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DESIGN AND PERFORMANCE EVALUATION OF LOW COST ONE DIMENSIONAL DIGITAL FLUID FLOW METER

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Abstract- *Portability, performance and thriftiness are the cardinal challenges for the measurement instrument manufacturers. But in advances of semiconductor technology, have enable the measurement industry to meet the challenges by increasing instrument performance, efficiency, user-friendliness and also lowering overall control costs. This paper depicts design and performance assessment of a user friendly digital fluid flow meter by which fluid velocity can be determined of an open or closed channel at any depth. It can also be used in determination of submerged object movement. In this measuring instrument, two LASER and light dependent resistor pairs are used to make such sensors in a common stand to detect time of a floating ball for a specific distance while microcontroller, liquid crystal display etc. used for executing program and displaying fluid velocity.*

Keywords: Floating ball, LASER-LDR pair, Liquid Crystal Display, Microcontroller, Wooden Stand

1. INTRODUCTION

Determination of exact velocity of fluid like water, oil, diesel etc. is an important phenomenon in our day to day life. Knowing fluid's velocity, we can design any fluid related control system easily. Among various fluid flows, open channel flow measurement is more challenging. Like many other applications of fluid flow measurements, water velocity at different depth in a river need to be determined for appropriate strengthen protection (by giving sandbags –gabions protection) at its' banks and sides to diminish hydraulic forces. The aforementioned velocity measuring device meets these challenges very smoothly. There are different types of flow measuring hydraulic devices such as Venturimeter, Orifice Meter, Pitot Tube etc. which are based on Bernoulli's flow equation [1]. As the fluid flow is not uniform, it varies depth to depth; these flow measuring instruments don't give us exact velocity for any specific depth rather than mean velocity. So, to determine velocity of any certain distance and at any depth of a channel, we design this one dimensional digital fluid flow meter. Moreover, a set of formulae need to be memorized to calculate fluid velocity through these types of hydraulic devices. But, in case of this digital fluid flow meter, there is nothing to be memorized as the necessary formulae are used in the internal software which automatically calculate and shows in the Liquid Crystal Display (LCD) unit. After calculating mean velocity using this new device we compare with the traditional ways where all about % errors are founds for water flow in an open channel with the mean velocity. In this device, two sensor made of LASER-LDR pair are placed at a specific distance in frame for laboratory purpose. When a very low weight floating ball with low friction passes two sensors consecutively, the microcontroller measures required time and execute other arrangement as per command. Using this measuring instrument, a series of laboratory hydraulic experimental study on different riverbank protection materials launched in Hydraulic Laboratory, Dept. of Civil Engineering of Chittagong University of Engineering & Technology (CUET) and hence, the device calibrated with the measured data. Mathematical Model for Sensors, Device Overview, Mechanical and Electrical Design, Accuracy, Uses in Physical Life, Scope of Study are given in the following. By all the experiment the devices is found more efficient for certain cases. Moreover, the design simplicity and cost effectiveness make it more effective to use in the concerned arena.

2. MAHEMATICAL MODEL FOR LASER-LDR PAIR ARRANGEMENT

The motion of a fluid like that of solid is described quantitatively in terms of the characteristics known as velocity. However, in case of solids it is generally sufficient to measure the velocity of the body as whole, but in case of fluids, the motion of fluid may be quite different at different points of observation. Therefore the velocity V at any point of fluid mass is expressed as the relation between the displacement of fluid element along its path and the corresponding increment of time as the later approaches zero. A particular point, P (distance OP= r from the origin) in the space occupied by a fluid in motion is selected which may be denoted by coordinates *(x, y, z)* shown in Fig. 1. Since this point is fixed in space, the coordinates x, y, z and the time, *t*, are independent variables. At this point if *ds* is distance travelled by a fluid particle in time *dt* then the velocity V of the fluid particle at this point may be expressed as.

$$V = \lim_{dt \to 0} \frac{ds}{dt}$$

The velocity is a vector quantity and hence it has magnitude as well as direction. Therefore, the velocity V at any point in the fluid can be resolved into three components u, v and w along mutually perpendicular directions *x, y and z* respectably.

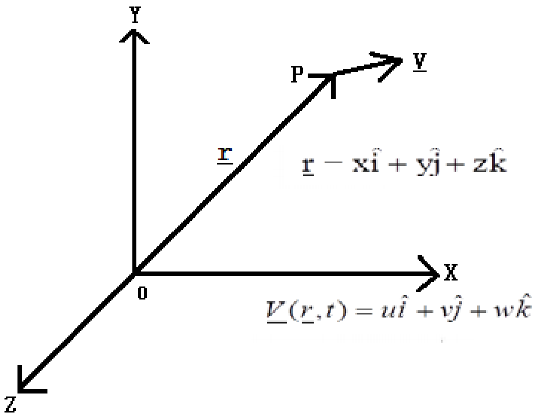

Fig1: Co-ordinates for a fluid particle.

Each of these components can also be expressed as the limiting rate of displacement ds in the corresponding direction. Thus if *dx, dy* and *dz* are the component of the displacement ds in x, y and z directions respectably, [2] then

$$u = \lim_{dt \to 0} \frac{dx}{dt}$$

$$v = \lim_{dt \to 0} \frac{dy}{dt}$$

$$w = \lim_{dt \to 0} \frac{dz}{dt}$$

$$V = iu + jv + kw$$

Where *i, j* and *k* are the unit vectors parallel to the x, y z axis respectively. But, this velocity measuring device is implemented assuming steady as well as uniform flow up to 1 inch depth and so on till bottom point and hence, the quantity *v* and *w* is equal to zero. So, the velocity of the fluid is

$$V = u = \lim_{dt \to 0} \frac{dx}{dt} ---------------- (1)$$

If the right hand side parameters of equation (1) for a layer are known, the fluid flow of that that layer easily. To determine these parameters for a certain fluid level in a channel, a wooden frame (aluminum frame also preferable) are made where two sensor are placed at 15 centimeter (cm) apart from each other.

Distance between two sensors, dx = 15 cm

Time required for fluid particle to pass the sensors consecutively measured by the microcontroller = *dt* milliseconds. Friction less with very low weight floating, half-submerged, full-submerged etc. circular plastic balls are used here to determine the fluid particle movement considering fluid particle moves as like as ball moves. Assuming the average velocity of the fluid between two sensors up to 1 inch depth from surface of the fluid is *V* in meter/seconds, we have the following expressions.

$$V = \frac{15}{dt} \frac{centimeter}{miliseconds}$$

$$or, V = \frac{15 * 1000}{dt * 100} \frac{meter}{seconds}$$

$$or, V = \frac{150}{dt} \frac{meter}{seconds} -------- (2)$$

Based on equation (2) a program is loaded into microcontroller which execute a series of codes and display one dimensional fluid velocity at 16*2 LCD display.

3. SYSTEM OVERVIEW

Actually this is a mechatronics project where both electrical and mechanical conceptions are combined. The mechanical part mainly a frame in which two LASER-LDR pairs are spaced keeping 20 centimeters between them.

Figure-1 shows the arrangement of the system by means of block diagram.

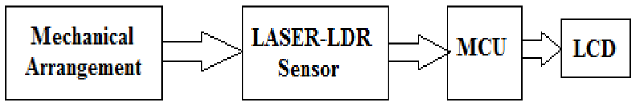

Fig2: Block diagram of the system.

Two sensors which are placed at a certain distance defined the states of the circuit whether it starts counting or stop. When an object e.g. sandbag, table tennis ball passes through the first sensor microcontroller flag bit starts counting and continue its operation until it passes through the second sensor [4][5]. Once the object passes through second sensor and counting stops and performs further actions to display the velocity of that object in the fluid. As Table Tennis ball is all about 2.4 gram and it also smooth, we may neglect its friction and weight affect in this measurement system. It is more significant side for this project is that by this measuring instrument sandbag/ rock moving velocity can easily be determined. Moreover it mitigate the exaggerate complexity in design procedure and implementation. The sensor LASER-LDR which has been used here has high speed [6], high resolution and highly accuracy in detection. Laser sensor allows easy position setup and alignment with its visible laser spot [7]. By a complete flow chart the total algorithm has depicted in the following figure.

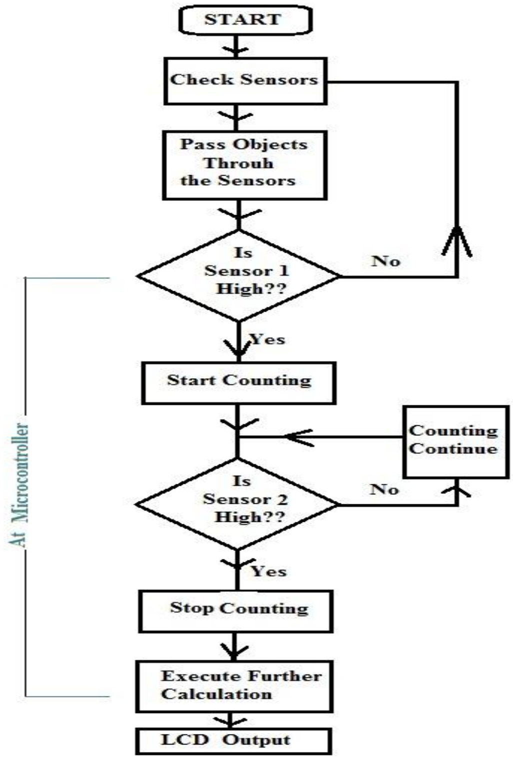

Fig3: Flow chart of the system.

4. DESIGN AND IMPLEMENTATION

4.1 Mechanical Section

During design and implementation a sensitive mechanical arrangement is set up to measure the fluid particle movement with the help of nearly weightless object which is passed through two LASER-LDR made sensors and hence the time consumed to pass those sensors is measured by software arrangement. It demands the following arrangement: a stand with two LASER sensors 15 centimeter apart each other in one side and two LDRs on the other side as like figure-3. The stand should be portable and sensitive whose LASER ray must fall on the LDR kept on the other side. So, to implement such kind of stand we use wood as stand material for portability and easy access [8][9]. The sensors are places at the bottom of the stand and 5 holes are kept in the upper side of the stand to detect the floating particle at different water level or depth. The whole arrangement is done only for the testing purpose for the velocity measurement of fluid flowing in C4 Tilting Flume [3]. The stand used for sensors placing can move vertically and horizontally in the lab test fluid channel. By changing the vertical position of the stand hence the sensor, fluid velocity at different level of the channel can easily be determined as well as changing its horizontal position, velocity at different position of the channel in same level can measure.

4.2 Electrical Section

In the velocity meter circuit arrangement LDRs are used to detect the variation of light intensity of LASER ray. When there is no object or interrupt in between LASER and LDR contact, the whole LASER ray fall on the LDR. As a result LDR shows low resistance but when an interrupt occur means a particle moves through the ray, the state of the resistance of LDR changes to high. The resistance variation is stretched to microcontroller via a high gain operational amplifier [10]. The circuit arrangement is done such a way that when no light fall on the resistor, the microcontroller input bit is low and for light fall, this is vice versa. When the object is passing the sensor and when not these both condition circuit arrangement and output condition are depicted in the following diagram.

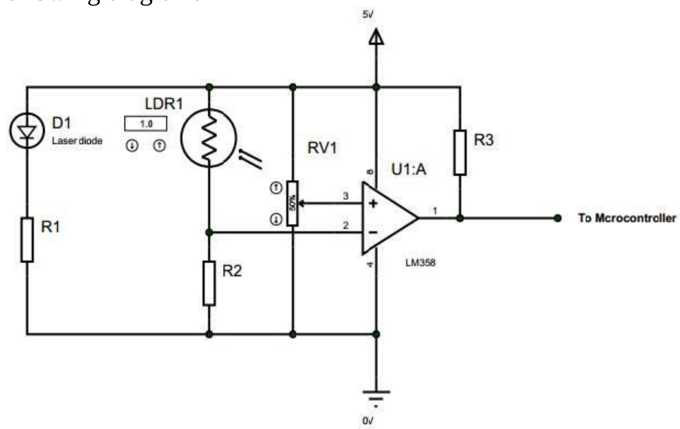

Fig4: Circuit Diagram for Sensor Part

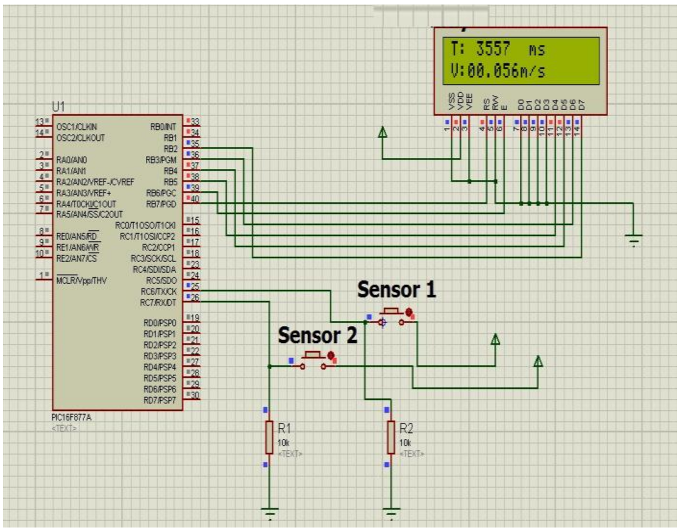

Fig5: Circuit arrangement and output condition when object crossed two sensor consequently.

In circuit arrangement of microcontroller consists of five I/O ports are recognized by Port A (RA0 to RA5), Port B (RB0 to RB7), Port C (RC0 to RC7), Port D (RD0 to R7) and Port E (RE0 to RE2) [12]. According to loaded program at MCU, its tim0 bit starts counting like a stop watch with higher accuracy [11]. When sensor 2 high (i.e. object passes through the 2nd LESER ray & LDR resistance changes) tim0 ends counting. Total distance is known as two sensors are placed at a known distance & total time is counted. So, according to v=s/t formula the velocity v can be easily calculated and displayed in the display.

4.3 Software Coding

The software function of this digital velocity meter design is achieved by Assembly Language. The program basically highlights data acquisition from the sensor and then processes the data in MCU and display real-time data in the display.

5. Conclusion

As a velocity measuring devices the digital fluid velocity meter has a huge application in practical life. It can be used in industrial sectors as well as the laboratory experiment very conveniently. By sensing the velocity of any fluid at certain time any machine can make a decision that what to do in certain velocity level such as in case fluid measurement in pipe, chemical measurement in reaction plant and sand monitoring system in industry. But according to the practical and control capability the ratings of sensors and other parameter will be changed. The sensor input signal of this velocity meter is analog which is converted finally into digital by an ADC which is used always in integer. So where there is a very precise velocity measurement like biomedical engineering and sophisticated chemical plant there it will give a little bit trouble and the total design should be made in different way.

6. References

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