Fuel Level Measurement Techniques: A Systematic Survey

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Abstract-Petrol bunk frauds were very common in recent time. Many of the petrol bunks today manipulated pumps such that it displays the amount as entered, but in reality, the quantity of fuel filled in the customer's tank is much lesser than the displayed value. The pumps are cheated for the benefit of the petrol bunk owner. This results in huge profits for the petrol bunks, but at the same time the customers are being cheated. Majority of the two wheeler vehicles in India consist of analog meters which will not help to precisely know the amount of fuel currently in the vehicle and also it is not possible to cross check the quantity of fuel filled at the petrol bunk. Also in this modern and competitive world, products are being digitized owing to its benefits, user friendliness. So we are conducting a project named "design and development of a digital fuel level indicator for two wheelers". It consists of creating a digital display for the exact volume of fuel contained in the fuel tank. The above furnished fact is considered in the project and its found out that a proper solution for indicating the accurate availability of fuel in the tank digitally. A sensor and a microcontroller is used to find out the fuel level which is economic and also accurate. This paper focuses on the study of various fuel level measuring sensors suitable for our project. Some issues with respect to the existing level measurement techniques are identified and so a better alternate digital sensing technology has been suggested, described and justified.

Index Terms: float gauge, fuel level measurement, ultrasonic sensors,capacitance sensors etc.

1. INTRODUCTION

Up until now the accuracy of the fuel level measurement has not been of great importance. The purpose measuring the fuel level has been to present the information on the dashboard with a fuel level meter. Instead of accuracy the two most important things have been to avoid rapid changes in the fuel level displayed and the meter must indicate that the tank is empty when the fuel level is below a predefined level. This system is not capable to provide the exact value of fuel in the fuel tank. Also such system cannot protect us from getting cheated at petrol pumps and thiscosts more for less amount of fuel so filled.So it becomes necessary to develope such a system which gives exact (numeric) value of fuel in fuel tank.

2. FUEL LEVEL MEASUREMENT TECHNIQUES

2.1 Fuel guage

A gauge (or gas gauge) is an instrument used to indicate the level of fuel contained in a tank. Commonly used in cars, it may also be used for any tank including underground storage tanks. The system consist of two important part that is for sensing and indication of fuel level. The sensing unit usually uses a float type sensor to measure fuel level while the indicator system measures the amount of electric current flowing through the sensing unit and indicates fuel level.

There are various techniques to implement sensing and indicating systems.

- traditional float type measurement technique
- microcontroller based fuel measurement technique

Presently the most common and traditional fuel indicator system makes use of the resistive float type sensors to measure the level of fuel in the tank and this system consists of two units i.e.,the sender unit responsible to measure the level of fuel in the tank, the gauge unil responsible to display the measured fuel level to the driver. Another technique is known as the Smart fuel gauge system, which is similar to the traditional technique but also makes use of embedded systems such as microcontrollers or microprocessors for providing better accuracy.

2.1.1 Operating principal

The traditional fuel indicator consists of two units i.e. the sending unit and the gauge. The Fig (1) shows the commonly used traditional fuel measurement system. The sending unit is located in the fuel tank of the car and it consists of a float, usually made of foam, connected to a thin, metal rod. The end of the metal rod is mounted on a variable resister or potentiometer. The variable resistor consists of a strip of resistive material over it which moves across the variable resistor changing the resistance and flow of current depending on the movement of the float with respect to the level of fuel present in the fuel tank .

The Fig (1) shows that the fuel in the fuel tank is almost empty and the float has moved to the bottom of the tank moving the strip on the resistor thus increasing the resistance to maximum and current flow through the resistor becomes minimum thus displaying fuel empty on the gauge[1]. The gauge consists of a bimetallic strip i.e. a strip made of different kinds of metal and whose thermal co-efficient of expansion differs from each other. When resistance is decreases current increases and thus the strip is heated during which one metal expands less than the other, so the strip curves, and this bending action is what moves the needle move on the fuel gauge. As resistance increases, less current passes through the heating coil ,so the bimetallic strip cools. As the strip cools, it straightens out, pulling the gauge from full to empty.

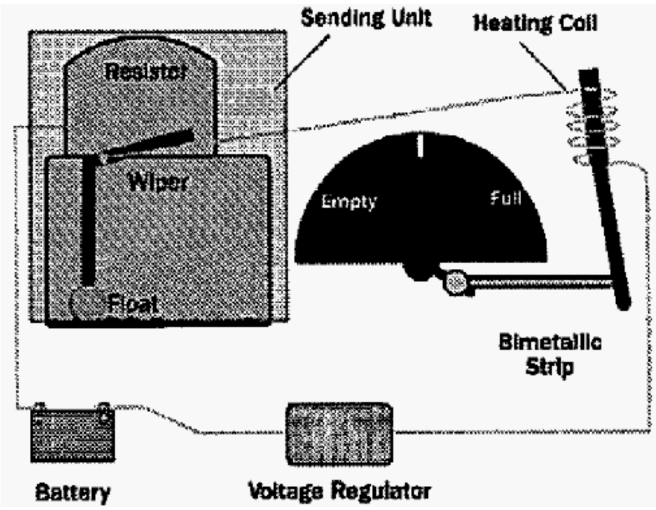

Figure1. Traditional Fuel Measurement System [1]

The smart fuel gauge system techniques has been implemented in some newer cars in which, instead of sending the current directly to the gauge, an intermediate microprocessor is used to read the output of the resistor and then communicate with the dashboard for displaying the fuel on the gauge corresponding to read output voltage from sending unit and these system actually help to improve accuracy of system.

2.1.2 Comparison of existing techniques

The traditional float type resistive measurement technique has bad accuracy issues compared to that of the microcontroller based technique and the reason for this is its mechanism, it is noticed that the gauge tends to stay on full for quite a while after filling up and this is because when the tank is full, the float is at its maximum raised position while its upward movement is limited either by the rod its connected to or by the top of the tank and therefore this means that the float is submerged and it won’t start to sink until the fuel level drops to almost the bottom of the float, hence the needle on the gauge won’t start to move until the float starts to sink. Something similar can happen when the float nears the bottom of the tank. Often, the range of motion does not extend to the very bottom as shown in Fig (1), so the float can reach the bottom of its travel while there is still fuel in the tank. This is why, on most cars, the needle goes below empty and eventually stops moving while there is still gas left in the tank. The newer cars have a microprocessor that reads the variable resistor in the tank and communicates that reading to another microprocessor in the dashboard thus displaying the fuel level and a fuel light indicator signal with respect to the fuel level such as a red light when low on fuel and green light when tank is full. In this technique, the Car makers can tinker with the gauge movement a little while compensating for the shape of the tank by comparing the float position to a calibration curve and this curve correlates the position of the float with the volume of fuel left in the tank. This allows the gauge to read more accurately, especially in cars with complicated gas-tank shapes The microprocessor can also provide some damping to the needle movement i.e. when the car goes around a turn, or up a hill, the fuel can slosh to one side of the tank and quickly change the float position and if the needle were to respond quickly to all of these changes, it would be bouncing all over the place, instead the software calculates a moving average of the last several readings of the float position. This means that changes in needle position occur more slowly; therefore this may have been noticed when filling up car tank that the tank is fulfilled long before the needle reaches full, however the cost of implementing this technique is more expensive and complex compared to that of the traditional technique, therefore the trade off in the microprocessor based technique is the cost and complexity for gaining accuracy and its vice versa for the traditional technique i.e trade off accuracy for reducing cost of development and complexity of the system.

2.2 Capacitance level sensing

In a capacitive fuel level sensing system, the capacitive sensors have two conducting terminals electrodes and the gap between the two rods is fixed the fuel level can be found by measuring the capacitance between the two conductors immersed into the fuel as shown in the Fig (2).

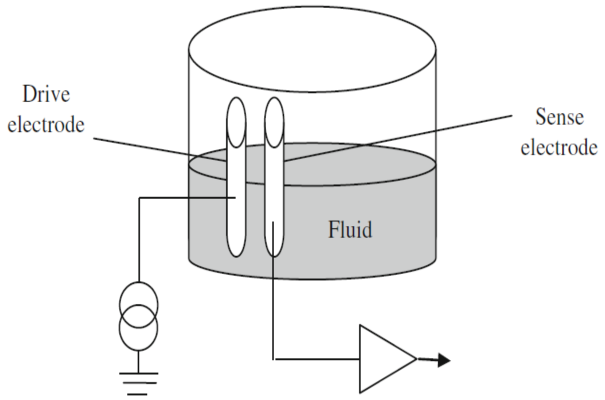

Figure 2: Capacitive level sensing

Since the capacitance is directly proportional to the dielectric constant between the parallel rods or plates, therefore the fuel rising between the two parallel rods leads to increase or change in the net capacitance value of the measuring tank as a function of fluid height. If the dielectric behaves even slightly as a conductor then this can reduce the performance of the capacitor. The dielectric material used should ideally be an insulator while chemically fuel will have other contents mixed in it increasing the conductivity of electrons to some extent, therefore a common method used to overcome this problem is placing an insulating layer on each of the rods in order to preserve the performance of the measuring system. Capacitive type fuel level measurement system can make use of multiple capacitors or multi-plate capacitors which has an advantage of an increased capacitance value and accuracy. Multicapacitor systems share the common dielectric constant, which is essentially the fluid itself in capacitive type fluid level measurement systems. If a capacitor is constructed with 'n' number of parallel plates, then the overall capacitance will be increased by a factor of (n-1) as illustrated with an example in [2]

Advantages of capacitance

- Cost effective
- Fast speed of responce
- Interface measurement
- Operate well with high temperature and pressure

2.3 Level sensing by electronic load cell

Weighing a vessel or tank containing either liquids or fuel is a very accurate method of determining level. This type of measurement requires the use of ELECTRONINC LOAD CELLS. Load Cell are strain gauge assemblies that provide an electrical output proportional to the applied load. The use of LOAD CELLS for level measurement requires an accurate value for the density of the material being measured. If the actual density of the material is less than expected, the tank can overflow while the level reading still shows sufficient room to continue filling. Density is a very important aspect of measuring level and it must be known in order to accurately measure level of a material. Strain gauges load cells are generally in the form of a beam, column, or other stress member with strain gauges bonded to them. When a weight or load is impressed against a member, the strain gauge is deformed and its electrical resistance changes in a bridge circuit, which provides an output that is proportional to the force acting upon the load cell .

2.3.1 Operating principal

In the beginning the force or pressure is applied to the load column,due to which it gets compressed and its length gets reduced. This column acts as the primary transducer since it converts the applied force into change in length, however this change in length is not measured directly. At the same time, the strain gauge connected to the load column gets compressed. This strain gauge acts as the secondary transducer since it records the displacement of the load column. Since the strain gauge is compressed,its length gets reduced, which depends on the magnitude of the applied force on the top of the load cell. As the resistance of the strain gauge changes when its length changes. This change in resistance can be recorded by the wires connected to the strain gauge. The resistance change is calibrated against the applied force, thus the recorder directly gives the value of the applied pressure or the force. For the measurement of the tensile force, usually the bonded wire type of strain gauge is used. While in case of the compressive force, the length of the strain gauge reduces, in case of the tensile applied force its length increases.The fuel tank calibrated using the standard procedure.The calibration of the tank purely based on the weight. Load cell is a transducer which converts the weight/force into an electric signal. Hence the tank mounted on a Load cell by drilling two holes in the tank. The output voltage coming from the load cell was passed on to an voltage amplifier. The amplified voltage was fed to an ADC such that the ADC passes a corresponding digital value to the microcontroller. An external power supply was used for the circuit by means of an adaptor. The adaptor voltage was regulated by a voltage regulator. This voltage was fed to a microcontroller. The microcontroller interfaced with a LCD so as to display the accurate digital value.

2.4 Ultrasonic sensing

The principle of ultrasonic devices is based on the amount of time it takes to send and receive reflected ultrasonic sound wave from the media Ultrasonic waves are similar to audible sound waves in that they are mechanical waves.

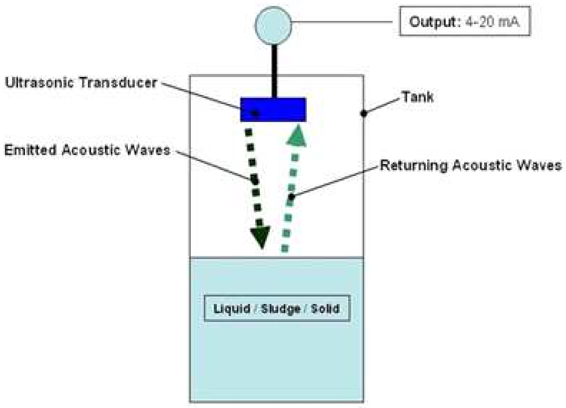

Figure3: Ultrasonic sensing

The speed of ultrasonic waves can be more easily influenced than the speed of light. The temperature and type of gaseous media have a tremendous effect on sound waves. The temperature of the gaseous media influences the speed of the wave. The higher the temperature, the faster the sound waves travel. While the temperature at the level device can be compensated by a temperature sensor in the ultrasonic device, the level measurement will only be accurate if the entire space between the sensor and liquid are the same temperature. The type of gaseous media also influences the speed of the sound waves. For example, sound travels almost three times faster in helium than it does air. Most ultrasonic devices can be programmed for the type of gaseous media the sound waves will travel through.

Advantages of ultrasonic sensors

- Non-contact (lowest cost)
- Installation at top
- Accuracy independent of density changes, dielectric or conductivity
- No calibration with medium required

3. CONCLUSION

The existing traditional and the microcontroller based float type measurement techniques are far from exact and are on the conservative, however the microcontroller based technique is more accurate compared to the traditional technique but still lacks accuracy due to fuel sloshing in the tank unless float sensor is calibrated with respect to the size and curves of the tank. So by using any one of the level measuring sensor described above will most likely be more accurate, more reliable, and cheaper than other analog meters, and will allow for added features that benefit both the customer. In the near future, the different vehicle company manufacturers will implement this kind of fuel system which also provides security for the vehicle owners. Not only will the measurement be more accurate, but, the consumers also will not be cheated for their hard earned money.

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