(16) Development of Point Current, Gate Opening, Inundation River Sensor for IoT System

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To deal with the disaster caused by visualization of river water flow and sophistication in river management, we deal with various kinds of information, multi-point and a large amount of river-related information. And we are conducting research and development toward the promotion of river IoT. As a first step, we devised and prototyped a reed switch type point current sensor and carried out the factory and on-site experiments. In the on-site experiment at watarase river, the problem peculiar to multi-sites clarified. And as a result of examination of countermeasures against them, the resolution reduced up to 30 times or about 1/1.5 by changing the type from a reed switch to acceleration, hence the completeness improved. Also, it was conceived that this acceleration type application applies to gate opening degree and inundation sensor as the second and third stage. In this paper, we discuss the problem and countermeasures of the reed switch type point current sensor in the field experiment, the principle of the accelerator sensor, adaptability to the river, comfirmed 0.11°/digit resolution and about 0.5° accuracy of accelerator sensor as a result of comparison experiment between sensor output and actual angle, new principle of three kinds of sensor.

Key Words : *Iot, sensor network, point current sensor, gate opening sensor, inundation sensor*

1. INTRODUCTION

At the time of the flood, many people lost their lives and this is often caused by the individual judgment of people. So, we developed a disaster alert tool including the element of gamification that public can use in daily life, intuitive visualization of various kind of river information, which will lead to the disaster reduction[1)]. So, the research and development is pursued for the sophistication in river management by adapting the sensor network which is the main element of IoT.

To adapt rapidly growing IoT to the river management, we are researching and developing a wide variety of unique river sensor that can be installed in large quantities with low power consumption, simple, compact and affordable. The on-site testing of point current sensor was formulated at the Watarase river office of Ministry of Land, Infrastructure and Transport(MLIT) as the first stage and reported that the concept of non-human, continuous flow rate observation can be done[2)]. After that, several problems were clarified in the on-site testing and in the course of studying the countermeasures, it was confirmed that accelerator type was more effective than reed switch type. Besides, as an application of this accelerator type, we could design a new flap gate opening sensor and inundation sensor. In this paper,

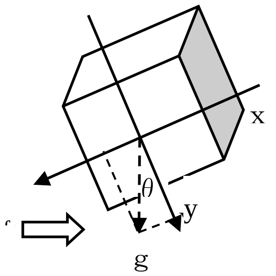

Fig.1 3-Axis accelerator sensor during measurement

we report on work related to the accelerator sensor device, the principle, adaptability to the river and result of factory testing.

2. RELATED WORK

(1) For point current sensor

After factory and on-site testing on the point current sensor, several problems and challenges were identified. The Reed switch type sensor has a very low resolution, i.e. 3°/digit (logically). So, using accelerator sensor there is a possibility of achieving high resolution. There were iron sand and insect inside the point current sensor which can be solved by structurally changing the air room. Bending of the detection arm can be prevented by replacing φ3 by φ5.

(2) For gate opening sensor

In this paper we explain detail design and operation of gate opening sensor[3]. As far as I know, the detection of self-weight flap gate has not been put into practical use for the reduction of equipment cost.

(3) For Inundation sensors

There are many kind of water level sensor. The proposed inundation sensor is based on an accelerator sensor considering that it is the first attempt that has not been conducted so far to use in a river and river-related places.

3.OBSERVATION SYSTEM AND ACCELERATOR SENSOR

(1) Outline of an observation system

The observation system configuration include three types of sensors.

The sensor unit includes a plurality of point current sensors, gate opening sensors and multiple inundation sensors. These sensors are connected to the wireless device (transmitting side) with a serial signal. WiSUN can be used for wireless transmission up to about 500m[4] distance. On the other hand, using LoRa low power consumption can be realized with a transmission distance of about 1 km. The internet can be used to access site data.

(2) A Principle and considerations

Acceleration is calculated by the displacement which is detected as a change in electrostatic capacitance. According to Newton's law,

$$F = m \times a \tag{1}$$

$$F = k \times x \tag{2}$$

$$a = \frac{k \times x}{m} \tag{3}$$

Here, 'x' is the extension distance of the spring and 'F' is force. Since coefficient 'k' and the mass 'm' are known values, from the equation (3) the acceleration can be obtained by measuring the moving distance 'x' of the mass[5].

Fig.1 is an example of measuring the flow velocity by attaching a 3-axis accelerator sensor to the detection arm of the point current sensor. When the direction of water flow is set to x and gravity is set to y, the detection arm is inclined by θ. Assuming that the gravitational acceleration is g [m/s 2], the equations (4) and (5) are obtained.

$$x = g \times sin\theta, \quad y = g \times cos\theta \tag{4}$$

$$\theta = \sin^{-1}\frac{x}{\sqrt{x^2+y^2}} = \cos^{-1}\frac{y}{\sqrt{x^2+y^2}} \tag{5}$$

That is if the accelerations in the x and y-direction of the sensor are obtained, the angle θ can be calculated and it is not necessary to consider the influence of the gravitational acceleration.

In above equation the angle θ is calculated in the stable state, but in case of fluctuation in flow velocity, it may be slightly changed. Other factors, for example, mounting structure, ground vibration, debris flow, etc will influence the measurement accuracy. These can be removed by secondary processing of data like filter and smoothing depending on observation purpose.

4. FACTORY TESTING

(1) Factory testing method of accelerator sensor

The actual measurement comparison of the ac celerator sensor is carried out by angle measuringequipment possessed by Takuwa Corporation.The angle measuring equipment has angle detection accuracy of 0.008° as a design value and displays in units of 0.01°.

Fig.2 shows the factory testing of the accelerator

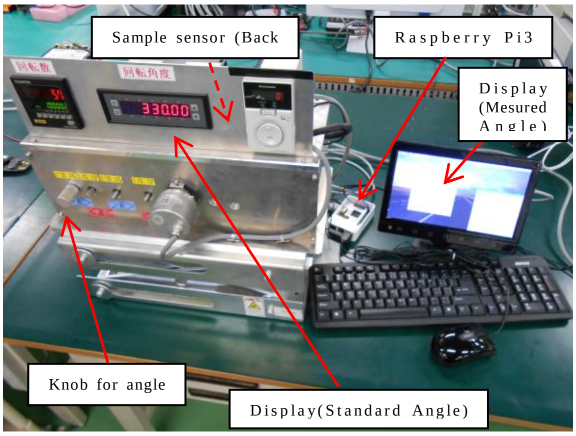

Fig.2 Angle measurement experiment

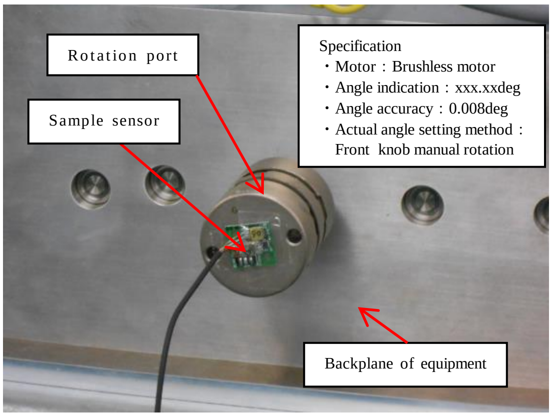

Fig.3 Status of sensor to be measured (back of equipment)

sensor. Also, **Fig.3** shows the state of the sensor to be measured attached on the back of the device. By rotating the knob of Front panel manually, the angle measuring device rotates the rotation port together with the sensor. Actual angle (Standard angle) is displayed in a display panel of device and output of sensor is displayed as an integer between -512 and +511(digit) through Raspberry Pi 3.

(2) Experimental results of the accelerator sensor

Fig.4 shows the data of two accelerator sensors of serial number 05 and 06, for 3 successive times x, y, z sensor output (measured) for total 18 lines. The only first data on the x-axis of the sensor 06 was measured every 10°, and the other were measured every 30°. Since the saturation amount of y is slightly larger than that of x, both x and y should be considered to get high accuracy. The measurement was carried out 3 times at the same angle and output value was almost the same. A phase difference between x and y is 90°. The deviation between line x and y is confirmed to be about 80° which is caused due to manual installation.

Fig.5 shows 6x1, 6y1 and the angle error between the measured value and standard angle after analysis. Although the error is within the range of -1 to +1 for 0 to 360°, in practical use the measurement range of

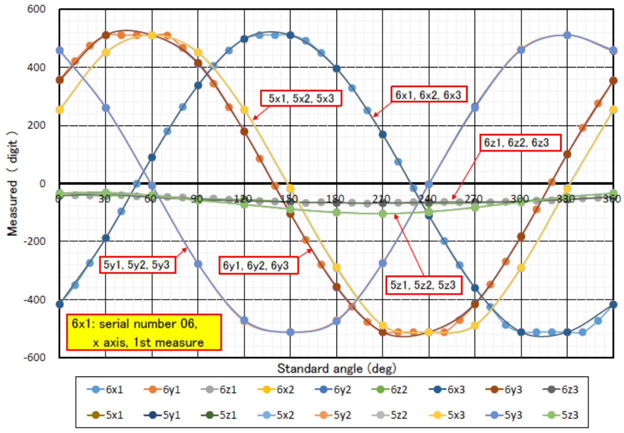

Fig.4 All data of actual measurement

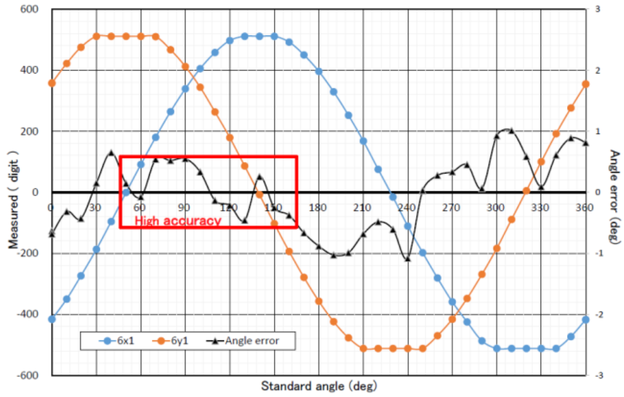

Fig.5 The first x,y data and angle error of sensor 06

point current sensor is 60°. So by using a range with relatively small error, for an example, by using 50 to 160°, an accuracy of ± 0.5° can be expected.

Table 1 shows a part of output numerical data 6x1, 6y1 and the angle error. From 6x1 in Table 1, (60.02 - 50.03) / (91 + 1), that is, 0.11° / digit resolution can be calculated.

5. ABOUT 3 ACCELERATOR SENSORS

(1)For point current sensor feature

This sensor is used to measure the velocity, based on the same principle as reed switch type sensor. **Fig.6** shows the structure of the new point current sensor. An accelerator sensor module is waterproofed and fixed to the rotating shaft, suspended in a watertight case. Detection arm directly contacts the water flow. The accelerator sensor rotates according to the flow velocity. The flow velocity can be calculated from rotation angle detected by the accelerator sensor using 3-degree polynomial equation obtained from factory testing.

(2) For gate opening sensor feature

The gate opening sensor is used for monitoring the status of flap gate. The principle is same as point

Table 1 First x, y data of sensor 06 (Excerpt)

Standard angle(Deg)	6 x 1 (digit)	6 y 1 (digit)	Angle error (Deg)
50.03	−1	511	0.14
60.02	91	511	−0.08
69.98	180	510	0.54
80.00	264	467	0.52
90.00	339	412	0.55
99.99	405	344	0.33
110.00	458	263	−0.14
119.98	497	179	−0.22
129.99	511	86	−0.46
140.00	511	−8	0.26
149.99	511	−103	−0.25
159.99	492	−194	−0.38

current sensor. Since, the opening sensor is installed to flap gate directly the sensor rotates together with the flap gate, there is no moving part in the sensor. The output of the sensor can be used to directly observe the rotation angle of flap gate.

(3) For inundation sensor feature

The inundation is used for very small range i.e. 38mm measurering water level. The principle is same as point current sensor. The inundation sensor can be installed to any places like a power pole. Water enters the sensor from the inflow hole on the bottom surface of the case, and the float rotates in the vertical direction around the rotation axis. The water level can be calculated from rotation angle detected by the accelerator sensor using 3-degree polynomial equation obtained from factory testing.

7. CONCLUSION

In this paper, we explain observation system, summarized the principle of the accelerator sensor and attention points when using in the river.

As a factory testing, the measured value of the accelerator sensor and the standard angle measuring device were compared and investigated. The angular resolution was 0.11°/ digit in the region of linear part, also it was confirmed that accuracy of ± 0.5° can be expected. Also, we prepared prototypes of three kinds of sensors, explained their structure, technical points, and effectiveness of adaptation to rivers.

New technology is introduced using IoT and advanced application of general purpose sensor. We think that there is a possibility that river information which could not be observed so far can be easily observed in the future. But, since data acquisition and verification have not yet been realized in actual machines, we will conduct experiment and experience more cases in the future. We will strive

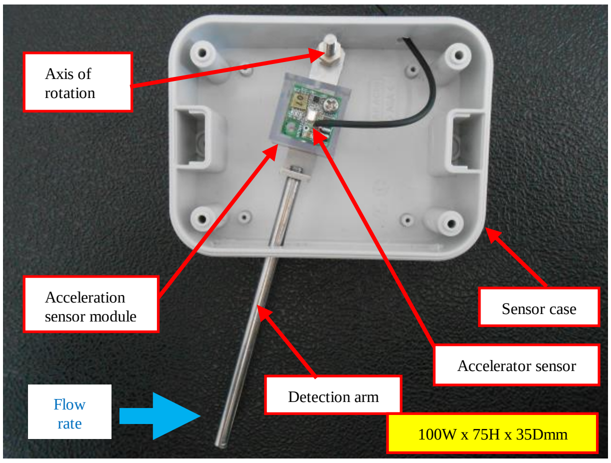

Fig.6 Structure diagram of point current sensor

to upgrade technologies to further improve river management in future and hope that we can contribute to disaster reduction.

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