International Journal of Technical Innovation in Morden Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 3, Issue 12, December-2017

DESIGN AND ANALYSIS OF AUTOMATIC CALIBRATION OF FLOWMETER

SAI LALITH KUMAR RAJU K , DR. K. VIJAYA KUMAR REDDY

Professor, Department of Mechanical Engineering
JNTUHCEH, Hyderabad.

CENTRAL INSTITUTE OF TOOL DESIGN, HYDERABAD

In collaboration with

DEPARTMENT OF MECHANICAL ENGINEERING

JNTUH COLLEGE OF ENGINEERING (AUTONOMOUS), HYDERABAD

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

HYDERABAD-500085, TELANGANA 2017

1. ABSTRACT

This project deals with automating the current "flow calibration method" which is used in many industries that requires more human effort. The device that must be calibrated by automation is a glass tube rotameter. The glass tube rotameter is a variable aperture flowmeter designed to give a visual indication of flow of wide range of liquid and gases.

This device currently used in industries uses a float inside the glass tube which moves to and fro along the axis of the glass tube. The to and fro motion along the axis is according to the flow of the fluid in the glass tube. Automatic recognition of float, automatic signal acquisition and processing is achieved.

Flow sensors, the devices that detect and measure water flowing through pipes. G1/2 Hall Effect water flow sensor is used as a sensing unit with a turbine rotor inside it whose speed of rotation changes with the different rate of flow of water. The Hall Effect sensor outputs the corresponding pulse train for frequency input to the microcontroller. The whole system comprises of AT89S52 microcontroller, G1/2 Hall Effect water flow sensor, relay, optocoupler, a water pump, 5V supply, LCD, keypad and some passive components. The AT89S52 microcontroller is programmed in Keil development Tool.

Experiments are conducted to see how flowmeters can be calibrated with reduces human effort. It is shown by the result of experiments that automatic recognition of float, automatic signal acquisition and processing are to be achieved. It is to meet the industrial field demand of float flowmeter automatic calibration.

2. INTRODUCTION

Across various industries, measuring the flow of liquid or gas demands superior instrument performance.

Each flow application presents its own unique metering challenge. From high operating pressures and changing fluid viscosities, to pulsating flow streams and corrosive environments, flowmeters must demonstrate high accuracy and reliability.

The performance of a modern flow measurement device is ultimately dependent upon the proper functioning of its sensors or other signal-producing elements, which have an active relationship with the flowing fluid.

Recent years, people spend a lot of time researching on the flow equations of rotameters, and the correction of flow measurement error in non-standard state. However, traditional rotameters that tested by hand, cause Low efficiency, big error, and no real-time. These need to be solved urgently when today is industrialization and electrification. This project puts forward a device based on image processing technology to automatically identify float flowmeter. Image processing technology in recognition of the scale and the float, has been relatively mature. There are many specific identification methods, such as central projection method, subtraction method, template feature method, Hough transform method, least square method, and the combination of them. Therefore, it is feasible to use the image processing technology in the identification of rotor flowmeter. In this paper, we get flowmeter images by MVC - II - 1MM camera. To automatically identify float position, we use some functions, such as edge detection, filtering, binary, expansion, refined, etc, and then write algorithms to automatically detect the float position according to specific morphological features of flowmeter image.

Accurate flow measurement is an essential step both in the terms of qualitative and economic points of view. Previously a technique known as ultrasonic flow measurement a non-invasive type of measurement is widely used to calculate flow, because of its capability to avoid noise interferences in its output. Now a day due to its non-linear characteristics its use is restricted. Various types of flow meters are available in the market.

Some of the meters like velocity meters use a sensor which calculates the flow rate based on the speed of water, ultrasonic sensors which works on two different principles that is transit time measurement principle and other is based on Doppler Effect but these are having high cost of maintenance.

Another aim of this project is to develop a prototype of a low-cost turbine type water flow meter which measures flow rate of water passed through pipelines. This type of flow meter not only conserves the water by only providing the required amount of water but also saves the energy by having the pump automatically off. Pump turns off after the amount of time set by the user. The system is fully user friendly.

3. LITERATURE SURVEY

3.1 Selection of sensor

Flow sensors, the devices that detect and measure water flowing through pipes, are becoming necessary components of efficient systems and mainly acts as a sensory organ for the brain in the controller, giving it information to make operating decisions. Flow meter basically works with the output of the flow sensor. In this system in order to calculate the flow the rotor surrounded by a magnet along with the Hall Effect sensor is used. This is known as G1/2 water flow sensor.

As the water flows through the rotor, it's blades rotates. As the turbine rotates magnetic field is produced and accordingly an Ac pulse is generated which is then converted into the digital output with the help of Hall Effect sensor placed just after the turbine. The number of pulses generated per litre can be counted by the software programming.

Thus, pulses produce an output frequency which is directly proportional to the volumetric flow rate/total flow rate through the meter. Also measuring flow rate through rotating rotor provides high accuracy, excellent repeatability, simple structure and low-pressure loss.

Table 1 lists the specifications of water flow sensor.

Parameters of Sensor	Value / Range
Working Voltage (Volts)	5 - 24
Maximum Current (mA)	15
Flow rate range (L/min)	1 - 30
Operating temperature (°C)	0 – 80
Liquid temperature (°C)	<120
Operating humidity (RH)	35%-90%
Operating pressure (Mpa)	Under 1.2
Store temperature (°C)	-25 to +80

3.2 Working theory of Hall Effect Sensor

Hall Effect sensor attached to G1/2 water flow sensor is a transducer which examines the rotations of rotor and passes the pulse train which is in the form of electrical signal as a frequency input to the microcontroller that is programmed to convert it to flow rate. They are temperature resistant and stress resistant sensor especially suited for electronic computation.

Sensor consists of multiple bladed, free spinning, and permeable metal rotor as shown in figure.

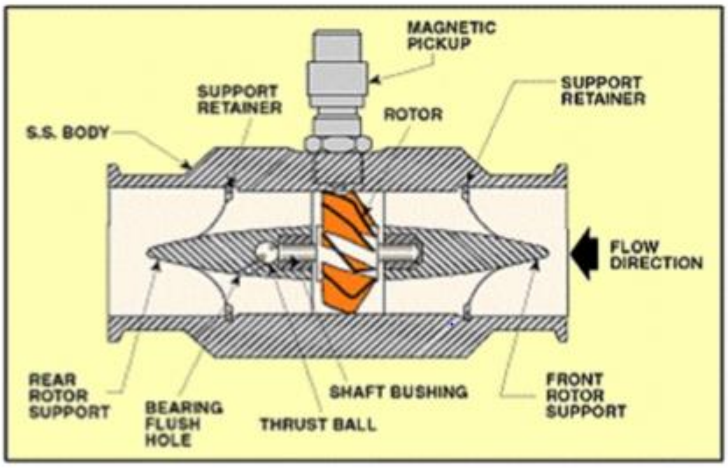

Figure . Internal structure of G1/2 water flow sensor

The main benefit of using water flow sensor with Hall Effect sensor is that it is highly durable due to non-contact detection, works with high speed operation over 100 kHz, operates with stationary input, no moving parts, highly repeatable operation, highly resistant to contamination such as dust, dirt & oil, small in size and easy subsequent signal processing due to digital output.

Hall Effect sensor working flow is shown in figure

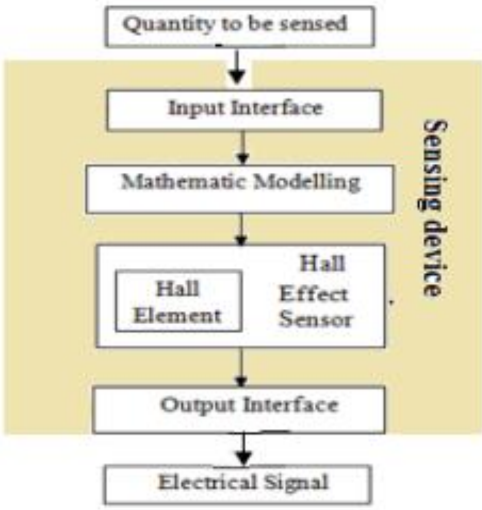

Figure 1. Working flow of water flow sensor

In order to measure the quantity of water being passed in particular time through the sensor it is first passed through the rotor present inside the sensor with magnet attached to it which is taken as input interface in the flow. Formulas are applied in order to measure the number of rotations in a minute of rotor.

Hall Effect sensor has a Hall element which is a magneto-electric transducer and is made of a thin semiconductor layer as shown in figure 2 with two input voltage terminals and two output voltage terminals. The magnetic flux perpendicular to the semiconductor layer generates a voltage by the Lorentz force.

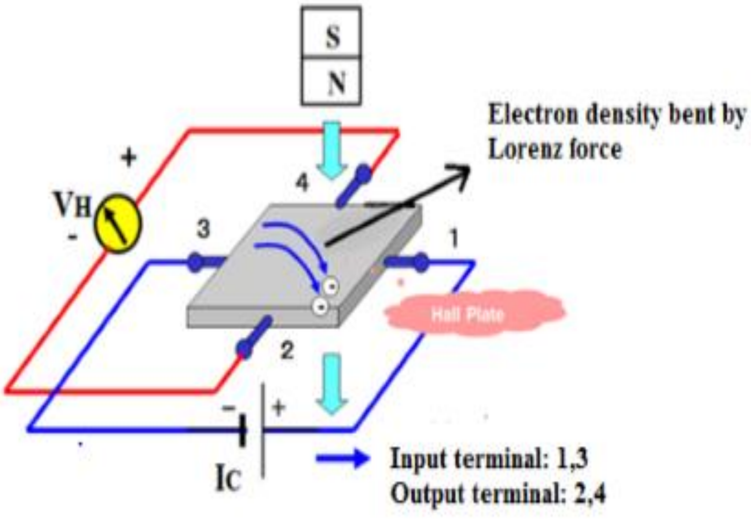

Figure 2. Behaviour of hall element in presence of magnetic field

The Hall voltage produced in the Hall element is directly proportional to the current produced (I) and the magnetic flux density (B) as shown in equation 1.

$$V_H = R_H\,(I/T * B) \tag{1}$$

Where, VH is Hall voltage, RH is Hall Effect coefficient, I is current flowing through sensor in amperes, T is thickness of sensor in mm and B is magnetic flux density in Tesla, Ic is drive current. Hall voltage is of the order of 7 µV/Vs/gauss in silicon and thus requires signal conditioning for practical applications. Signal conditioning circuit consists of a voltage regulator, a signal amplifier that is differential amplifier and a Schmitt trigger in order to convert the analog output to digital output on a single silicon chip as shown in figure 3. A voltage regulator is used to automatically maintain a constant voltage level with the amplifier to amplify the Hall voltage according to the application.

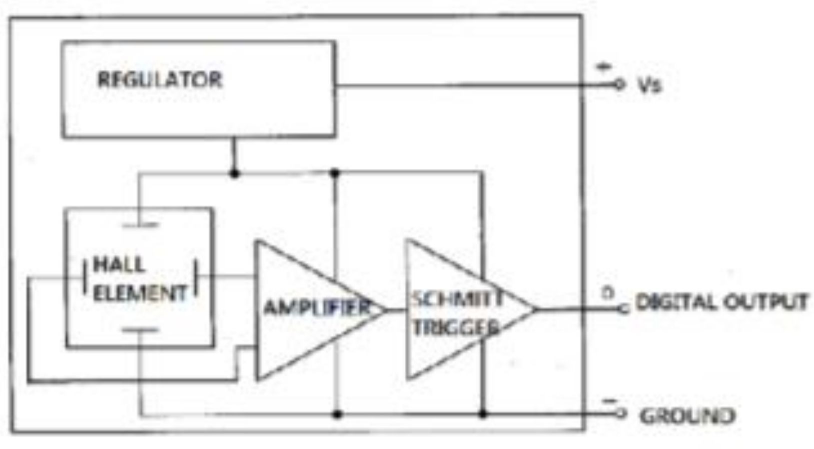

Figure 3. Digital output Hall Effect sensor

The comparison of the output from the differential amplifier is done with the preset reference and if amplifier's output exceeds the reference, the Schmitt trigger turns on and when it falls below the reference point, the Schmitt trigger turns off.

3.3 Transfer Function of Hall Effect Sensor

The transfer function for a digital output Hall Effect sensor incorporates hysteresis as shown in Figure 4.

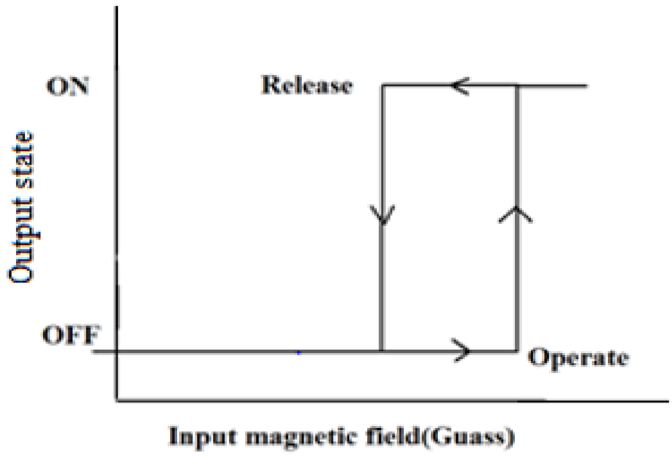

Figure 4. Transfer function of Hall sensor

The principal input/output characteristics are the operate point, release point and the difference between the two. As the magnetic field is increased, the output of sensor remains the same until the operate point is reached. Once the operate point is reached, the state of the sensor will change. There will be no effect of further increased magnetic field input. Now if magnetic field comes below the operate point, the output will remain the same until the release point is reached. Now at this point the sensor returns to its original OFF sate. This hysteresis eliminates the false triggering that can be caused by minor variations in input.

4. METHODOLOGY

4.1 Composition of the hardware float recognition system

There may be bright spots in the pictures of glass rotor flowmeter. First, we use strip light treated by diffuse to evenly illuminate the glass rotor flowmeter. By this means, we can prevent the effect of uneven light and reflective glass, and effectively inhibit the generation of spot. Then, we collect the flowmeter images through the MVC - II - 1MM camera, and the image information will be sent to a computer through the USB interface and BMP files are formed. Finally, we complete the process of image processing, rotor recognition and calculation, and display the results.

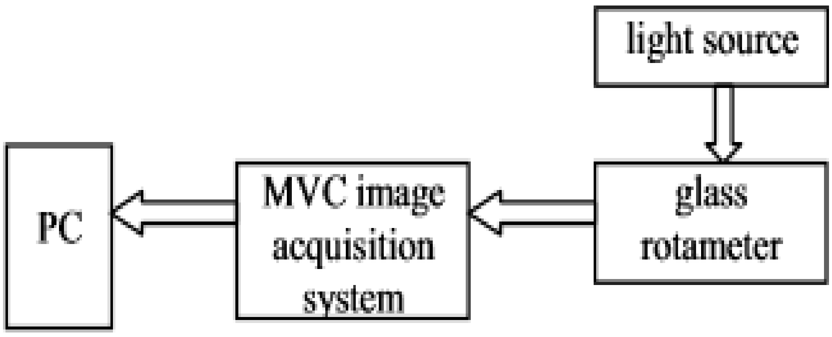

Figure 5. Automatic float flowmeter's float identification system

4.2 Image processing and rotameter height recognition

As the height of the rotameter in the glass tube has relation to the fluid flow, the camera should be shooting the whole flowmeter, and then transports it to computer. The computer runs the entire system's core-recognition algorithm. It mainly contains four parts of pre-treatment, scale recognition, float recognition and reading.

In Automatic Interception of Meter's Glass Tube Images in this system, we need to not only measure the float of one flowmeter in different times, but also identify the floats in different flowmeters. This means that the float position in the original images is not fixed. So we first position the glass tube. The process includes: log edge detection, inflation, and smooth operation, the result is shown in Fig.6 (b). After the operation, the flowmeter can be distinguished from the background.

IJTIMES-2017@All rights reserved

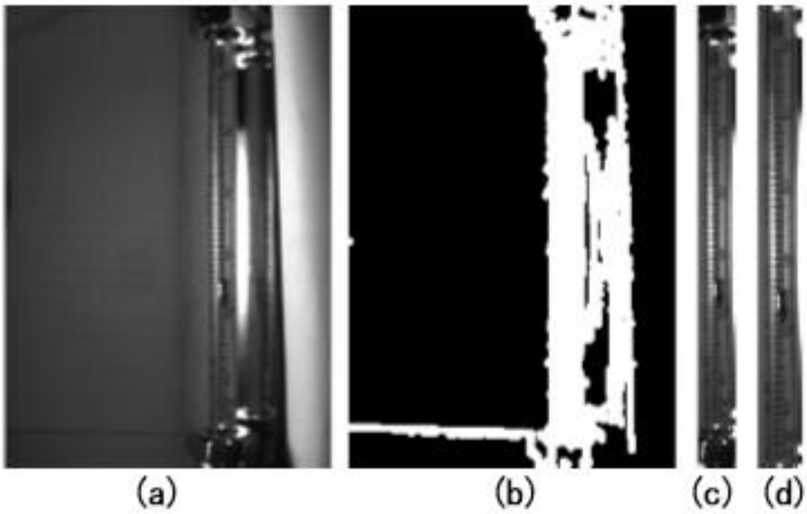

Figure 6. Process of automatic float flowmeter interception in the image.

4.4 Edge detection operators

The algorithms of Robert, Prewitt, LoG, Canny, etc, are the classic edge detection. Canny algorithm of image edge detection is the most delicate. However, as Canny is also sensitive to the noice of the background, in this project, we choose log algorithm. The Laplace operator published by Hildreth and Marr, is regarded as one of the best edge detection, its characteristic is using gauss filter for image smoothening.

The Gauss function is (2):

$$h(x,y) = -e^{-\frac{x^2+y^2}{2\sigma^2}}. \tag{2}$$

σ is standard deviation in (2). Equation (2) is a smooth function. If we convolve the image and filters, it does both smoothening the image and reduces the noise, when it filters isolated noise and small structure. The Laplace operator for this function is (3):

$$\nabla^2 h(x,y) = -[\frac{x^2+y^2-\sigma^2}{\sigma^4}]e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{3}$$

Calculate Laplace operator in order to get double edge image. Then locate the edge by finding zero crossing of two edges. (3) Flowmeter location algorithm First, use vertical positioning on flowmeter, it refers to confirm where the border of flowmeter glass tube may be by vertical projection of the whole picture. Extract it for accurate positioning of the flowmeter and reducing range of target. Set Fig.6(b) as an M*N image f(i,j), and get vertical direction projection statistics according to (4), statistical curve is shown in Fig.7. The area in Fig.7 corresponded to flowmeter edge has two characteristics, firstly, it is composed by many adjacent dots of large value, secondly, the dots change little. Therefore, intercept all the points greater than 5 quarters of the maximum

SUMJQ, than count connected points domains, and respectively calculate the variance between points in each domain and their differences with maximum SUMJQ. Choose the minimum variance to determine the connected domain, which locates glass tube left and right edges.

$$\mathrm{SUM}_{JQ}(i) = \sum_{j=1}^{N} \mathrm{f}(\mathrm{i}, \mathrm{j}) \tag{4}$$

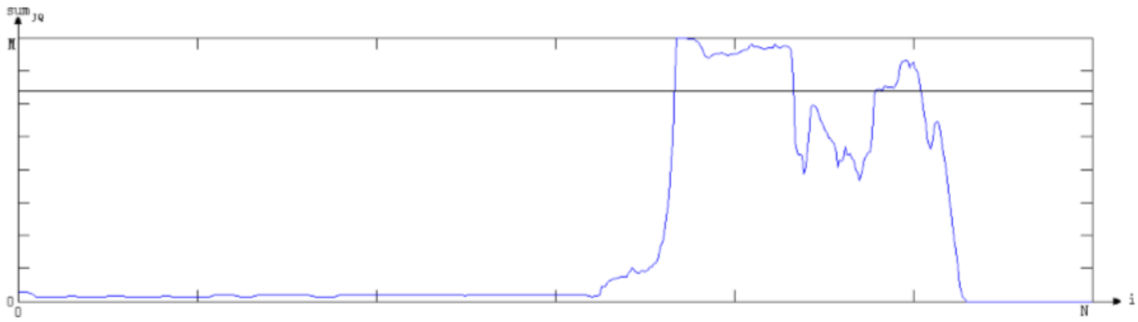

Figure 7. Vertical projection statistical curve

$$SUM1(j,i) = \sum_{i=1}^{N} \sum_{j=i}^{i+N/3-1} SUM_{JQ}(j)/j \tag{5}$$

After a number of experiments, we finally decide to take the projection algorithm mentioned above. We have adopted a different kind of algorithm. From Fig.6(b), we find that when i is the left glass boundary, and j the glass width, Row i of SUM1 has the most maximum, and the maximum number is j. According to this, the original image can be automatically intercepted, and the flowmeter image Fig.6(c) is obtained.

We can see from Table 2, the time of numerical accumulation method used is about 10 times the vertical projection method. Therefore, on the basic that both algorithms are able to meet the requirements, we finally chose projection method.

Num	*time of Numerical accumulation method (s)*	*time of vertical projection method (s)*	Num	*time of Numerical accumulation method (s)*	*time of vertical projection method (s)*
1	0.451	0.049	11	0.445	0.041
2	0.446	0.042	12	0.436	0.043
3	0.474	0.038	13	0.439	0.038
4	0.550	0.037	14	0.439	0.038
5	0.492	0.039	15	0.441	0.038
6	0.4478	0.043	16	0.438	0.041
7	0.440	0.061	17	0.431	0.037
8	0.439	0.041	18	0.439	0.038
9	0.437	0.038	19	0.435	0.038
10	0.458	0.039	20	0.444	0.040

In the image processing, we only require float glass tube flowmeter recognition. In order to reduce the processing difficulty, we need to remove the glass tube and base in Fig.2(c). Use the method of horizon positioning to reach this purpose. With left glass tube border as a starting point, intercept an image with same width of glass tube.

$$\mathrm{SUM}_{jq}(i) = \sum_{j=1}^{n} \mathrm{h}\,(\mathrm{i},\mathrm{j}) \tag{5}$$

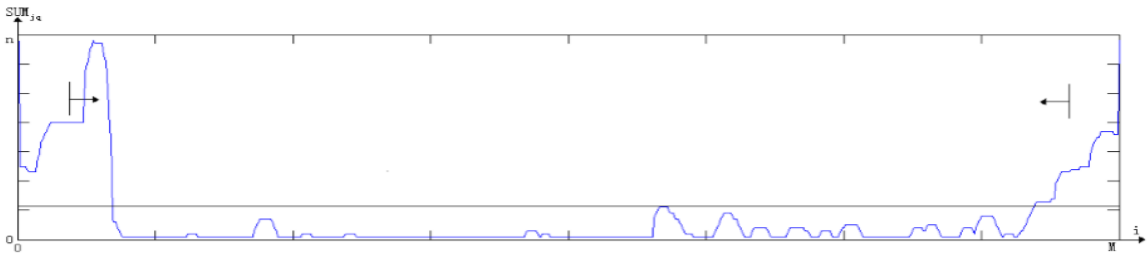

Figure 8. Horizontal projection statistical curve

Assume the candidate domains image h(i,j) for level localization is M*n, horizontal projection statistical is shown in (5), all the candidate domains horizontal projection statistical curve is shown in Fig.4. In the diagram, longitudinal coordinates SUMjq(i) means the quantity of 1 pixel in Line i, and abscissa means the i line. Black horizontal line cuts up threshold, and it used to decide the up and low boundary that may be.

In this device, we use the scale value to represent the float position in the flowmeter, so we need to distinguish calibration in picture. Scale positioning on the glass tube flowmeter, the scale marks arrangement is regular, which is an obvious characteristic, in addition, the scale length in each image has certain proportion of the width of the glass tube. With the above two conditions, the scale image boundary is definite. Take edge detection image a(i,j) Fig.4(d), set it as an m*n one. It's known that the length is n/4. Vertical projection statistical refers to (6). Use (8) for variance comparison. Take the point where is VARmin as the left margin of scale image.

IJTIMES-2017@All rights reserved

$$SUM3(j) = \sum_{i=1}^{m} a(i, j) \tag{6}$$

$$\overline{SUM3}(j) = \frac{\sum_{i=j}^{j+n/4} SUM3(i)}{n/4+1} \tag{7}$$

$$VAR(j) = \sqrt{\frac{\sum_{i=j}^{j+n/4} (SUM3(i) - \overline{SUM3}(i))}{n/4}} \tag{8}$$

4.5 Scale analysis

Calibration analysis process is shown in Fig.9. Calculate pixel summation of each line in binary image according to the horizontal projection method, if the summation is greater than two-fifths of image width, we can see the line as a scale. In order to guarantee accurate calibration, we want to ensure that each scale line width of a pixel here, so we take the deepest gray line as scale line. Deal with binary image by expansion, opening and closing operation, and makes the pattern pixels feature more obvious. After that, calculate pixel summation between adjacent scale lines, because the summation there is significantly larger.

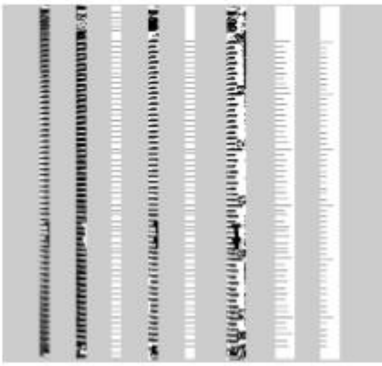

Figure 9. Scale analysis

For easier conversion, long calibration identification is also needed. Left boundary of the long calibration image consistent with the calibration image border, and its width is one half of flowmeter width. Search every line of the long scale binary image from the last row to find beginning of scale, and then jump to the next line. Each scale line length is obtained in this way. Long scale search process is shown in Fig.6. I_kd_sum1 and I_kd_sum record all scale line length. I_b_sort1 and I_b_sort sort I_kd_sum from large to small.

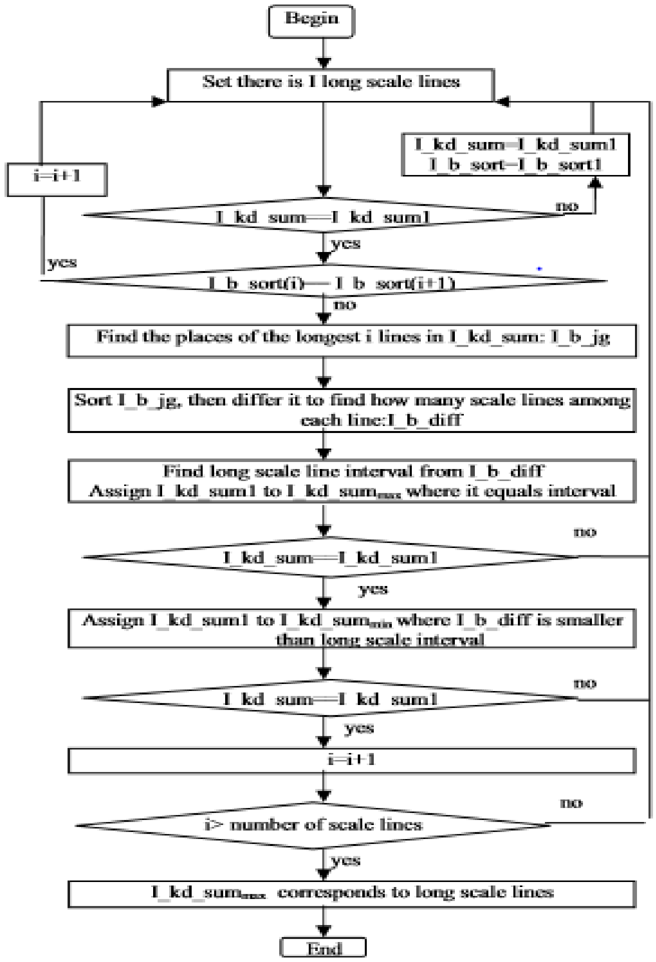

Figure 10. Flow chart length scale

4.7 FLOAT RECOGNITION

We want to identify float height, that is to find the float edge. Here can use long scale images as float image. First calculate to get binary image. As we are requiring the relative position of float height and scales, float should be in the scale range. To locate the float approximate position, set a template, where k is float image width, and l is a quarter of k. Match this template with binary image, in order to find float approximate location. Intercept an m1*n1 image b(i,j) near the float.

4.7.1 Projection method to analyse float edge

$$SUM4(i) = \sum_{j=1}^{n1} b(i,j) \tag{9}$$

Calculate image b(i,j) by (9), and Fig.11 is obtained. As the float edge gray value gradient changes, we can find a peak that its left has 0 point. Compare the peaks in Fig.11, we can see the abscissa of the first peak is the float edge position.

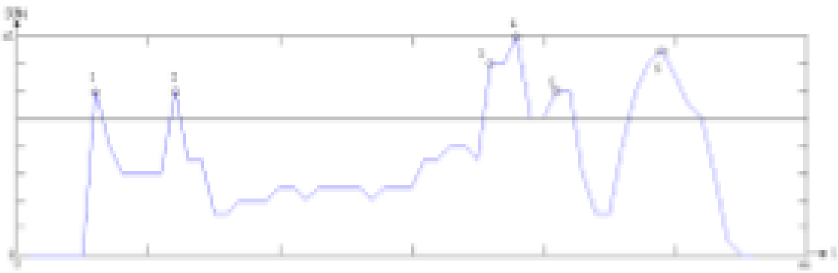

Figure 11. Float edge detection picture by projection method

4.7.2 Pixel search method to analyse float edge

According to the feature that all the pixels under float edge is 0, and the upper 1, search each row to find the edge pixels and record them in SF. When SF is least except 0, the float edge in the image is got. In order to solve the problems of longitudinal attitude in the glass tube, take secondary recognition method. Take 0.1 threshold to get a new binary image, then perform operations of smoothing and opening and closing. Search for the edge of the row next to SFmin's row in the new image. If SFmin is greater than or equal to SF1, we get the float height in the form of pixel values.

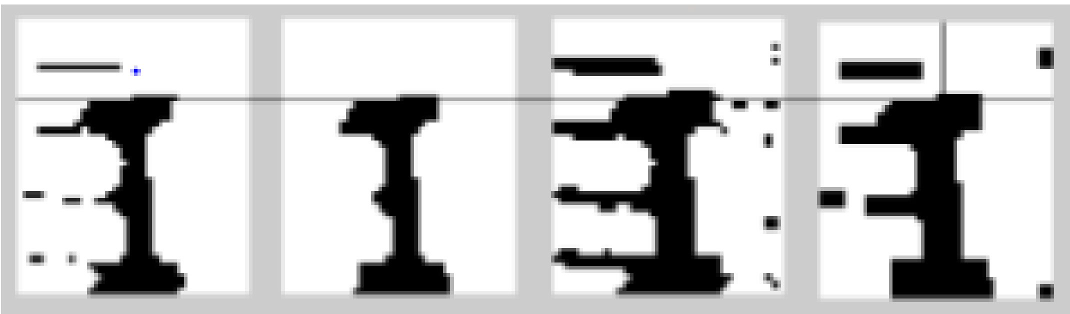

Figure 12. Float edge detection picture

We can see from Fig.13, the second method is especially suitable for overlooking the flowmeter.

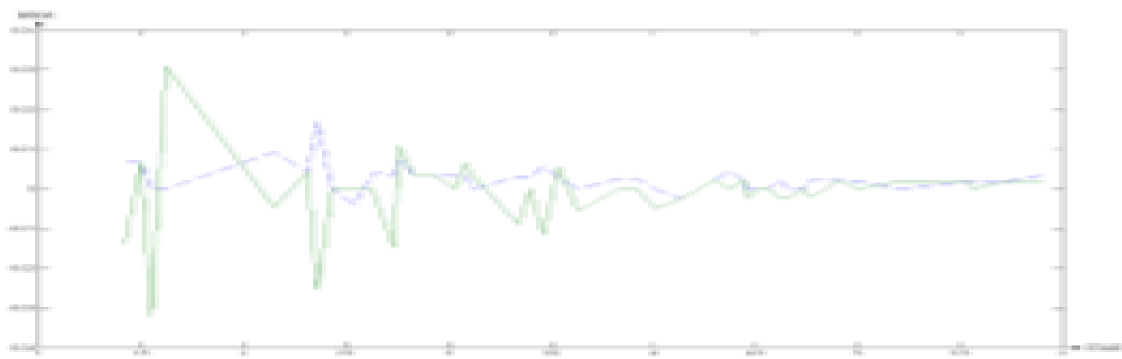

Figure 14. Figure of float edge detection method error comparison

IJTIMES-2017@All rights reserved

We choose the algorithm of smaller error. Compare the pixels of scales with float pixel got by the second method, and we can get float edge's calibration value. This method is especially suitable for changing float flowmeter occasion, as well as it can excuse the repeated artificial calibration.

4.8 SYSTEM DESIGN AND DEVELOPMENT

The selection of a microcontroller plays very important role in any embedded system. According to the need of the system a microcontroller is chosen. Here in this system in order to design a low cost automatic water flow meter Atmel AT89S52 microcontroller is used. We have designed and developed a low-cost water flow meter mainly to deliver only the correct amount of water as per requirement. It can also be useful in detecting catastrophic problem due to plugging/hose break so that this can be corrected. Keeping records of flow meter readings regularly can indicate when the pumping system is deteriorating.

AT89S52 microcontroller is used to monitor the sensor with which LCD is interfaced to display the flow rate of water. Flow rate can be determined inferentially by different techniques like change in velocity or kinetic energy. Here we have determined flow rate by change in velocity of water. Velocity depends on the pressure that forces the through pipelines. As the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basis relationship for determining the liquid's flow rate in such cases is shown in equation (10).

$$Q = V * A \qquad (10)$$

Where, Q is flow rate/total flow of water through the pipe, V is average velocity of the flow and A is the cross-sectional area of the pipe. Viscosity, density and the friction of the liquid in contact with the pipe also influence the flow rate of water.

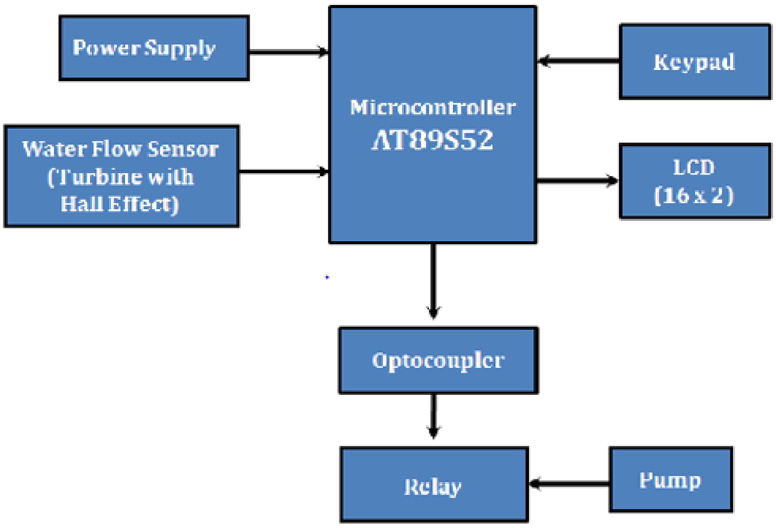

Figure 15. AT89S52 microcontroller based system

AT89S52 microcontroller based system is shown in figure 15. A pump is used to supply water through the sensor. Inlet of water to the sensor is through the pump and outlet of water is from another side of sensor which is fed directly to the field. When no water flows through the pipelines as if the supply of water stops at any moment the pump gets automatically off hence saving the electricity too. Optocoupler is used to prevent high voltages from affecting the system receiving the signal. This prototype works on the basis of time which means that it works for the particular amount of time that is set by the user through the keypad according to the need. According to the need if the time set is for example 1 hour, the system gets automatically off after 1 hour. The system is programmed according to the requirement. So, this reduces the man's effort of keeping eye every time and also helps in conservation of water.

4.8.1 Flow diagram of the system

The system working flow is described in figure 16. Water when passes through the rotor cause the rotor to rotate at the speed equivalent to velocity of water. Rotor's speed changes with different rate of flow of water. As each blade passes through the magnet magnetic field is created at the base of the Hall sensor and thus pulses are generated. These pulses produce an output frequency proportional to the volumetric flow/ total flow through the sensor. This frequency is converted to the flow rate by using software program for microcontroller AT89S52.

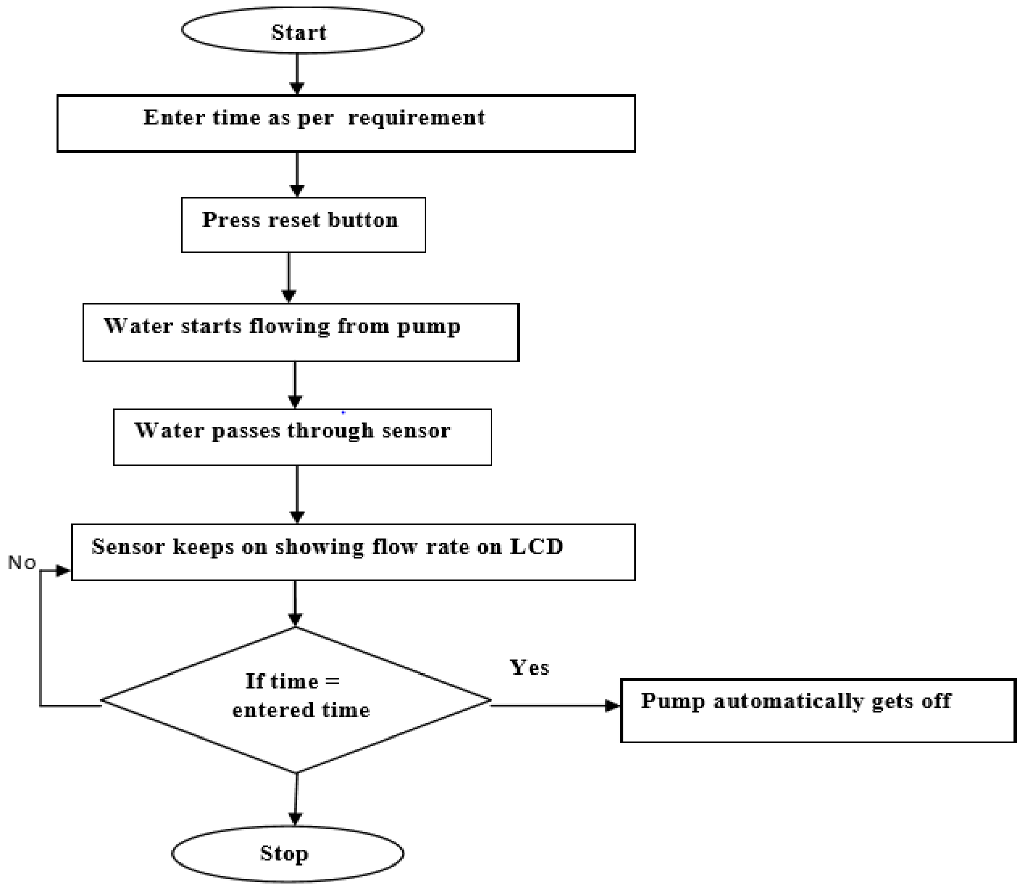

Figure 16. Flow chart of the system

5. RESULTS AND PERFORMANCE ANALYSIS OF FLOWMETER

The table 3 lists reading of water flow rate with different multiplication factors with and without sensor.

Multiplication factor	Observed reading with sensor (Litre per minute)	Actual reading (Litre per minute)
1.5	19	20
1.6	18	20
1.7	20	20
1.8	23	20
1.9	24	20
2.0	25	20

As in table 3 with the increase in multiplication factor the readings shown by the sensor degrade as compared to actual readings and a point comes where it becomes close to the actual value that is the rate at which the water actually flows as measured without the sensor.

6. CONCLUSION

In summary, a technique to automatically calibrate flowmeters like glass tube rotameter is introduced. The first principle is to respectively extract scale and float images though glass rotor flowmeter image and automatic identification. Experiments have proved that this method reach a 10% minimum scale line resolution. Using the scale as calibration object, this calibration method is convenient, and without calibration object automatic measurement is realized. We not only reduce the workload and duty cycle, but also improve the degree of automation. Application of hall sensor in this field proves to be a good system that can detect the leakage in the pipelines if we observe the flow rate of water regularly, and at last but most important that is in the terms of cost the system proves to be a low cost with many of the benefits as compared to the other products available in the market. So, development of low cost water flow meter can reduce human interaction. This system eliminates the manual mistakes in flow rate measurement. Also, it is more accurate in comparison to other types of meters. This system is more attractive, as it provides automatic operation with great accuracy and the most too cheap method to measure flow rate of water.

LITERATURE REVIEW

- http://airccse.org/journal/ijcsea/papers/3313ijcsea06.pdf=Research on automatic calibration facility of mechanical pointer type flowmeter
- https://www.plantservices.com/assets/Media/1007/WP_Calibration.pdf = understanding your choices in flowmeter calibration
- Visited the facility where the calibration of flowmeters takes place and analysed the process.
- Jia Yonghong. Digital Image Processing, Wuhan University Press, 200309.
- Rafael C.Gonzalez Richard E.Woods Steven L.Eddins. Digital Image Processing Using MATLAB, Electronic Industry Press, 2005-09.
- Pelin Gorgel, Ahmet Sertbas, Osman N. Ucan. Journal of Medical Systems[SpringLink], 2009-06.
- Gonzalez, R.C. and Woods, R.E. [2002].Digital Image Processing, 2nd ed., Prentice Hall, Upper Saddle River, NJ
- Cao Huidan, Shen Yuming, Application of MATLAB Image Processing Technology in Sewage Monitoring System孳J揩荸9th International Conference on Measurement & Instruments, 2009,8(3);993-995.
- Zhang Yujin, Image Engineering, Tsinghua University Press, 2007.