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REVIEW ON DESIGN AND FABRICATION OF ELECTROMAGNETIC FLOWMETER

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Abstract: Electromagnetic flowmeter measures the flow rate when the coil generates the magnetic field of specific field strength and velocity a voltage is induced which is proportional to the flow. Electromagnetic flowmeter operation is based on famous Faraday's law of electromagnetic induction. With time there are various advancements in the development of this equipment. This paper explains about the methodology of how the flowrate is measured by changes in the fabrication and construction of the meter. The meter can be used for liquids are corrosive acids, sludges, wastewater, acid slurries, oil and gas water injection, paper, and pulp.

Index Terms **- Electromagnetism, flowmeter, Magflow.**

I. INTRODUCTION

"Designing is the process of Devising a system, component or process to meet desired needs and Fabrication is the creation of metal structures by cutting, bending and assembling processes".
Flow measurement is the quantification of bulk fluid movement. Obstruction type, electromagnetic, positive displacement type, Fluid dynamic, Inferential, Aanemometer, Ultrasonic and Mass flow meter are the variety of ways for flow measurement.
"If you can't measure it, you can't manage it". Most often use quote in industry particularly relevant for flow measurement. The flow meter is used to measure the flow rate with high speed, precision, and accuracy. Flow meter are used in many process control industries including chemical and pharmaceutical, food and beverages, oil and refineries, pulp, and paper etc.
Many conducting fluids that are difficult to handle and hazardous for human being can be measured accurately by using electromagnetic flowmeter. Medium conductivity could be as low as 5 µS/cm. It can detect flow by using Faraday's law of induction. Inside an electromagnetic flowmeter there is an electromagnetic coil that generates a magnetic field and electrodes that capture electromotive force (Voltage).

II. LITERATURE SURVEY

Jun Yao, WeiKang Ying and Bin Li[6] proposed that as in the industry it is required to perform multitasking and the measuring instruments can be made novel with some modifications. Like in this case the Electromagnetic flowmeters are been made more precise, highly responsive, and simple structured. As EM flowmeters can measure only the flow of conducting liquid but in this experiment, it is stated that by providing double excitations i.e. an additional voltage is induced to the conventional electromagnetic flowmeter to measure the flow and conductivity both in the fluid simultaneously. By faraday's law of EMI, the velocity of the conductor changes the value of the induced voltage this setup is connected the operational amplifier and with the input impedance of the amplifier the voltage can be measured and the combined resistance determines the conductivity. And to this the excitation is provided to measure the conductivity simultaneously with the flow.
Mohammad Kazeminejad[3][4] proposed in his paper about complete analysis for circular E.M. flow meter, and its design. This analysis is dependent on induced voltage. The structure of circular electromagnetic flow meters is divided into two section, one is signal detecting unit and second one is the signal conditioning unit. Author has got some promising experimental results; on how the design works in different states. The outcomes of induced voltage between the electrodes of fully filled pipe and 60% filled pipe was compared. The paper also describes the effect of increase in fluid flow velocity and fluid conductivity on EM flow meter.
The Electromagnetic flow meter by Yukio Sai, Yousuke Kubota[7] proposes Magnetic field is generated when a wire of the coil conducting a current is mounted outside or within the body of meter. The average velocity of the flow is in proportion to the voltage induced in the fluid flowing from a pipe which acts as a conductor. Electromagnetic flow meter has an excited square wave signal. In excited square wave signal current is supplied to the loop which is excited. An attractive field is produced in this excited loop electrically. The signal is generated in an electromagnetic flow meter which give a pipe tube which is protected internally from which a fluid is passed which capture a magnetic field which is generated in that which initiate a sign upon which flow rate is a couple of electrode terminals that are mounted at opposite of each other recommended by Toshio Sekiguchi. The electromagnetic flow meter consists of magnetic field that generates the magnetic field which is perpendicular to the emf generated in the liquid.
Mannhaz E Riester H proposed that electromagnetic flow meter has an excited signal which generates square waves. Toyofumi Tomita proposed that magnetic field is generated in the conductive liquids. The voltage which is induced in the conductive liquids

is measured by the pair of electrodes which are placed opposite sides of each other. The flow rate signal in sample hold circuit is corresponding to the half period of the signal flow rate.

Pradnya.kulkarni [et al][2]in Implementation Paper on two wired electromagnetic flowmeters given a detailed comparison between electromagnetic flowmeter and various types of flowmeters as mentioned below in table.

Types of Flow Meter	Advantages of Electromagnetic Flow meter over other flow meters
Ultrasonic Flow meter	Measuring range situation can be enhanced
Coriolis mass flow meter	Liner relationship between flow rate and measured variable.
Thermal mass flow meter	Appropriate for hydraulic solid conveyances
Differential pressure flow meter	Little upkeep, but still informal to uphold
Turbine flow meter	No moving parts
Variable area flow meter	Unaffected by changes in temperature, thickness, consistency, obsession, and electrical conductivity.
Vortex flow meter	Harbour and outlet range not required

Table 1: Comparison of Flowmeters with Electromagnetic Flowmeter

Colm Slattery and Ke Li[5] proposed that electromagnetic flowmeters achieve high accuracy in industrial applications. Electromagnetic flowmeters are mostly used for measurement of liquid flow due to its numbers of advantages. The electromagnetic flow meter measures the volume flow which means that fluid density, temperature, pressure, and viscosity is insensitive to the changes in effects of measurement. When the calibration of the electromagnetic flow meter is completed with water it can be used to measure the other types of conductive fluid with no additional correction. The electromagnetic flowmeter producers' differential output. It's sensitivity Ranger's between 150 microvolts/(mps) to 200 microvolts/(mps). The output signal of the sensor amplitude gets double as the excitation current alternates its direction. For the flow rate measurement range of 0.5 meters/second to 15 meters/second, the sensor output signal amplitude ranges from 75 microvolts to approximately 4mV to 6mV.

Lubomir Slavik [et al][1]in magnetic circuit of electromagnetic flow meter with capacitive electrodes paper deals with analysis of magnetic circuit of electromagnetic flowmeter with capacitive electrodes. For creating homogenous magnetic field with constant magnetic flux density, they have come with capacitive electrodes. They created an automatic apparatus which measures magnetic flux density in the horizontal plane. The design with ferrite core has much higher volume and weigh. But on the other hand, best sensitivity, and consequently best accuracy of result value of flow reached by homogeneity in the volume between plane electrodes. When saddled coils where used he ratio between maximum and minimum of B (magnetic flux density) in the whole volume between plane electrode reaches value 3.5, By using magnetic circuit with ferrite core has the ratio nearly of 1.07.

III. Principle Of Methods

Electromagnetic flow meters are also called as MagFlow meters. MagFlow meters are volumetric flow meters which is usually used for fluid application where the fluids experience the drop-in pressure and fluids which consist of conductivity.

Electro MagFlow meters is based on Faraday's law of electromagnetic induction. According to Faraday's law when a medium which is consist of conduction passes into a magnetic field, it gives rise to a voltage which is directly in proportion to the speed of the medium, length of conductor and the density of the magnetic field.

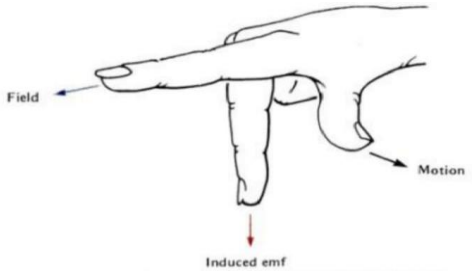

Figure 1. Fleming's Right-Hand Rule

Magnetic field is generated when a wire of the coil conducting a current is mounted outside or within the body of meter. The average velocity of the flow is in proportion to the voltage induced in the fluid flowing from a pipe which acts as a conductor.This induced voltage can be detected by the sensing of electrodes which is mounted on the electromagnetic flow meters which is then sent to transmitters which helps to calculates the rate of flow based on the dimensions of pipe. The volumetric flow rate is in proportion the the induced voltage.

The fluid which must be measured has to be electrically conductive. Faraday's law specify that the voltage signal is dependent on the average velocity of liquid, strength of magnetic field and the length of conductor. As the flow meters are located and set in motion, it starts its performance with the pair of magnetic coils that are charged. When the energy passes into the coil, they induce magnetic field that is perpendicular to the axis of the two electrodes and conductivity of the liquid. The liquid moves across elongated axis of the MagFlow meter, which makes the generated emf perpendicular to the speed of fluid and the magnetic field.

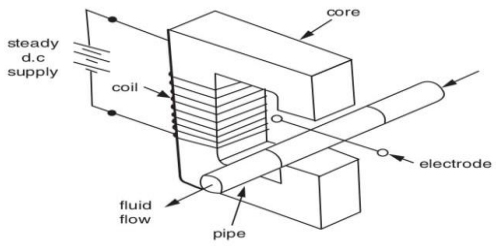

Figure 2. structure of electromagnetic flowmeter

As the conducting fluid flows into the magnetic field, the voltage is induced in the coil. Two stainless steel electrodes which are mounted converse of each other is used to measure the induced voltage in the coil, this voltage is in proportion to the speed of flow rate of liquid. These two stainless steel electrodes which are mounted inside the flow meter are afterwards connected to an electronic circuit which is advanced that has capability of processing the signals. This processed signal is then fetched to the microprocessor which calculates the volumetric flow rate of the fluid.

IV. MATHEMATICAL MODEL

The principle of all types of electromagnetic flow meters is based on the second Maxwell law, so called Faraday's law of induction:

$$U = -\frac{d\Phi}{dt} + \oint_C (\boldsymbol{v} \times \boldsymbol{B}) d\boldsymbol{r} ,$$

Nomenclature: -

U Voltage

Φ Magnetic Flux

t Time.

and electric field intensity incurred by magnetic flux density inside the pipe and velocity of the liquid in pipe is defined by Lorentz forces:

$$E = v \times B$$

where E is vector of electric field intensity, and v is vector of velocity of the liquid, B is magnetic flux density. Voltage U is generated on electrodes, which are placed perpendicularly to both B and v:

$$U = v . B . D$$

Here, D is Diameter of the cross-section of pipe (distance between electrodes).

V. FABRICATION

- It has two field coils installed on opposite sides of meter and two electrode one on each wall to measure voltage.
- Coils creates magnetic field in pipe when fluid passes through it, creates a voltage which is measured by electrode.
- It can be installed horizontally and vertically (conditional).
- The best way is to install vertically with fluid having upward directed flow, this will have filled or empty pipe.
- To measure flow, it is required that pipe must be filled.
- Down flow will not provide such condition.
- Electromagnetic flow metre can be installed horizontally but must avoid half-filled pipe.
- The outlet and inlet runs are provided for proper flow direction.

VI. LIMITATIONS

Though this flowmeter is highly advantageous as compared to others, but it also has some limitations. For measurement of flow it requires minimum conductivity of 5 µS/cm which certainly means that in case of nonconducting fluids the meter will not function. Further it requires full flow in the pipe and moreover there should not be any air bubbles as this would result into miscalculation of the flow. And as this is an electrical device so there must be grounding for the protection and avoiding any external interferences.

VII. CONCLUSION

The Important feature of any type of flowmeter is to measure accurate flow measurement. This paper gives you the detail study of electromagnetic flowmeters in various parameters and the complete information related to EM flowmeter and explain about its fabrication.

Points of Comparison	EM Flowmeter with capacitive electrode	EM Flowmeter (Oil Bubble)	Double excitation EM Flowmeter	EM Flowmeter with ADC	Circular Pipe type Flowmeter
Excitation	DC	AC/DC	AC	AC	AC/DC
Electrode	Placed outside of pipe (Planner Electrode)	Placed inside pipe along two opposite edges of pipe diameter	Outside of the pipe. (Nickel-alloy C-276)	Perpendicular to flow direction and magnetic field.	Placed inside the pipe
Principle	By calculating capacitance between the electrodes flow is calculated.	The emf changes as oil bubble appears which causes deviation in the measurements.	Change in resistance leads to change in conductivity and EMI.	E.m.f is proportional to the volume flow generated between the pair of electrodes.	Change in volume rate leads to change in voltage
Piping Parameters	DN40 (mostly ceramic material)	0.2R (R-radius of the bubble)	50mm Diameter	Non-magnetic material.	Non-magnetic material and 60% filled.
Applications	Non-corrosive liquid , Clean Water	Oil, Petroleum	Food and Beverages, Oil and Refineries, Pulp and Paper, Waste water treatment plant, etc.	Process control industries including Chemical and Pharmaceutical, etc.	Conductive fluids, such as acids, polymer in chemical industry etc.
Conclusion	Much higher homogeneity is reached. (1.07)	EM flow meter measure two-phase flow of oil water	Fluid conductivity is directly proportional to reciprocal of fluid inherent resistor.	Drawbacks of analog EM flow meter solved such as power cost response time.	Voltage variation between two electrode for two different state of fluid level are simulated

Table 2: Comparison of Reviewed Papers

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