ISSN 2229-5518

Accurate fuel level measurement system with tilt compensation using tilt sensor

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Abstract— Fuel level indication is very critical in automobiles, as it helps the user estimate the distance that can be covered with the available fuel. Inaccurate fuel level indications can lead to wrong estimations and cause inconvenience to the user. Conventional fuel level sensors, particularly in two-wheeled vehicles, are primarily variable resistance based; in these sensors, resistance changes with the amount of fuel in the tank. There are various other kinds of fuel level sensors, such as magnetic float and reed switch based or hall-effect based sensors. In these sensors, there is the possibility of error in the fuel level measured because the sensors only measure the height of the fuel level from a reference plane. For a given quantity of fuel, the fuel level height varies when the fuel tank is tilted. Conventional fuel level sensors account for neither the fuel tank tilt nor the vehicle tilt angle. This consequently produces wrong fuel indications when the vehicle is tilted. This paper describes how a single chip MEMS based tilt sensor can be used to determine accurate fuel levels by compensating for the error caused by the tilt of fuel tank or vehicle. Furthermore, data obtained from the same sensor can be used to monitor various other parameters, such as the vibration, yaw, and roll-over of the vehicle. This reduces the number of sensors used in a vehicle

Index Terms— Automobile, Fuel level sensor, Micro Electro Mechanical Systems (MEMS), Tilt sensor.

1 Introduction

All automobiles have an indication displaying the amount of fuel available in a reservoir. The indication could be gasoline/diesel level in tank or gas pressure in a cylinder or State of Charge (SOC) of battery depending upon the kind of fuel consumed by the automobile.

When it comes to indication of available fuel in case of liquid fuel (gasoline/diesel), the fuel level is dynamic. The available fuel in tank is measured by sensing the height of fuel level from a reference plane like tank bottom or top. The fuel level is stable only if the vehicle on which the tank is mounted is stationary or stable. Otherwise, the fuel level continuously fluctuates with road surface variations, surface inclination, vehicle tilt, vibration etc.

Commonly used variable resistance based fuel level sensors have a floating member that floats on the fuel and moves along with fuel level [1]. A moving contact connected with the float slides over a resistive track based on the float movement along with the fuel level. Based on the position of the moving contact on the resistive track, the sensor exhibits different values of resistance corresponding to the fuel level.

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This system has following problems:

- Reaction of the resistive track/moving contact surface with the fuel leading to error in output of sensor [2]-[5]
- Wear out of the resistive track/moving contact [6] [7]
- Damage/bending of moving contact causing intermittent or no connection between moving contact and the resistive track
- Deposition of oil or dirt on the surface of resistive track/moving contact leading to error in sensor output [6]

Also, the current fuel level sensors do not have the provision of sensing the vehicle tilt. When the vehicle is tilted, all the fuel gets accumulated on one side of the tank due to gravity. As a result, the fuel level increases on the side to which vehicle is tilted and reduces on the opposite side. Fuel level sensor gives output corresponding to the increased/decreased fuel level when the vehicle is tilted. The fuel gauge in turn indicates incorrect high or low fuel level based on the output from sensor. Due to this incorrect indication, the user ends up with incorrect estimation of coverable distance with the available fuel.

To overcome the above mentioned problems, a sensor with no moving contacts can be used. Secondly, the error in indication due to vehicle tilt can be eliminated by sensing the vehicle tilt along with fuel level and compensating the deviation of fuel level from actual fuel level. This helps in indicating actual fuel available irrespective of vehicle tilt or road inclination.

In this design a MEMS based tilt sensor is used to sense the fuel level as well as the vehicle tilt. This sensor does not have any moving contacts and senses both fuel level and vehicle tilt. The methodology that can be adopted for realizing the vehicle tilt compensation in fuel level indication will be explained.

ISSN 2229-5518

2 DESCRIPTION OF THE SYSTEM

2.1 Construction

A fuel tank holds the fuel in an automobile. The fuel level sensor is mounted on any one of the walls of the tank. A cuboidal tank is considered for the explanation. The fuel level sensor consists of a floating member which floats on the fuel, a connecting rod or float arm on which a tilt sensor is mounted is connected to the float at one end and the other end is pivoted to a mechanical housing which in turn is fastened to the tank wall. The fuel level sensor is shown in Fig. 1.

In this example, the fuel level sensor is mounted to the top face of the tank and at a lateral distance D from the center axis of the tank. Side view and front view of the tank half filled with fuel and with fuel level sensor mounted in it is illustrated in Fig. 2 and Fig. 3 respectively.

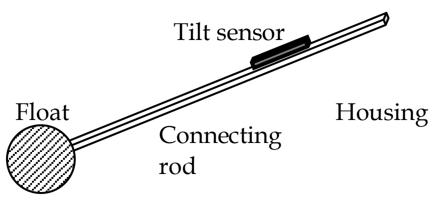

Fig. 1 Construction of fuel level sensor

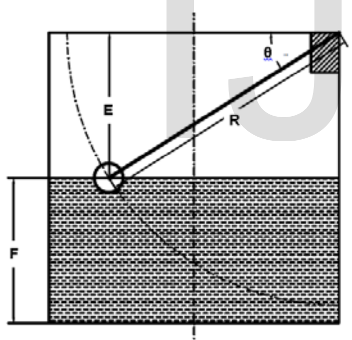

Fig. 2 Side view of the fuel tank containing fuel and fuel level sensor

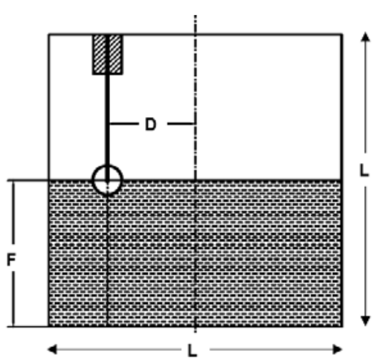

Fig. 3 Front view of the fuel tank containing fuel and fuel level sensor

2.2 Functioning of system

The block diagram of the system is shown in Fig. 4 wherein the fuel level and vehicle tilt signal data is fetched from a 2-axis tilt sensor which is mounted on the connecting rod of the fuel level sensor. This data is conditioned and fed to a controller which calculates the accurate fuel volume available in the fuel tank based on data received from tilt sensor. The calculated fuel volume is then displayed to the user on a display unit.

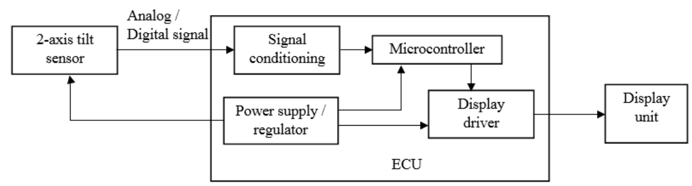

Fig. 4 Block diagram of the system

The MEMS based tilt sensor used here is an accelerometer capable of sensing tilt in 2 axis [8]-[10]. The first sensing axis is along the longitudinal axis (x axis) of the vehicle and corresponds to the fuel level measured. The second sensing axis is along the lateral (y axis) of the vehicle and corresponds to the sideways vehicle tilt or roll angle. The signal output given by the tilt sensor corresponding to different tilt angles is practically measured and shown in Fig. 5 and 6.

The controller calculates the fuel level from the x axis put from the sensor which represents the tilt angle of the connecting rod. Simultaneously, the controller calculates the vehicle tilt angle from the y axis signal of the tilt sensor. Based upon the x axis data, the controller calculates the apparent volume of fuel available in the tank and from the y axis data the controller calculates the compensation to be done to find actual fuel volume. The controller then does the compensation and calculates the actual fuel volume. The actual fuel volume is then displayed in the display unit.

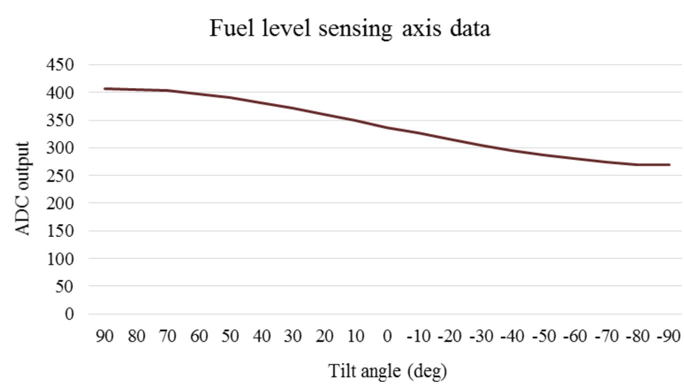

Fig. 5 Tilt sensor output data practically measured for different tilt angles in x axis.

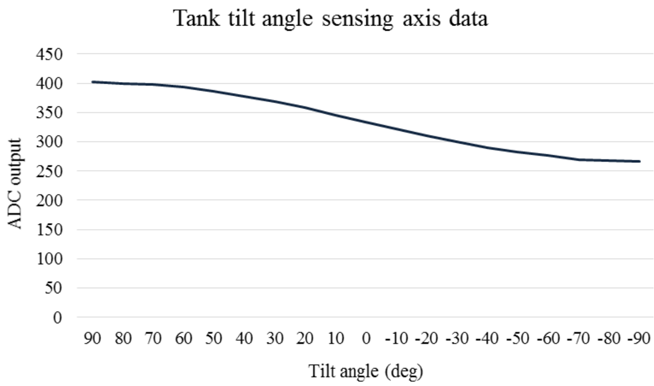

Fig. 6 Tilt sensor output data practically measured for different tilt angles in y axis.

3 Methodology for Fuel Volume Calculation with Compensation

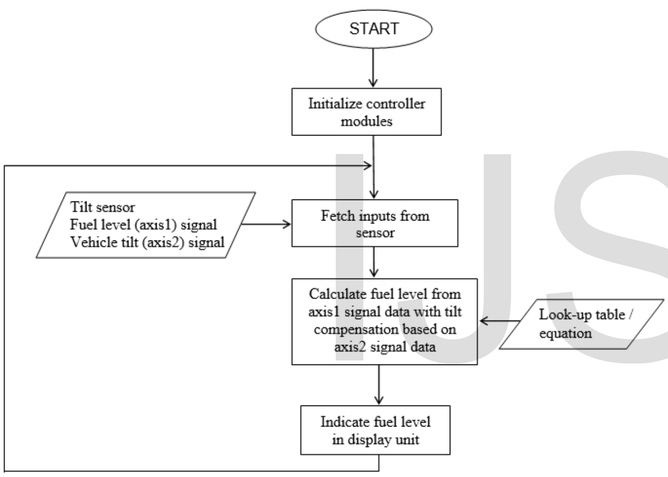

Fig. 7 Flow chart for calculation of actual fuel volume by controller

Fig.7 represents the flow chart which is followed by the controller in order to calculate and display the actual fuel volume from the data received from tilt sensor. The controller can follow an equation relating the actual fuel volume, apparent fuel volume and vehicle tilt or it can follow a look-up table. The above two methodologies are realized by developing the relations as explained below:

3.1 Equation relating actual fuel volume, apparent fuel volume and vehicle tilt for error compensation

Considering Fig. 2, which shows side view of a fuel tank in the shape of a cube of sides L having a fuel level sensor with connecting rod of length R. For the amount of fuel present in tank, the tilt angle of connecting rod (and tilt sensor) with respect to horizontal plane is θ. The tilt sensor gives output signal in x axis corresponding to this angle. The distance between top face of tank to the fuel level E can be found using,

$$E = R.\sin\theta.$$

Having known E, the height of fuel level from tank bottom F would be,

$$F = L - E$$

So the volume of fuel in the tank is calculated using,

$$Fuel\ volume = L^2 * F$$

Fig. 3 shows the front view of the fuel tank and the fuel level sensor is mounted at a lateral distance D from the center axis. Tilt in vehicle results in tilting of the tank and fuel level sensor with respect to vertical plane. Consider the tank tilted towards left by an angle α from the vertical plane as shown in Fig. 8. The fuel inside maintains its surface horizontal and hence the fuel level measured will be F′ for the same fuel volume while the fuel level is F when the tank is not tilted. Increase in fuel level due to tilt in tank assembly by an angle α is ΔF. To determine ΔF consider triangle abc in Fig. 9.

$$\Delta F = D.\tan(\alpha)$$

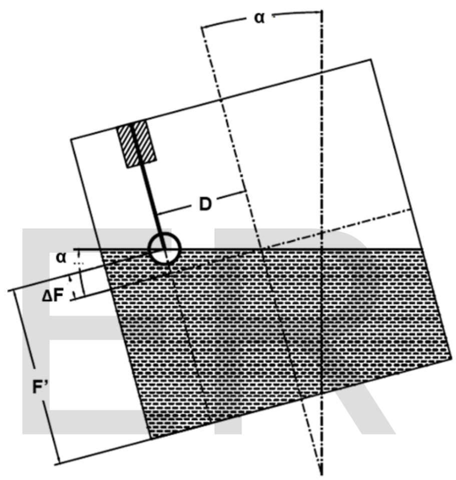

Fig. 8 Fuel tank tilted towards left by an angle α

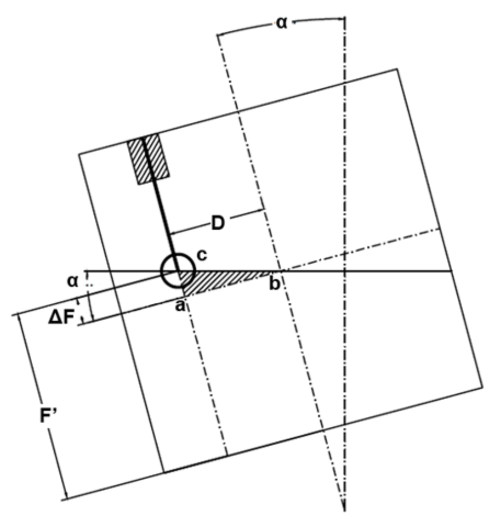

Fig. 9 Representation of triangle abc in tilted fuel tank

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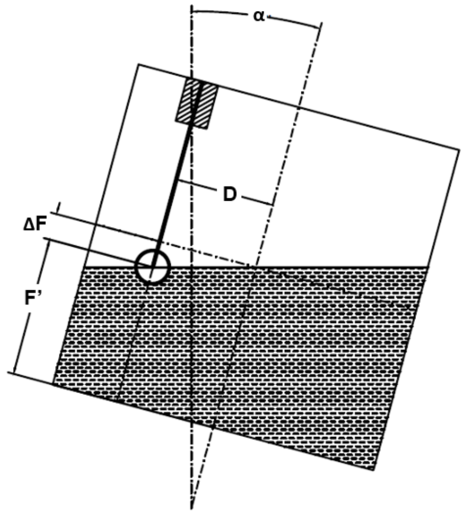

Fig. 10 Fuel tank tilted towards right by an angle α

In case the fuel tank is tilted on the other side, as shown in Fig. 10, α value will be negative and hence, ΔF will be negative.

The actual fuel level can be calculated by

$$F = F' - \Delta F$$

From this, Actual fuel volume can be calculated using,

$$Fuel\ volume = L^2 * F$$

3.2 Look-up table relating actual fuel volume, apparent fuel volume and vehicle tilt for error compensation

For tanks with irregular shape where equation development gets complicated, look-up table based tilt compensation and fuel volume estimation can be used. For developing the look-up table, behavior of tilt sensor output may be recorded for different fuel volumes from empty to full condition in a reference tank or in a 3 dimensional model at various tilt conditions on both left and right sides. This look-up table will have the readings of actual fuel volume, x axis tilt and y axis tilt.

The controller can refer to this table for every reading it receives from the tilt sensor and determine the actual fuel volume directly.

4 CONCLUSION

A system for accurate fuel level sensing in automobile is developed. This system determines the actual fuel level in a reservoir without getting affected by the inclinations in lateral axis of the vehicle. The sensor also overcomes some of the drawbacks of the commonly used variable resistance based fuel level sensors. The MEMS based tilt sensor data can additionally be used to sense other vehicle parameters like rollover, vibration, acceleration, crash etc. which in turn can help to reduce the number of sensors used in the vehicle.

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