [9,10]. The two arms of fused coupler are used for transmitting and receiving the light radiation and the other as probe for the measurement. The distance between the probe end and the reflector affect the intensity of light received by the receiving fiber. The characteristic curve of the effect shows a linear region (back slope) of 1mm distance and is dependent on the type of fiber used. To increase this range a concentric cam along with cam follower and a connecting rod with float is introduced [11]. The basic function of the cam is to convert circular motion into a linear one. This is referred to as reciprocating movement. A cam-follower is connected to transfers the cam's movement.

International Conference on Optics in Precision Engineering and Nanotechnology (icOPEN2013),
edited by Chenggen Quan, Kemao Qian, Anand Asundi, Proc. of SPIE Vol. 8769, 87692A
 · doi: 10.1117/12.2021239

From the geometry of the Figure 1, the displacement (AB) of the cam follower is

AB= OQ (1-cos θ)   (1)

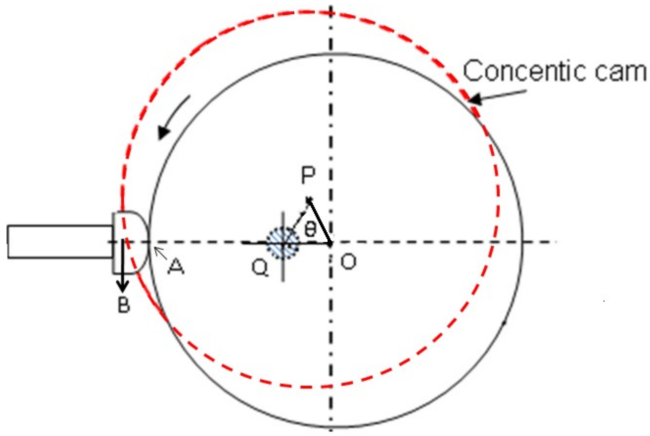

Fig. 1. Geometry of the concentric cam.

Where OQ is the offset of the cam. The cam in its lowest position is shown by full line and when it has rotated through an angle 'θ', by dotted lines and P is the new position of the Cam centre. When 'θ' is equal to 0º no displacement occurs for the cam follower and it is twice the offset value when 'θ' is equal to 180º.

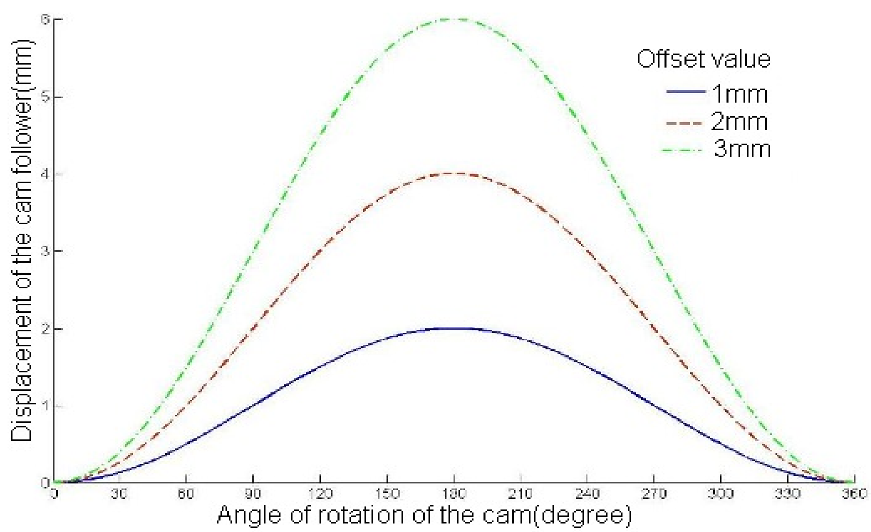

Fig. 2. Displacement of the Cam follower with respect to cam rotation

Figure 2 shows the simulated results of displacement of cam follower for varying angles of rotation of the cam for different values of offset. From the plot it is evident that for 0.915 mm linear displacement of cam follower the angle of rotation is in the range of 55º to 110º. If the offset value increases for a fixed value of displacement of cam follower the angle of rotation of the cam decreases.

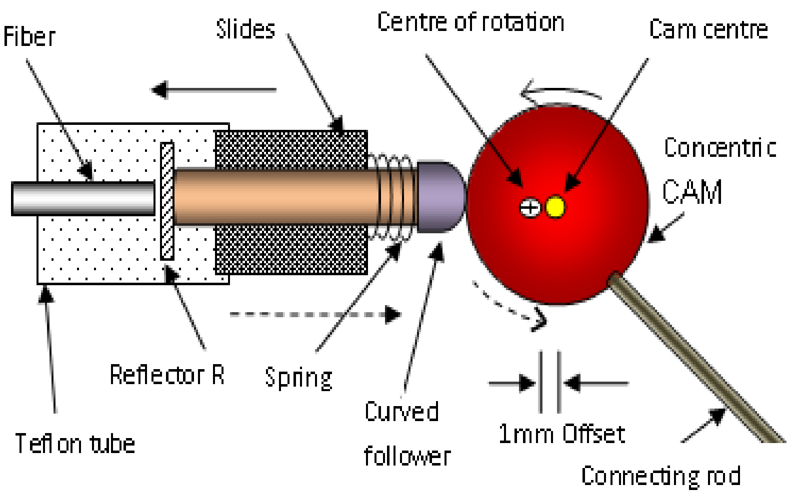

Fig.3. Schematic of the sensor head

The schematic of sensor head is shown in figure 3. It consists of a concentric cam (25 mm diameter) whose centre of rotation is offset by 1mm. The cam follower (35mm long) has a semispherical end to have a point contact with the cam's periphery and can easily follow the cam's contours and movement. It is allowed to move smoothly through the slides of length 25mm. For the cam follower to maintain constant contact with the cam periphery a spring is used. A reflector (R) of diameter 10mm is fixed to the other end of the follower. The end of the common arm of the 50:50 (2X1) fused coupler is positioned before the reflector (R).

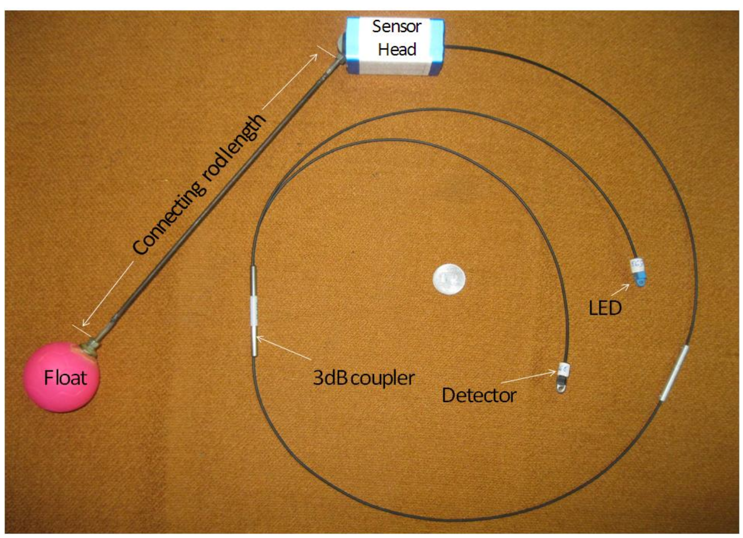

Fig. 4. components of the liquid level sensor

Figure 4 shows light source, LED (IF-E 96), is connected to one arm of the fiber coupler and the other arm is connected to the detector (IF-D 93) to sense the intensity of the light received. The end of the probe was fixed and the reflector was attached to the cam follower. The probe and the reflector was encapsulated using a Teflon tube to avoid the effect of stray light and dust on the reflector (R).

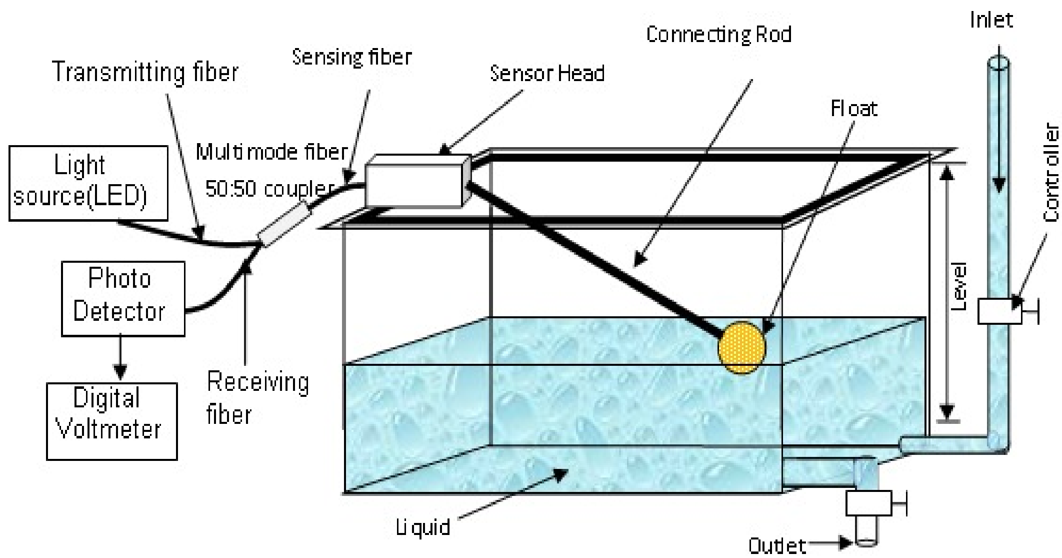

Fig. 5. The Schematic Experimental Setup of level sensor

This sensor head is fixed to one of the walls of a rectangular tank (400mm X 200mm X 350mm) having an inlet and outlet arrangement along with the controllers to control the level of the liquid present in the tank shown in Figure 5. A float (5cm diameter) is attached to the connecting rod and is allowed to come into contact with the liquid level. As the liquid level varies the float displaces from its earlier position making the cam to rotate about its offset axis. This results in displacement of the cam follower, consequently the separation between the reflector (R) of the cam follower and the tip of the fused coupler arrangement end changes. The change in spacing results in change in the intensity of light sensed. The 1mm offset of the cam is considered to achieve maximum allowable angular rotation to get maximum level measurement range.

3. RESULTS AND DISCUSSION

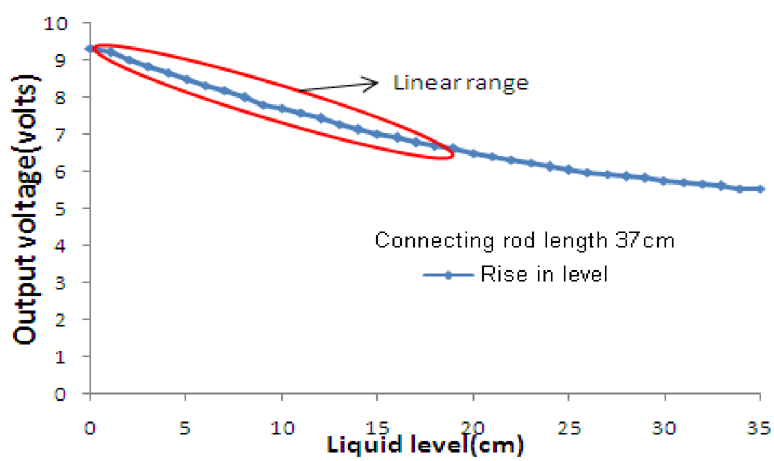

Fig.6. Linear range of the sensor characteristic curve

Figure 6. shows the sensor output voltage variation for a level change of 35cm. But, the slope of the characteristic curve is nonlinear for the entire range. A 99.7% linearity is observe within the range of 0 to 19cm and is taken for the measurement of liquid level.

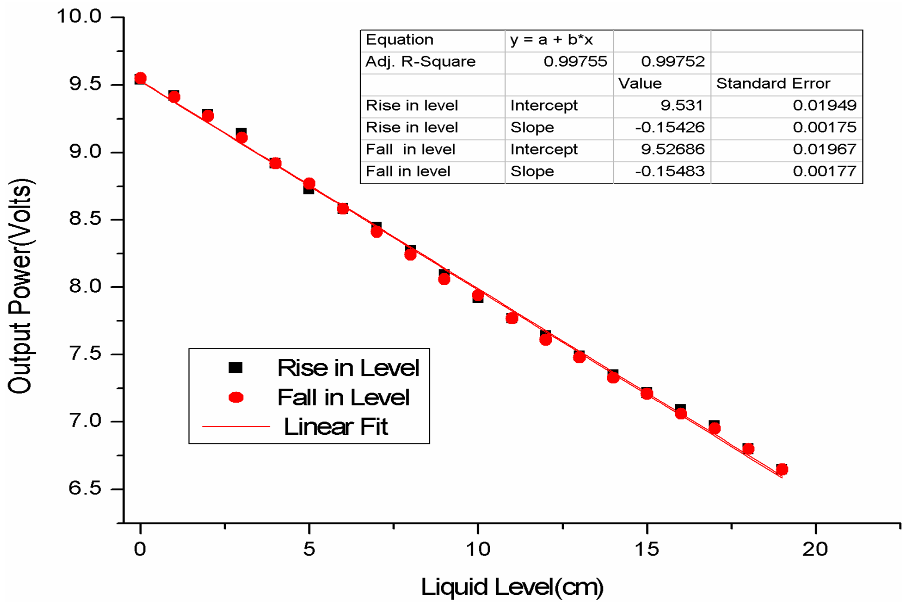

Fig. 7. Variation of output power with rise and fall Liquid level

Figure 7. shows the sensed output voltage variation during rise and fall of liquid level. Regardless of the direction of liquid level variation the datum traces almost coincide indicating a fair reversibility. To check the repeatability, the output voltage was recorded for 4 trials of increase in level and is plotted. Figure 9, which confirms good repeatability

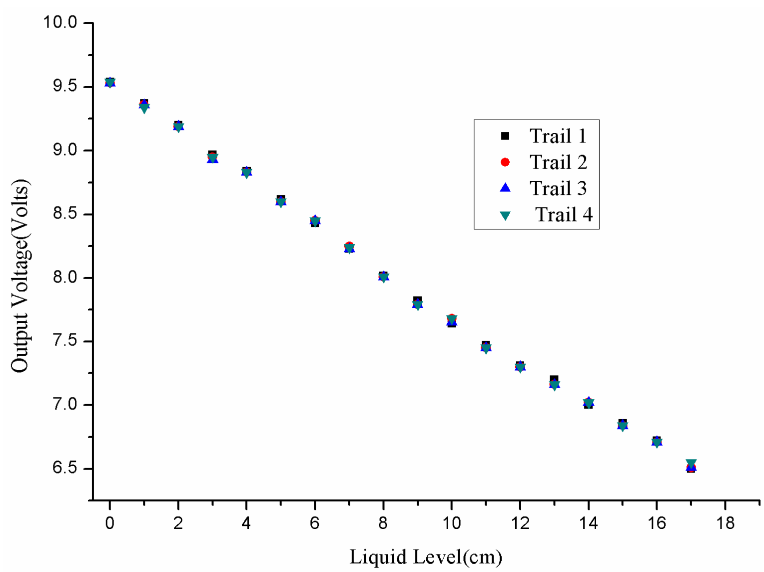

Fig. 9. Repeatability of the sensor during rise in level at four different trials.

CONCLUSION

In this paper a concentric cam based optical fiber level transducer was proposed. It is mainly comprised of a fused fiber coupler and a reflector attached to a cam follower. The float movement due to change in liquid level modulates the reflected light falling on the reflector that determine the level. The range of level sensing depends on the length of the connecting rod with float connected to the cam. The prototype sensor with 19cm and 17cm ranges and sensitivities -0.15483volts/cm and -0.17979volts/cm was developed and calibrated. The isolation of sensor head along with cam from the supporting electronics, make the sensor suitable for measuring liquid level safely. We can use the sensor arrangement for continuous and discrete liquid level sensing applications, thus providing a liquid level sensor that is inexpensive with a very simple fabrication process

REFERENCES

[1] Thomas A. Hughes, "Measurement and Control Basics", 3rd Edition, ISA Press (2002)

[2] Eldar Musayev, Sait Eser Karlik, "A novel liquid level detection method and its implementation", Sensors and Actuators A 109, 21–24 (2003)

[3] Krohn, D. A., [Fiber Optic Sensor Fundamental and Applications], 3rd, ISA, (New York),(2000)

[4] Pabitra Nath, Pranayee Datta and Kanak Ch Sarma, "All fiber-optic sensor for liquid level measurement", Microwave optical Technol Lett 50, 1982–1984(2008)

[5] M. Bottacini, N. Burani, M. Foroni, F. Poli, and S. Selleri, "All-plastic optical-fiber level sensor", Microwave OptTechnol Lett 46, 520–522(2005)

[6] Pekka Raatikainen, Ivan Kassamakov, Roumen Kakanakov, Mauri Luukkala, "Fiber optic liquid level sensor", Sensors and Actuators A 58, 93-97(1997)

[7] K. Iwamoto and I. Kamata, "Liquid-level sensor with optical fibers",Appl. Opt. 31, 51-54 (1992).

[8] S.Binu, K.Kochunarayanan, V P Mahadevan Pillai, N.Chandrasekaran, "PMMA (polymethyl methacrylate) fiber optic probe as a noncontact liquid level sensor", Microwave and optical technology letters 52(9), 2114- 2118 (2010)

[9] Samyan, yono hadi pramono, Ali yunas Rohedi,Febdian Rusydi and A. H. Zaiean, "Theoretical and experimental study of fiber-optic displacement sensor using multimode fiber coupler", Journal of Optoelectronics and Biomedical Materials 1(3), 303-308(2009).

[10] Werner Daum, Jurgen Krauser, Peter, E., Zamzow and Olaf Ziemann, [POF-Polymer Optical Fibers for Data Communication], Springer (2002).

[11] Kurmi, R. S. and Gupta, J. K., [Theory of Mechanics], S. Chand and Company ltd.