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(54) Title: AN ELECTROMAGNETIC FLOWMETER

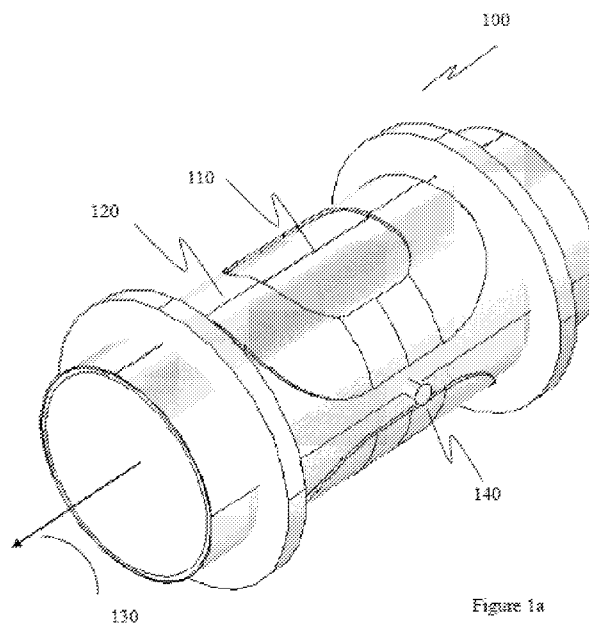


Figure 1a

(57) Abstract: The present invention relates to an electromagnetic flowmeter comprising a coil for generating electromagnetic field, a pair of electrodes; wherein the coil is constructed and mounted on the surface of the conduit such that: a first angle subtended at a centre of the conduit on a cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the inner periphery of the coil and the surface of the conduit on the cross sectional plane; a second angle subtended at the centre of the conduit on the cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the outer periphery of the coil and the surface of the conduit on the cross sectional plane; and the value of first angle is less than a third of the value of the second angle.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,  
KM, ML, MR, NE, SN, TD, TG).

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## AN ELECTROMAGNETIC FLOWMETER

### FIELD OF THE INVENTION

[001] The present invention relates generally to an electromagnetic flowmeter and more particularly to an electromagnetic flowmeter for measuring flow of fluid flowing in a conduit.

### BACKGROUND OF THE INVENTION

[002] Measurement of flow of fluids through a conduit or pipe can be done by numerous ways like using electromagnetic flowmeters. Electromagnetic flowmeters are popular flow measurement devices owing to their non-invasiveness and accuracy.

[003] A typical electromagnetic flowmeter works on Faraday's law of electromagnetic induction. An electromagnetic field is imposed within a conduit/flow pipe having a flow of fluid with a certain level of conductivity. Electromotive force (EMF) induced as a result of the interaction of the electromagnetic field with fluid molecules (ions in the fluid), is measured using electrodes provided at the pipe side walls. The measured EMF is proportional to the flowrate and thus used to measure flowrate. While electromagnetic flowmeters are attractive given that they are non-invasive, accurate and simplistic in construction, it is desirable to improve accuracy of measurement.

[004] Accuracy of measurement in electromagnetic flowmeter means linearity of sensitivity where sensitivity is equal:

Induced EMF/velocity of the fluid,

under varying flowrates or velocities. A primary cause of non-linearity in the sensitivity is the velocity profile across the pipe cross section which changes in shape under varying flowrates. As the flow gets more and more turbulent the profiles get flatter towards the center inducing non linearity in the sensitivity-flowrate curve. Magnetic field distribution can be manipulated using external high

permeability materials like electrical steel or nickel based steels. However, this adds cost to the flowmeter.

[005] Hence there is a need for an electromagnetic flowmeter that can be used for measuring flow rate of fluids accurately that can establish a magnetic field with a particular distribution and can minimize the non-linearity effect without compromising on cost, simplistic construction, non-invasiveness and resistance to corrosion.

## SUMMARY

[006] The above-mentioned shortcomings, disadvantages and problems are addressed herein which will be understood by reading and understanding the following specification.

[007] The present invention provides an electromagnetic flowmeter for measuring flow of fluid flowing in a conduit, wherein the electromagnetic flowmeter comprises: at least one coil excited by an excitation unit for generating an electromagnetic field, wherein the bottom surface of the coil is mounted on a surface of the conduit; a pair of electrodes mounted on the conduit for measuring potential difference generated by the interaction of electromagnetic field in the fluid to determine the flow of fluid in the electromagnetic flowmeter; and wherein the at least one coil is constructed and mounted on the surface of the conduit such that: a first angle is subtended at a centre of the conduit on a cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the inner periphery of the coil and the surface of the conduit on the cross sectional plane; a second angle is subtended at the centre of the conduit on the cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the outer periphery of the coil and the surface of the conduit on the cross sectional plane; and wherein the value of first angle is less than a third of the value of the second angle.

[008] In an embodiment of the electromagnetic flowmeter the coil for generating an electromagnetic field is a saddle-shaped coil.

[009] In an embodiment of the electromagnetic flowmeter the coil for generating an electromagnetic field is a flat coil.

[0010] In an embodiment of the electromagnetic flowmeter the coil for generating an electromagnetic field has plurality of layers and is wound on at least one bobbin.

[0011] In an embodiment of the electromagnetic flowmeter the first angle is half of the second angle.

[0012] In an embodiment the electromagnetic flowmeter mentioned herein above further comprising wherein the excitation unit is controlled by a processing unit.

[0013] In an embodiment the electromagnetic flowmeter further comprises a processing unit, wherein the processing unit acquires signals from the electrodes and processes the signal for measurement.

[0014] In an embodiment the electromagnetic flowmeter comprises a display for indicating the determined flow of fluid in the conduit.

[0015] In an embodiment the electromagnetic flowmeter the determined flow of fluid in the flow pipe is transmitted to a remote control center of the electromagnetic flowmeter for storage or analysis.

## **BRIEF DESCRIPTION OF DRAWINGS**

[0016] Figure 1 illustrates an electromagnetic flowmeter for measuring a flow of fluid in a conduit/flow pipe.

[0017] Figure 2 illustrates a cross-sectional view of the electromagnetic flowmeter.

[0018] Figure 2a illustrates a coil of the electromagnetic flowmeter with inner span.

[0019] Figure 2b illustrates a coil of the electromagnetic flowmeter with outer span.

**DETAILED DESCRIPTION**

[0020] The present invention is related to an electromagnetic flowmeter for measuring flow of fluid in a conduit/flow pipe. The present invention provides an electromagnetic flowmeter which is low in cost and provides accurate measurements. In this invention in order to improve accuracy the magnetic field is manipulated by changing coil dimensions, using guidelines from a finite element analysis of the electromagnetic flowmeter.

[0021] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific embodiments, which may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the embodiments, and it is to be understood that other embodiments may be utilized. The following detailed description is, therefore, not to be taken in a limiting sense.

[0022] Figure 1 illustrates an electromagnetic flowmeter 100. Figure 1 shows an electromagnetic flowmeter, which comprises a conduit/flow pipe 110 through which fluid flows, a coil 120 excited electrically by an excitation unit (not shown) for generating electromagnetic fields that interact with the fluid passing through the conduit/flow pipe where 130 indicates the direction of flow of the fluid, a pair of electrodes (140- referencing an electrode shown in the figure, 150 referencing an electrode not visible in the figure but present at the opposite side of the conduit/flow pipe facing the electrode 140).

[0023] The flowing fluid passes through the conduit/flow pipe in the electromagnetic flowmeter. The coil is provided on the surface of the conduit/flow pipe, as shown in figure 100, and once the coils are electrically excited, they generate an electromagnetic field that traverses the conduit/flow pipe volume. As will be known to the persons skilled in the art, the coil can be of different shapes depending on the need for magnetic field intensity. Interaction of the magnetic flux

and the moving fluid, causes a potential difference (Faraday's law of electromagnetic induction) to be measured by the electrodes provided at the walls encompassing the cavity.

**[0024]** A typical saddle coil can be used which is made by wrapping a coil winding about a permanent fixture in a flat (i.e., planar) orientation, then wrapping the winding with a tape or fiberglass material that covers top and bottom portions of the winding. Next, the winding is removed from the fixture and placed over part of a cylinder to bend it to a desired saddle shape. Then a coating on the winding is bonded together to harden the winding in the desired shape. Lastly, the winding assembly is secured to a mounting location on a pipe using conventional threaded mechanical fasteners (e.g., studs, bolts and clamps).

**[0025]** The analysis performed using Finite Element Model provides for a value for span of the coil used to obtain optimum signal strength and magnetic field without an increase in cost.

**[0026]** Figure 2 illustrates a cross-sectional view of the electromagnetic flowmeter. The coil for generating electromagnetic field is shown as 200 in the cross sectional front view, wherein the bottom surface of the coil is mounted on a surface of the conduit. A central axis 210 is shown in Figure 2 that passes through the cross-sectional centre of the conduit. As seen from Figure 2, a first angle  $\Theta$  (theta) is subtended at a centre of the conduit on a cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the inner periphery of the coil and the surface of the conduit on the cross sectional plane. The first angle (theta) forms an inner span  $S_i$  which is shown in Figure 2a.

**[0027]** A second angle  $\phi$  (phi) is subtended at the centre of the conduit on the cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the outer periphery of the coil and the surface of the conduit on the cross sectional plane. The second angle  $\phi$  (phi) forms an inner span  $S_o$  as shown in Figure 2b.

**[0028]** In this invention, for obtaining optimum signal strength and accuracy of measurement by the electromagnetic flowmeter, the first angle is adjusted such that value of first angle is less than a third of the value of the second angle.

**[0029]** For a preferred embodiment of the invention, the first angle is half of the second angle. For example, the second angle is experimentally set at 160.5 degrees approximately so the first angle is set at 80.2 degrees approximately, in order to obtain optimum signal strength vis-à-vis accuracy of measurements. In another embodiment, since the first angle is less than a third of the value of the second angle, if the value of the second angle is 160.5 degrees, the value of the first angle maybe 0.6 times of the second angle, i.e., value of first angle is approximately 96 degrees. In another embodiment of the invention, if the value of the second angle is 160.5 degrees, the value for the first angle maybe 0.4 times of the second angle, i.e., value of first angle is approximately 64.2 degrees.

**[0030]** Figure 2a illustrates a coil of the electromagnetic flowmeter with inner span. Figure 2b illustrates a coil of the electromagnetic flowmeter with outer span. Figure 2a and Figure 2b shows a saddle shaped coil, popular in current electromagnetic flowmeters. Figure 2a shows the inner span  $S_i$  of the saddle shaped coil and Figure 2b shows the outer span  $S_o$  of the saddle shaped coil. From Finite Element Model analysis it is seen in a preferred embodiment of the invention, that due to span adjustment where the angle subtended by the inner span is half of the angle subtended by the outer span, there is a substantial improvement in accuracy or linearity.

**[0031]** In this invention, the coil for generating an electromagnetic field can be a flat coil. Also the coil for generating an electromagnetic field may have a plurality of layers and is wound on at least one bobbin. The electromagnetic flowmeter for exciting the coils for producing electromagnetic fields have a suitable power source and electronics circuitries for making potential difference measurements and display/transmitting the measured values. In an embodiment, the electromagnetic flowmeter can comprise a display for indicating the determined flow of fluid in the flow pipe.

**[0032]** In an embodiment, the electromagnetic flowmeter wherein the determined flow of fluid in the flow pipe (measured potential difference between the electrodes) is transmitted to a remote control center of the electromagnetic flowmeter for further analysis.

[0033] In an embodiment, the electromagnetic flowmeter is Internet of Things (IOT) enabled for providing remote controlling, better visibility of the working of the electromagnetic flowmeter, providing real time information to software systems and other surrounding IOT enabled systems.

[0034] This written description uses examples to describe the subject matter herein, including the best mode, and also to enable any person skilled in the art to make and use the subject matter. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

**CLAIMS**

1. An electromagnetic flowmeter for measuring flow of fluid flowing in a conduit, wherein the electromagnetic flowmeter comprises:
  - at least one coil excited by an excitation unit for generating an electromagnetic field, wherein the bottom surface of the coil is mounted on a surface of the conduit;
  - a pair of electrodes mounted on the conduit for measuring potential difference generated by the interaction of electromagnetic field in the fluid to determine the flow of fluid in the electromagnetic flowmeter; and
  - wherein the at least one coil is constructed and mounted on the surface of the conduit such that:
    - a first angle is subtended at a centre of the conduit on a cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the inner periphery of the coil and the surface of the conduit on the cross sectional plane;
    - a second angle is subtended at the centre of the conduit on the cross sectional plane perpendicular to the flow of the fluid in the conduit by two points at the intersection of the outer periphery of the coil and the surface of the conduit on the cross sectional plane; and
    - wherein the value of first angle is less than a third of the value of the second angle.
2. The electromagnetic flowmeter as claimed in claim 1, wherein the coil for generating an electromagnetic field is a saddle-shaped coil.
3. The electromagnetic flowmeter as claimed in claim 1, wherein the coil for generating an electromagnetic field is a flat coil.
4. The electromagnetic flowmeter as claimed in claim 1, wherein the coil for generating an electromagnetic field has plurality of layers and is wound on at least one bobbin.

5. The electromagnetic flowmeter as claimed in claim 1, wherein the first angle is half of the second angle.
6. The electromagnetic flowmeter as claimed in claim 1, wherein the excitation unit is controlled by a processing unit.
7. The electromagnetic flowmeter as claimed in claim 1, further comprises a processing unit, wherein the processing unit acquires signals from the electrodes and processes the signal for measurement.
8. The electromagnetic flowmeter as claimed in claim 1, comprising a display for indicating the determined flow of fluid in the conduit.
9. The electromagnetic flowmeter as claimed in claim 1, wherein the determined flow of fluid in the flow pipe is transmitted to a remote control center of the electromagnetic flowmeter for storage or analysis.

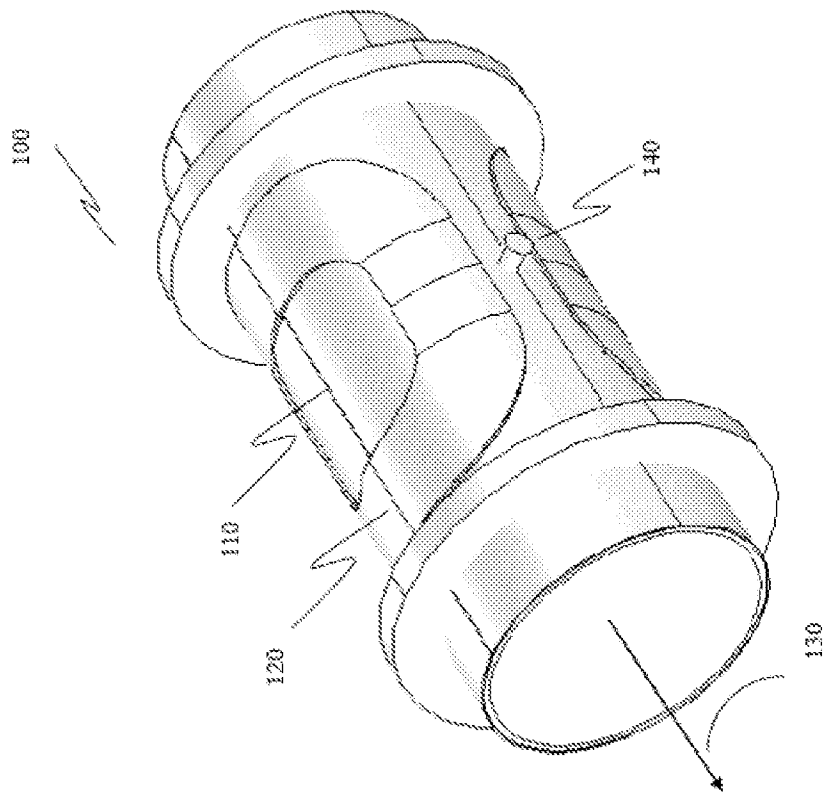


Figure 1a

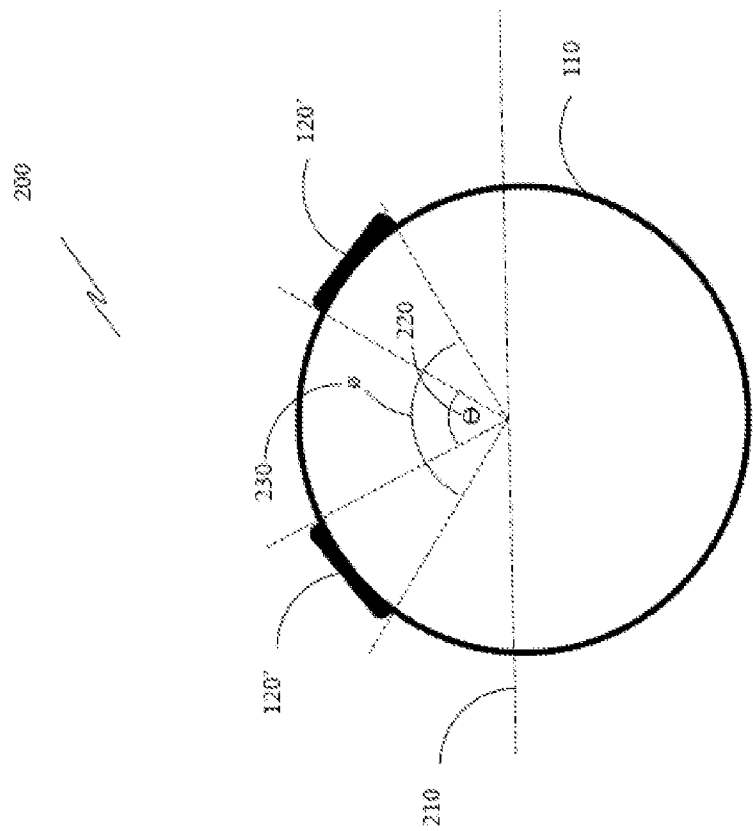


Figure 1b

Figure 1

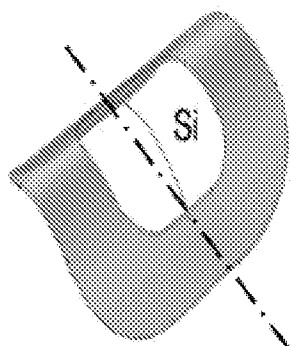


Figure 2a

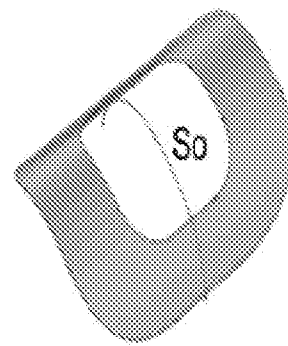


Figure 2b

Figure 2

# INTERNATIONAL SEARCH REPORT

International application No  
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## A. CLASSIFICATION OF SUBJECT MATTER

INV. G01F1/58

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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13/12/2017

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                       | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------|-----------------------|
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Information on patent family members

International application No  
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