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Design and Development of a Dielectric Sensor to measure the alcohol concentration on Flexible Fuel Vehicles

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ABSTRACT: A sensor was designed and fabricated for flexible fuel vehicles to detect the percentage of alcohol content in alcohol blend fuels. It works on the measurement of change in dielectric property of the ethanol-fuel mixture. Thus, sensor's dielectric constant was measured and accordingly, the ethanol composition of the mixture was calibrated. This triggered the actuator to effect equilibrium in FFV vehicles. Compensating circuit was also developed to reduce the capacitor artifact errors and concurrently, increase the accuracy of the sensor. The accuracy of the sensor is relatively up to 2% and testing was carried out with the reference liquids as well as with different compositions of alcohol blend fuels.

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KEYWORDS: Flexible fuel sensor, Dielectric constant, Capacitance measurement

I. INTRODUCTION

The world's energy requirement has been dominated by petroleum oil for centuries. In recent years the use of ethanol-gasoline mixture has increased to replace fossil fuel and for reducing the emission. Ethanol can be used up to 5% of petrol without any engine modifications, flexible fuel vehicles are those that can run up to 85% of ethanol without any modifications in the engine.

Ethanol-gasoline blends will always be in a separated form due to the difference in the rate of moisture absorption, as the density of ethanol is more; it gets settled to the bottom of the tank and petrol in the top layer[9], as the usage of ethanol will corrode the engine components and also changes combustion parameters such as air / fuel ratio of the fuel, therefore it is necessary to detect the alcohol content in the fuel and also to maintain ignition timing for the engine.[11] this study focuses on the development and application of fuel composition sensors for use in ffv engines. The various sensors of measuring the fuel composition sensors such as optical sensor[1,6], absorbance sensor[5,7], dielectric sensors are also discussed[3,4]. The sensor used in this study uses the dielectric property of fluid, this information is supplied in real time about fuel composition, these information will be useful in optimizing engine performance and protecting the engine through the use of warning signals pertaining to the suitability of the fuel for the application. Some of the problems associated with ethanol-gasoline blends are, low energy content, too-high-rvp vapour lock behaviour and water-induced phase separation, high corrosive property

Indian automobile: The Government of India has made mandatory of usage about 5% ethanol blending with petrol. An indicative target of minimum 20 per cent ethanol-blended petrol across the country has been set for the year 2017.[10]

II. EXPERIMENTAL WORK

A. To build up our Model

In our project, The sensor models of parallel and coaxial type were developed and the model was analysed using reference liquids, capacitance values were found out using **LCR** meterat different voltage frequencies. The dielectric constant is calculated from the capacitance value and compared with the standard literature values of reference liquids.

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Based on the error and other problem study was done to reduce these errors and modifications are made in the design to make the sensors of greater accuracy. The design and development stages of the sensors are described below.

III. DEVELOPMENT OF SENSOR

Parallel plate sensor:

The testing of parallel electrodes are done by fixing in glass plate, and kept separated by a distance of 1.5mm, capacitance reading was taken out in reference Liquids like Toluene, coconut oil and kerosene, as there are more error due to higher fringing effects, and also difficult to maintain the same space between them, so we go for the co-axial type of sensor.

Coaxial type sensor: This sensor consists of a cylindrical rod surrounded by a tube separated by the distance “d". The tests were carried out and verified with the various reference fluids like Toluene, coconut oil, lubricating oil etc, with the help of LCR meter the capacitance value of the air (**C_o**) and the other respective medium(**C_r**) were calculated. Dielectric medium value was calculated by the formula

$$K = C_o / C_r.$$

A) *Design of the sensor:*

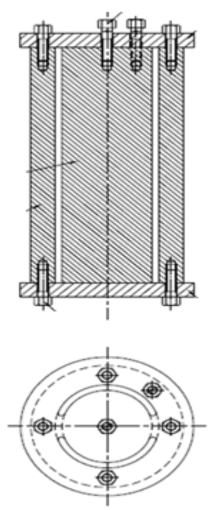

Figure 1. Sensor design

As many problems were begun to arise, certain modifications were made in the design in trial and error method to develop an accurate type coaxial sensor. Following lines shows the step by step modifications done for the various problems were detailed.

B) Validation

Capacitor artifact:

The various errors in the capacitive sensors are

- Stray capacitance:
  - Fringing effect.
  - Cornering effect
- Lead effect
- Ambient effect
- Spacing (d) of electrodes

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Table1.Problems and step by step modifications:

Problems	**Modifications**	**Error value**
More fringing effect	Insulation was made using Teflon at the top and bottom of the electrode using screw arrangement	More Reduction in error %
The screws for Teflon fixing with the capacitor produce effect	Initially insulation was made. Then cap type insulator was made and fixed	Error reduced
Leads and wires produce parallel capacitance effect	Insulation of the wire and leads was using insulator tap	Error reduced
More weight	Reduce the diameter of the cylindrical rod and reduce the thickness of the outer tube.	Affects (some error increased due to increase in distance between the electrodes)
More distance between the electrodes	Distance was reduced by increasing the inner rod diameter.	Error was reduced
Wiring of guarded electrode	Wiring was made internally	

Three terminal type sensor:

In order to reduce the stray capacitance the three terminal guarded sensors had been developed and experiments were carried out. The following fig shows the basic diagram of the three terminal guarded electrodes.

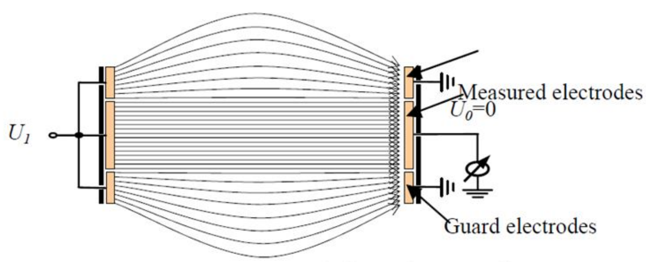

Figure2: three terminal electrodes

With the help of the guarding the electrodes, the stay capacitance was avoided. Due to this setup the measuring area was insulated from possible errors.

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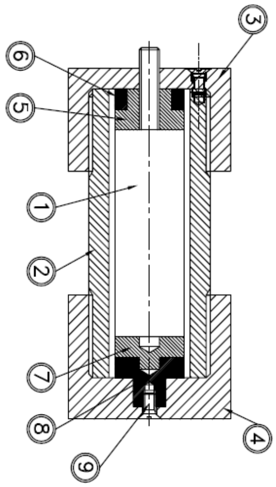
Design of three terminal guarded electrode sensor:



1- Center Electrode
2-Outer Electrode
3-Top Cover
4-Bottom Cover
5,7- Insulator(Nylon)
6,8-Guarded Electrode

Figure3. Design of three terminal sensors (1)

All the errors were reduced, but there are problems with wiring of the guarded electrodes. Hence the wiring was made internally through the inner electrode with proper insulation. The following figure shows that modified type.

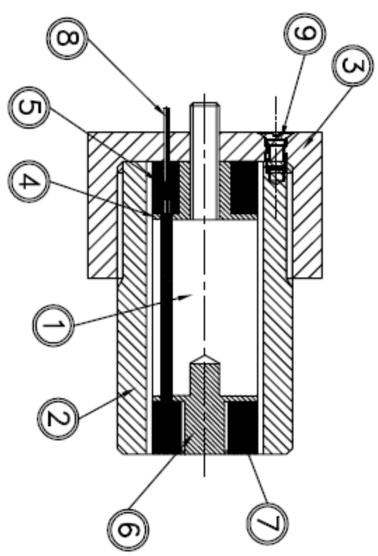


Figure4. Design of three terminal sensor(2)

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Circuit design:

The capacitance value from the sensor has to be converted to useful signal. oscillator circuit was developed to convert the capacitance into frequency. Based on capacitance the generated frequency will be varied. Then the frequency will be converted into voltage signal for further processing.

IV. TEST RESULTS AND DISCUSSION

A basic type of parallel plate and a coaxial type sensor were made, the readings were taken from reference liquids, and the values were analysed with the standard dielectric constant values, based on the error percentage, modifications were carried out in order to increase the accuracy of the sensor

1) Parallel plate sensor:

Standard dielectric constant value and sensor output value of parallel plate

Table 2.Results of parallel plate sensor

S.NO	Reference fluid	Measured Dielectric constant	Standard Dielectric constant (from literature)	% Error
1	Toluene	3	2.3	23
2	Coconut oil	3.3	3	10
3	Kerosene	2.1	1.8	15

2) Coaxial type sensor:

Figure5. Testing of sensor

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Table 3.Results of Coaxial capacitance sensor (prototype 1)

S.NO	Reference liquids	Measured Dielectric constant	Standard Dielectric constant (from literature)	% Error
1	Toluene	2.18	2.3	5.3
2	Coconut oil	3.004	2.9	3.3
3	Kerosene	1.72	1.8	4.4
4	Acetic acid	5.826	6.3	8.3
5	Acetone	3.1	2.85	8

Problems associated with prototype 1 are:

- More height.
- More weight.
- Lead effect.

The above sensor was modified by

- ✓ Reducing the height.
- ✓ Reducing the lead height.
- ✓ Insulation of the wires.
- ✓ Reducing the thickness of the outer tube.
- ✓ Reducing the diameter of the electrodes

Table 4.Results of Coaxial capacitance sensor (Prototype 2)

SI.NO	Reference liquids	Measured Dielectric constant	Standard Dielectric constant (from literature)	% Error
1	Toluene	1.98	2.3	15.3
2	Coconut oil	2.78	2.9	4
3	Kerosene	1.6	1.8	11
4	Acetic acid	5.8	6.2	6.4
5	Acetone	3.1	2.85	8

The increase in error values from table 5.3 are due to increase in spacing between the electrodes. Due to more spacing (d) between the electrodes, the polarization effect of the dielectric medium became weak and the capacitance value was reduced and affects the value of dielectric constant. Hence the distance between the electrodes should be optimum.

Table 5.Results of coaxial capacitance sensor (Prototype 3)

SI.NO	Reference liquids	Measured Dielectric constant	Standard Dielectric constant(from literature)	% Error
1	Toluene	2.23	2.3	2.7
2	Coconut oil	2.904	2.9	1.5
3	Kerosene	1.701	1.8	5
4	Acetic acid	6.55	6.2	5.4

Still more error in the sensor, the terminal guarded type was developed and readings was taken out

Table 6.Results of three terminal guarded electrode sensor (1):

SI. NO	Reference liquids	Measured Dielectric constant	Standard Dielectric constant(from literature)	% Error
1	Toluene	2.319	2.3	0.9
2	Coconut oil	2.934	2.9	1.5

This type sensor has problem in wiring of the guarded electrode. Hence wiring was made internally and reading was taken out.

Table 7.Results of three terminal guarded electrode sensor(2)

SI.NO	Reference liquids	Measured Dielectric constant	Standard Dielectric constant (from literature)	% Error
1	Toluene	2.308	2.3	0.09
2	Coconut oil	2.89	2.9	1

Finally a sensor of accuracy upto 2% was developed and with that various proportions of ethanol mixed (5%, 10%, 15%, 20%) petrol and diesel and dielectric values will be calculated using the sensors capacitance value. Then the experimental values has to be compared with the theoretical calculated values

V. CONCLUSION

Based on step by step modification on the basic type of coaxial capacitance sensor, finally a sensor of accuracy up to 2% was developed and testing was made on the various concentrations of fuel mixtures. After this circuit designing has to make to convert the sensor output to a useful signal from for further usage. Because of its more conductance property of Ethanol it affects the capacitance value of the sensor. Hence a compensating circuit is needed to compensate the error. So it has to be designed and measurements are to be taken in the future work.

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