Pressure Sensor Based on Ferrofluid

M.R.Jani
Associate Professor, Instrumentation and Control Engineering
Shantilal Shah Engineering College, Sidsar Campus, P.O.Vartej, Bhavnagar, Gujarat, India

Abstract- *Measurement of pressure is very crucial. The ferrofluid based pressure sensor is explained in the paper. The ferrofluid synthesizing methods, basic pressure sensors, circuit required to measure frequency/inductance and the microcontroller based system is explained.*

Keywords- Pressure sensor, Ferrofluid, Coil, Core.

I. INTRODUCTION

The pressure is a very important parameter in any industry. The pressure affects the quality of the process, the functioning of the equipment, safety of the instrument and the final product. It is required to be measured accurately and precisely. There are many pressure measurement techniques and sensors are available depending upon the application and the requirement. The pressure of the air on the earth surface in standard conditions is 1 atm. Basically pressure measuring sensors are classified in to three broad category Low pressure (bellow atmosphere pressure), medium pressure and high pressure (comparably higher than atmosphere pressure). Pressure measurement can either be relative to a reference value or on an absolute scale. Pressure measured relative to perfect vacuum is termed as absolute pressure. In differential pressure measurement, pressures of two distinct positions are compared. For example, pressure difference calculated by measuring it at different floors of a tall building will give us differential pressure. It can be defined as a subtype of differential pressure measurement where we compare pressure at any point to the current atmospheric pressure. Pressure sensors have been widely used in fields like automobile, manufacturing, aviation, bio medical measurements, air conditioning, hydraulic measurements etc.

The ferrofluid or the magnetic fluid is an interesting fluid, having characteristics of a Ferro material and a fluid as well. The ferrofluid is prepared by different methods. mainly by (a) solid state reaction and (b) wet chemical method. The ferrofluid is made by dispersing the ferro nano particles in the carrier fluid. The nano particles are surfaced by surfactant to avoid the agglomeration of the particle.

The major difficulty to prepare pressure sensor is to overcome the contacting nature of the sensor and allied instruments to the processing fluid and the size of the sensor. All the pressure measuring sensors require the physical contact with the process as well as it requires the secondary transducer to infer the pressure information from the physical property exploited in the primary sensor.

The paper describes the basic pressure measuring transducer made by ferrofluid, explains very small sized pressure sensor based on ferrofluid, suggests the improvement in it, the way to transmit the pressure data to the control room wirelessly.

II. THEORY

A. Magnetic fluid synthesis

Ferrofluids do not exist in nature and are artificially prepared. Ferrofluid (FF) synthesis is a two step process. First, magnetic nanoparticles of desired dimension are to be synthesized and then, they need to be dispersed in an appropriate carrier fluid. Typically, stable suspensions of magnetic particles in carrier liquids like oil, water or kerosene are desired. To overcome the problem of agglomeration, the particles are coated with a surfactant, made of long-chained molecules chosen in such a way that their dielectric properties match those of the carrier liquid. Figure 1 shows the components of ferrofluid.

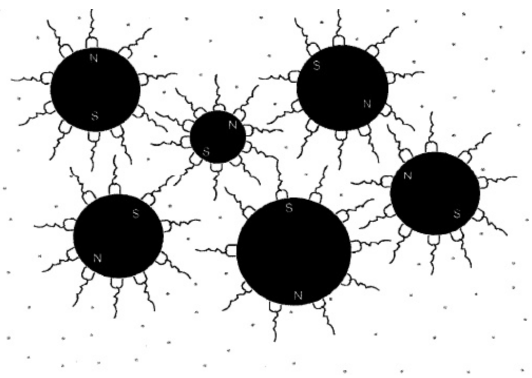

Figure 1 Ferrofluid Component

A surfactant can be categorized by the presence of formally charged groups in its head as anionic, cationic, zwitterionic and non-ionic surfactant. The very first method for the synthesis of magnetic nanoparticles and simultaneous synthesis of stable magnetic fluid was the method of grinding the solid materials in the ball mills. The method of chemical co-deposition is considered the most common and easiest method for the synthesis of magnetic nanoparticles[1-2]. The method of chemical co-deposition usually involves the deposition of Fe^{3+} and Fe^{2+} salts in the ratio of 2 : 1 in the water medium, using a strong alkali such as NaOH and KOH in the inert atmosphere and at low temperatures. The methods of hydrolysis and condensation of metal alkoxides or alkoxide precursors, leading to dispersion of oxide particles in the sol are called the sol-gel methods. Then, this sol is dried or gelled without a solvent. Water is a usual solvent, but the precursors can be also hydrolyzed with acid or alkali. Alkaline catalysis induces the formation of a colloidal gel, and acid catalysis produces the polymer form of gel. The rates of hydrolysis and condensation are the important parameters, which affect the properties of the final products. The particles are smaller at the slow and better controlled rates of hydrolysis. One more method of magnetic nanoparticle synthesis is the hydrothermal or hydrothermal/solvothermal. A good version of technology for obtaining soluble magnetite nanoparticles, based on the Massart method, is reducing hydrolysis of salts in the medium of polyatomic alcohols(ethylene glycol, di-, tri- and tetraethylene glycol, glycerol) with heating. This method allows good control of size and morphology of the products[2]. The microwave method for the synthesis of magnetic nanoparticles in a solution has the advantages of rapid volumetric heating, higher reaction rate, reduced reaction time and increased productivity as compared with the conventional heating methods. The microwave method is a fast, simple, and clean approach, saving time and energy, which yields a high quality product. Currently, the use of microwave reactors with the automatic control of temperature and pressure increases significantly the efficiency of synthesis and product quality. Another method for the synthesis of magnetic nanoparticles is the method of thermal decomposition (thermolysis). The method of thermal decomposition of precursors, containing corresponding metals, is the simplest way for preparation of magnetic nanoparticles. Currently, the most flexible and efficient method of obtaining the magnetic nanoparticles in solutions is thermolysis of metal-bearing compounds in high-boiling non-coordinating solvents in the presence of stabilizing agents. The method of laser pyrolysis consists in heating the moving mixture of gases by the continuous CO_2-laser for initiating and maintaining the chemical reaction until the achievement of the critical concentration in the reaction zone; then homogeneous nucleation occurs there, and nanoparticles are formed. Nanoparticles formed during the reaction are entrained by the gas flow and trapped by the filter at the outlet [3-4, 6-7].

B. Pressure sensor

Initially it must be noted that it is not easy to measure pressure directly from its action on the properties of a particular material. The sensitivity obtained in this case is extremely low and the performance is very poor. The only advantage is the very low cost. Therefore, the great majority of pressure sensors are “composite sensors” Figure 1[5].

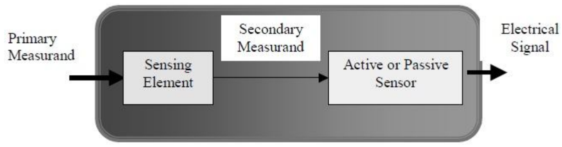

Figure 2. composite sensors

The sensing element is the device which ensures initial translation of the pressure (primary measurand) into another non-electric physical quantity, the secondary measured. The latter is translated by another sensor into an electric signal. Typically, the most widely used sensing element is the welded diaphragm with effective section S which can be planar, corrugated, cylindrical or a more complex geometric form according to the pressure range or the fluid under consideration [5].

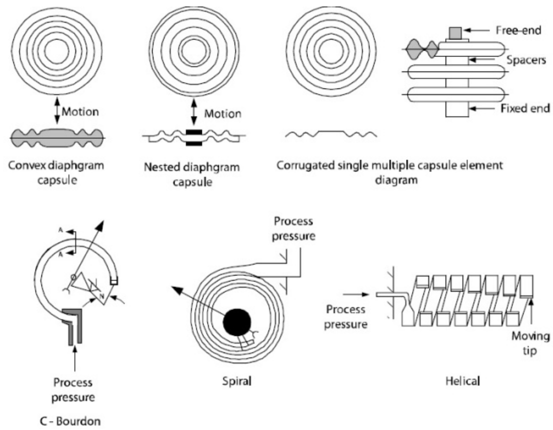

Figure 3 Elastic sensing elements

III. EXPERIMENTAL SETUP

The basic idea to measure pressure is to make an arrangement such that the pressure is applied to the disk type sensor, which is having a gape inside. The ferrofluid is filled inside the hollow disk. Figure 4 shows the disc with the capillary and the coil.


Figure 4 Sensor (Disk with capillary and coil)

When the pressure is applied to the disk, it deflects and due to its deflection, the ferrofluid inside the disk is displaced. The displaced ferrofluid, changes its position in the glass capillary. This capillary forms the core of the coil wound on it. The change in the level or the position of the ferrofluid in the capillary changes the permeability of the core of the coil. Finally this results in the change in the resonating frequency of the LC circuit. The coil is a part of the resonating circuit. The frequency measurement and transmission of the data is crucial as it must be accurate and error free. The ferrofluid characteristic like concentration of particles, etc changes the response of the sensor. If the density and or the viscosity is increased, the resolution improves while the response becomes sluggish. The diameter of the capillary has inverse relation to the resolution. The number of turns and the length of the coil has proportional relation to the sensing range.

The figure 5 shows the schematic diagram of the pressure sensing element with the complete system.

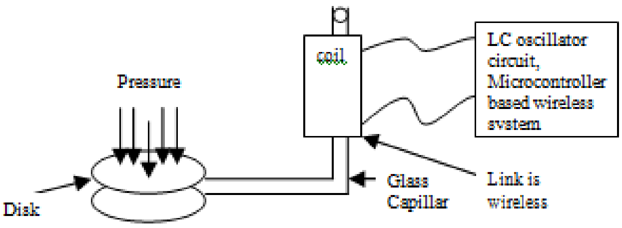

Figure 5 Schematic diagram

The figure 6 shows a typical circuit to measure the inductance in terms of frequency. The output from this circuit goes to the counter. The counter circuit counts and it can be used to display locally or it can be transmitted to the destination by means of the additional circuit.

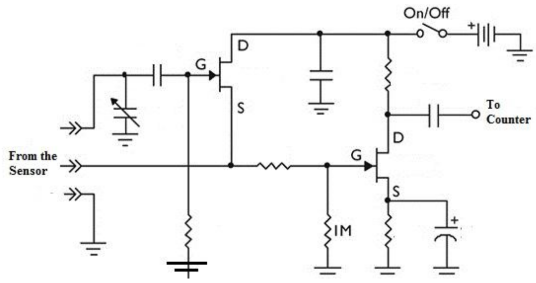

Figure 6 Inductance/ frequency measurement circuit

The microcontroller based system is used to transmit data serially. The wireless module (ESP8266 SoC based) can be used with the microcontroller to send data wirelessly to the control center. The data can be transferred using GSM module as well. It is not described in detail as it is very common and available on the internet.

IV. CONCLUSION

The use of the ferrofluid in the hollow disk makes it possible to measure pressure wirelessly, without the contact to the on site instrument from where the pressure is to be measured. The different types of ferrofluid can be synthesized by different methods to have different properties. The pressure sensor can be used to measure the pressure and the wireless module based on the microcontroller, enables the system to transmit the data to the control room wirelessly.

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