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EXPERIMENTAL INVESTIGATION OF EVAPORATIVE EMISSION WITH VARIATION IN MATERIAL CHARACTERESTIC AND FUEL LEVELS

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Abstract**—** The contribution of evaporative emission to the total emission from a vehicle is substantial and has become critical due to stringent emission regulations. Hence it is imperative to study the variation in evaporative emission and factors responsible for them. The material of construction of the fuel tank and the fuel level in that tank are the two parameters selected for this investigation. Two fuel tanks of equal dimension were fabricated with polycarbonate and mild steel. Experiments with various fuel levels were conducted in a mild steel fuel tank. The results indicated a higher evaporative emission levels from polycarbonate fuel tank when compared to mild steel tank which explained the effect of permeability in evaporative emission. The emission rates were found to be reducing with increasing fuel levels and this was due to the reduction in volume of free air inside fuel tank and reduced surface area at fully filled condition.
Keywords: Evaporative Emission, Fuel Tank

1. Introduction

Experiments were conducted for studying variation in evaporative emission at atmospheric temperatures from fuel tanks in the past. As the vehicle manufacturers were required to make fuel tanks in flexible shapes for more efficient packaging, materials such as polycarbonate were found to be suitable as the blow moulding process was found to be more efficient and cheaper than many other metal manufacturing processes. Empirical models have been formulated to predict the evaporative emission, experimental studies in the field was found to be limited. The literature reviews do not indicate evaporative emission with variation in the material of fuel tank. Evaporation inside a closed container always depends on the attainment of an equilibrium state between evaporation and condensation which is determined by the volume of free air inside the tank. As the same phenomenon is occurring inside the fuel tank also, a study on the variation in evaporative emission levels by varying the volume of free air inside the tank was found to be relevant. The volatility of a liquid is directly proportional to evaporation rates and the difference in volatility values make the high volatile gasoline suitable for the study and low volatile diesel to be neglected as the evaporative emission from diesel is not regulated. The volatility increases with temperature and will be higher in countries lying near to equator and this also makes this study relevant to the present scenario.

2. Experimental Procedure

The experimental setup consists of an insulated chamber capable of trapping hydrocarbon vapours for measurement as indicated in Fig.1. For the study of evaporative emissions two identical fuel tanks with 6000cc capacity were selected. One was made of mild steel while the other of polypropylene. These are common materials used to manufacture fuel tanks for Automobile applications. To study the variation in evaporative emission with fuel levels, a 5000cc mild steel fuel tank was used. For the measurement of hydrocarbon levels, a portable exhaust gas analyser, HORIBA MEXA 584L was used which provided the hydrocarbon measurements in parts per million (ppm) and the temperature was also recorded.

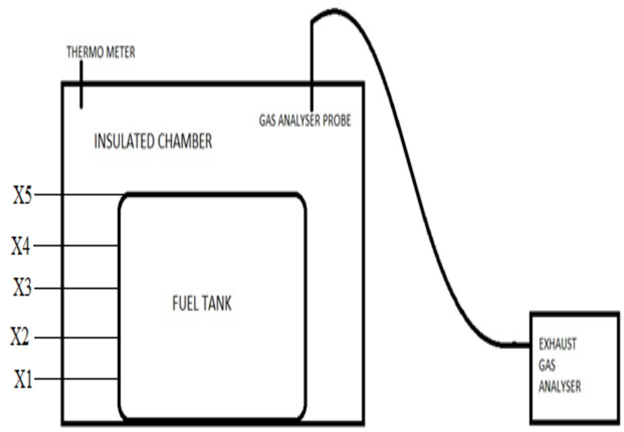

Fig.1 schematic diagram

1000cc of gasoline ($\frac{1}{5}$th of total capacity) was administered into one tank as it provided the maximum volume of free air inside the same. The tank was placed inside insulated chamber duly shielded from atmosphere as indicated in Fig.1. Temperature measurement was done and was found to be equal to the atmospheric temperature of 28^0 C. The entire setup was kept at ambient conditions of 28^0 C and 96kPa as shown in Fig.1 and allowed to heat up with daytime atmosphere temperature change of one degree only. Readings were noted at a time interval of 10 minutes and the experiment duration was 60 minutes as per FTP standards. The same procedure was repeated with fuel tank made of mild steel.

The evaporative emission test was conducted at five different fuel levels starting with 20% of fuel tank level to full tank of 100%. The emission levels at all this tests are recorded and a plot between hydrocarbons indicates the relationship with respect to increase in temperature.

3. Results and Discussion

3.1 Material Comparison

Maximum surface area and free air volume in contact with fuel surface are the two critical factors affecting evaporation in a closed tank.

For the first 30 minutes, the fuel inside the tank got heated up and the kinetic energy of the particles in fuel increased. The high energy particles at the surface of fuel level broke the weak intermolecular attractions and escape into the free air above. These evaporative emission from the fuel tank to the outer layer in the enclosure are measured by the exhaust gas analyser and the trend is as indicated in Fig. 2 and Fig. 3. The first 30 minutes indicate an increase in rate of evaporation.

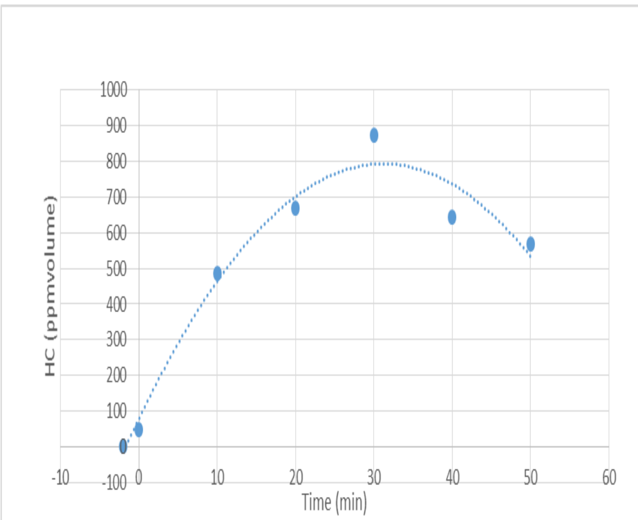

Fig.2 HC vs time for mild steel fuel tank

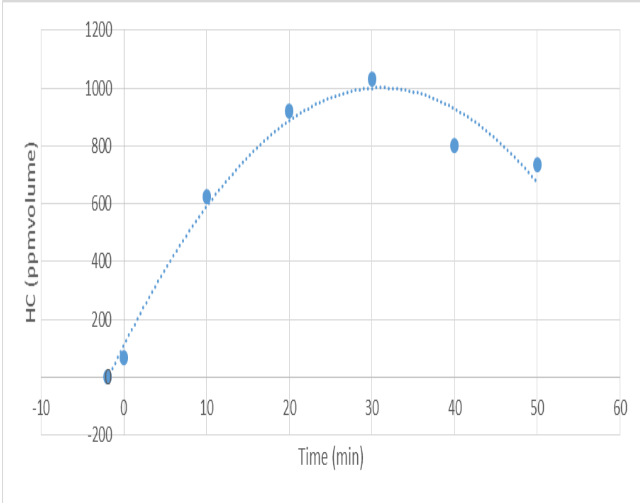

Fig.3 HC vs time for polypropylene fuel tank

Once all the higher velocity molecules in the fuel escaped to vapour phase, the average velocity of the remaining fuel particles reduced and this resulted in the reduction of temperature and as a result the kinetic energy of fuel molecules. Due to evaporative cooling, the reduction in temperature reduced the evaporation rate of gasoline as indicated in Fig. 2 and Fig. 3 and the mechanism of evaporation was found to be same irrespective of the material of fuel tank.

The resultant graph in Fig. 4 clearly indicates that the amount of evaporative emission from the mild steel fuel tank is less than that from the polypropylene one. This is may be due to the higher permeation losses from the polypropylene fuel tank and also the hydrocarbon emission from the material which is classified as back ground emissions.

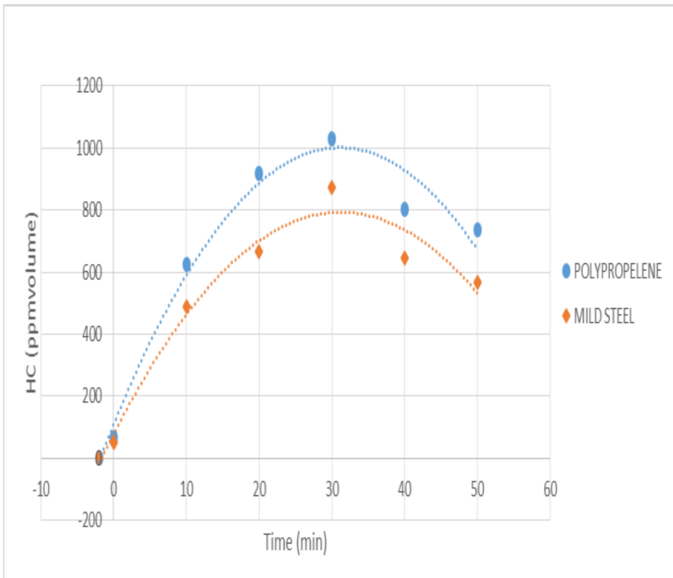

Fig.4 rate of emissions from the fuel tanks

3.2 Fuel Level Variation

For this experiment, different readings were taken with fuel levels from X1 to X5 in increments of 20 % (Refer Fig.1). It was observed that at lower fuel levels, evaporative emission increased as the fuel was heated up for the first 30 minutes and then the rate reduced as the evaporative cooling effect took over as indicated in Fig.5.

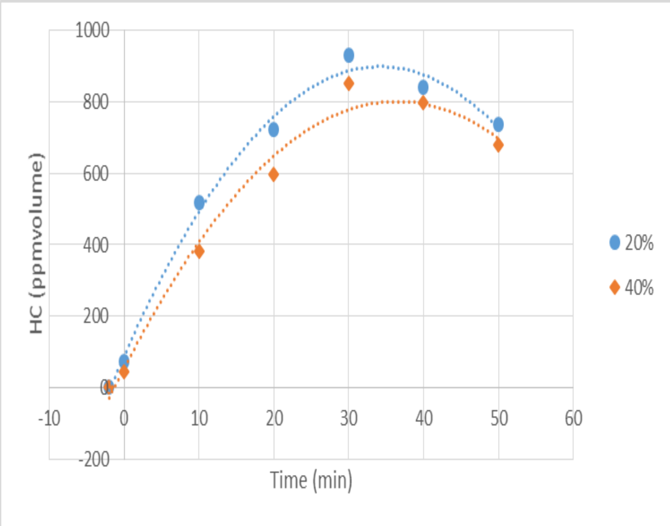

Fig.5 HC vs time for 20%&40% fuel tank level

It can be observed from Fig.6 that the evaporative emission increased till 40 minutes for 60% and 80% fuel levels and then reduced. Even though 100% fuel level shown a proportional increase with time, the amount of hydrocarbons measured in ppm were less compared to other fuel levels. This was due to the fact that the volume of free air in the tank was reduced as the fuel level increased. Vapour equilibrium was attained between the fuel particles in liquid state and the vapour above it. As the volume of free air inside the closed fuel tank reduced, the time taken for the air to get saturated and reach equilibrium also reduced.

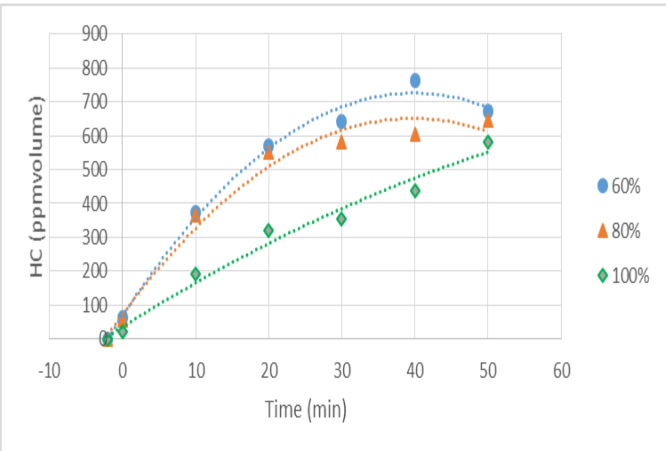

Fig.6 HC vs time for 60%, 80%&100% fuel level

To understand the variation in emission of evaporated hydrocarbons when the fuel level inside the tank is varied, all the readings were superimposed for easy and efficient interpretation.

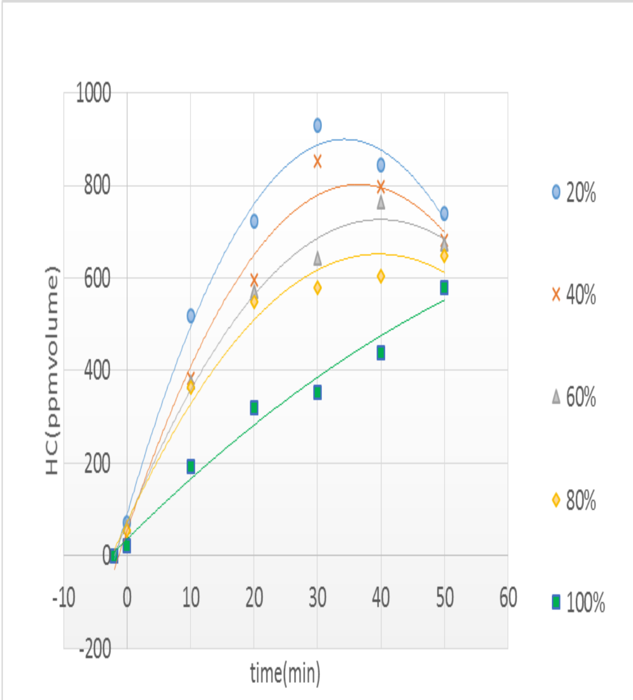

Fig.7 HC vs time for different fuel levels

As the fuel level inside the tank increased, there is a visible reduction in hydrocarbon levels as indicated in Fig.7. This observation can be explained by the fact that evaporation inside a closed fuel tank depend on the surface area of liquid and the amount of free air inside the tank. In this case, the critical factor which affects the change in evaporation will be the volume of free air inside the tank rather than the fuel surface area as it remained the same in all fuel levels except at 100% fuel level. The change in trend of graph at 100% fuel level which means that when the fuel is filled till neck, is the combined effect of volume of air and surface area.

4. Conclusions

From the results obtained during this study, it is evident that the hydrocarbon emission from polypropylene tank is higher than that of mild steel. This concludes that polymers and plastics which are made of hydrocarbon chains contributes to the total hydrocarbon emissions from a vehicle and are classified under background emissions. Also polymers have a higher permeability than metals which helps the hydrocarbon vapours inside the tank to diffuse out and it also contributes to the total evaporative emission as permeation losses. So it can be concluded that fuel tank made with metals have a lower evaporative emission when compared to those made with plastics and polymers.

The variation in evaporative emission levels was observed with fuel level and concluded that evaporative emission rates are reducing with increasing fuel levels which happens as a result of reduction in free air over the fuel and reducing surface area.

From the study made, it can be proposed that a vehicle having a fuel tank manufactured from metal losses only a lesser amount of fuel as evaporative emission when compared to plastic fuel tank. And also keeping higher fuel levels in the fuel tank reduces the diurnal emission rates.

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