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FIBRE-OPTIC TEMPERATURE SENSOR

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ABSTRACT

This experiment is a kind of nonfunction fibre-optic temperature sensor. It utilizes high-sensitive bimetallic strip for element of measuring temperature. The changing of bimetallic strip alterates intensity of light through fibre-optic. This equipment is simple in structure, subtle in design, extensive in application, and so on.

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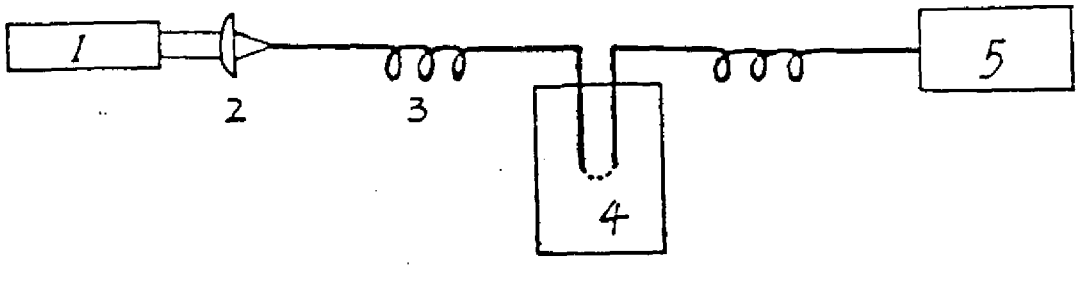
1. Introduction

Fibre-optic sensor is a new kind of science and technology which appeared first in the late seventies. Its appearance was respected highly in the developed industrial countries. If we compare fibre-optic sensor with others, its special advantages are high responsibility, little volume, light weight, antielectromagnetism perturance, stable chemical property, and so on. Fibre-optic sensor utilizes the relative property of light and other materials, and more than one hundred kinds of fibre-optic sensors have been developed, including temperature, pressure, displacement, electric field, magnetic field, gyroscope, and so on. Fibre-optic temperature sensor is one of applied extensively fibre-optic sensors. This paper relates a kind of nonfunction fibre-optic temperature sensor which is simple in structure, extensive in application, and other advantages. It is a kind ideal arrangement for measuring temperature.

2. Working principle and building of measuring-tip

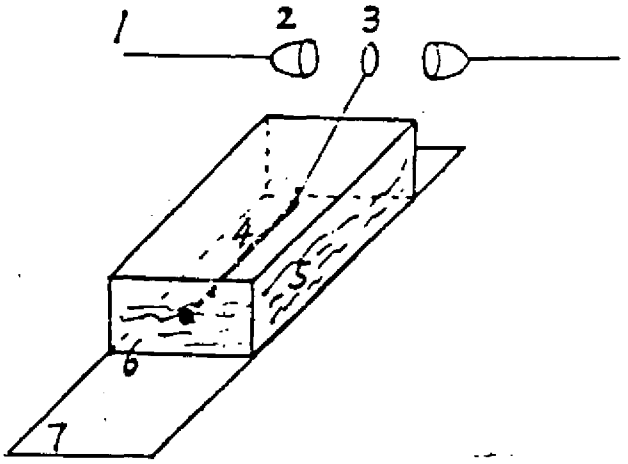
Nonfunction fibre-optic sensor is that fibre-optic only acts as medium through light, but showing changes of external messages is done by other sensitive material or elements which influence messages of light. It also has the same elementary natures of function fibre-optic sensor. The light source is a He-Ne laser in this experiment. The light beam (6328Å) which comes from He-Ne laser enters fibre-optic by focusing lens. The light in fibre-optic arrives at the head (measuring - tip) of sensor through long distance. The light messages influenced by environment around measuring-tip are transported by fibre-optic into detector which shows changing of light messages. (see Fig.1)



1 He-Ne laser 2 focusing lens 3 fibre-optic
4 measuring-tip 5 detector

Fig.1 The principle of fibre-optic temperature sensor

See Fig.2 about building of measuring-tip. The light transported by fibre-optic is expanded for homogeneous beam by convex lens, then it is focused by another convex lens into receiving fibre-optic which transports light to detector. In metallic cell there is methi-silicone oil which is a kind of special synthetic material which can conduct heat and unvolatiles. 5J11 heat bimetallic strip which has high responsibility is soaked completely into methi-silicone oil. One of both ends is fixed on metallic cell. Another links obstructor. The change of temperature results in deflection of bimetallic strip in methi-silicone oil. The change of bimetallic strip leads to moving of obstructor so that intensity of light is controlled. The more high temperature is, the more deflective bimetallic strip is, and the bigger displacement is in longitudinal direction, the bigger intensity of light is on detector.



1 fibre-optic 2 convex lens 3 obstructor
4 bimetallic strip 5 methi-silicone oil 6 metallic cell
7 regulator
Fig.2 Structure of measuring-tip

3. Measuring result and analyses

The relation of temperature and intensity of light in this experiment, to see table 1 about measuring result, and see Fig.3.

Table 1.

Temperatur(℃)			18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
first measure		ascent	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.8	0.9	—	1.6	2.1	2.6	3.2	4.1	5.2	5.6	6.2	6.0	6.0	6.7	5.4	5.0
		descent	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.9	1.2	1.5	1.9	2.4	2.8	3.6	4.7	5.5	6.1	6.8	6.8	6.2	6.6	6.4
second measure		ascent	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.8	1.0	1.4	1.7	2.2	2.7	3.2	3.6	4.6	5.0	5.5	5.2	6.2	4.5	4.8	4.5
		descent	—	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.8	0.8	0.9	1.2	1.5	1.9	2.4	3.2	4.0	4.8	5.5	5.8	6.3	5.9	5.4	5.1	5.4
average value			0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.8	0.8	1.3	1.6	2.1	2.6	3.1	3.8	4.8	5.5	5.8	6.1	6.0	5.6	5.1	5.1
absolute error	first	ascent	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	—	0.0	0.0	0.1	0.1	0.3	0.4	0.3	0.3	0.1	0.0	0.2	0.3	0.1
		descent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.3	0.1	0.3	0.2	0.1	0.0	0.2	0.7	0.8	0.7	0.5	0.3
	second	ascent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.5	0.4	0.8	0.8	1.0	0.6	0.4
		descent	—	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.1	0.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.3

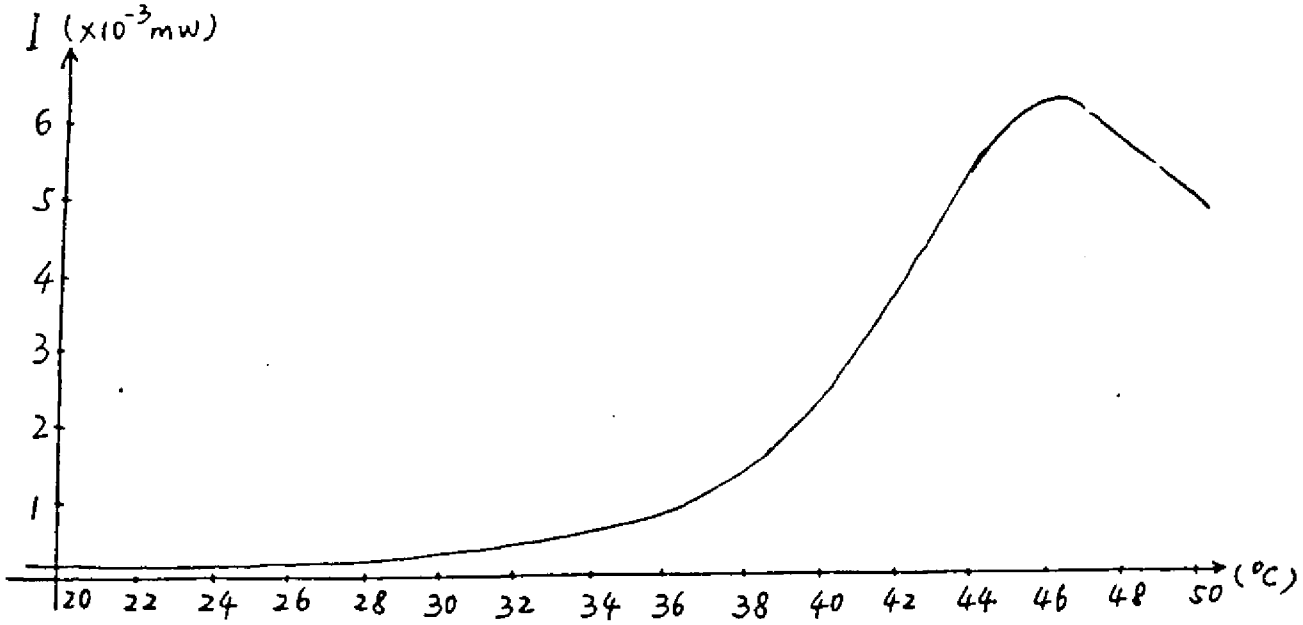


Fig.3

From the table we can find out that the fibre-optic temperature sensor has very good repeatability, ascending or descending succesively four times, measuring result all keeping little changing, and that from 18 °C to 42 °C absolute error of intensity of light is less than $\pm 3 \cdot 10^{-3}$ mv, relatively, the error of temperature less than ±1°C, so its stability is very high.

Analyses of result of experiment:

(1). reason of influencing error

a. The intensity of laser itself is a changing process of 'leaping mode'.

b. The intensity of light from laser contains messages of alternating current (100 Hz).

c. Laser is influenced by environment.

d. Influence of mechanical error in the arrangement.

(2). proving the experimental result according to theory.

Gauss beam from laser is:

$$V_{oo}(x,y)=C_{oo}EXP[-(x^2+y^2) \div (1\omega/\pi)]$$

See Fig.4.

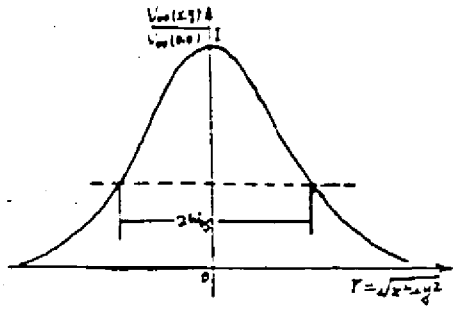


Fig.4 Gauss beam and size of light dot.

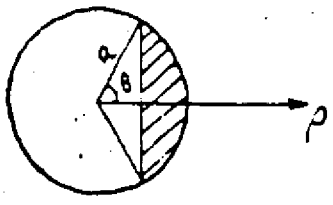


Fig.5 Area of transported light.

When temperature changes, bimetallic strip moves. The area of detected intensity of light is a segment. Supposing that radius of light dot is a, area of transported light is s, its angle is θ ($0 \leqslant \theta \geqslant \pi$), (see Fig.5).

Then

$$s=0.5a^2 2\theta - a^2 \sin\theta \cos\theta$$
$$=0.5a^2 [2\theta - \sin(2\theta)]$$

order

$$a=1$$

so

$$s=\theta - 0.5\sin(2\theta).$$

This area is superposition of areas of functions. See Fig.6(a). Fig.6(b) is result of folding of Fig.6(a). is function of temperature. The area corresponds to intensity of light. If we think further over Gauss beam[Fig.6(c)] as well as affect of straight edge diffraction, final result should be Fig. 6(d). It is found easily that theoretic analyses completely accords with experimental result, including instability of ending curve and obtuseness of head curve.

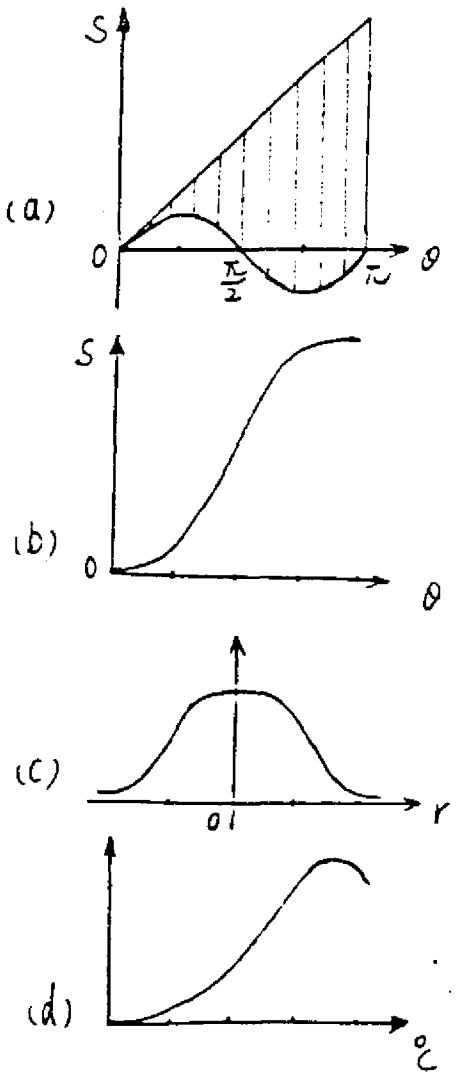


Fig. 6

4. Conclusion

In above analyses, we can find both theoretically and experimentally out that there is a kind of approximate linear relation. is approximately from $\pi/4$ to $3\cdot\pi/4$ in theory, but temperature is approximately from 20°C to 40°C in experiment. Both stability and repeatability are all very ideal. According to this case, this arrangement can also be becomed an alarm of temperature, when intensity of light arrives at the certain point, alarm begins ringing. The case can be realized completely in experiment.

Acknowledgments

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