Evaporative Emissions in A Two Wheeler Gasoline Fuel Tank: Cause and Calculation

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Abstract: The life line of our automobile industry is its energy source –petroleum products like petrol and diesel. But these are non-renewable sources of energy; it means that they will not last forever. Every drop of petroleum fuel counts, so it should be practice not to waste these precious energy sources. But since petrol is a very volatile fuel so during its use in vehicles a lot of fuel gets wasted in form of evaporative emissions. If these emissions could be checked through proper means then a lot of fuel can be saved. This research work is dedicated to the study of evaporative petrol emissions and factors on which it depends. This paper also gives a rough idea of amount of fuel gets wasted from a two wheeler fuel tank in a year.

Keywords: Evaporation, Emission, Fuel Tank, Temperature

1. Introduction

Evaporative emissions mainly consist of unburned hydrocarbons and main sources of evaporative emissions are Carburetor

Blow by emissions from engine Fuel tank

It is very important that evaporative emissions must be control because it leads to environmental pollution, depletion of conventional energy sources, loss of our money, and low mileage of vehicle….etc. And it is of further much importance in India because here nearly 75% of vehicle owners have either 2 wheeler or petrol cars.

It is mandatory to provide measure for control for blow by emissions from engine, and for these emissions most used technology used is Positive crankcase ventilation system (PCV)

But for control of evaporative emissions from fuel tank, little has been done in in

It has been decided that by 2020 India will implement BS VI, and to achieve those BS norms these hydrocarbon emissions have to be minimized or checked

2. Factors

2.1 Natural Factors

In this topic various cause and control of evaporative emissions from fuel tank have been discussed, in this some are natural controlled and some are user controlled

- Fuel properties-gasoline is a very volatile fluid its boiling point is ranges from 35 to 200 C therefore as the volatility increases evaporation also increases
- Shape of the fuel tank-if fuel tank is formed in such a way that it has large top surface area and high radiation exposer area then it leads to high evaporation of fuel.
- Amount of fuel-the amount of fuel in fuel tank also affects the evaporation rate it has seen that at low fuel rate more evaporation take place (say 40%) it is so because in this condition we have more unsaturated air above fuel top surface and it leads to more evaporation

• Air vent-every fuel tank is provided with an air vent for breathing, it is a necessary evil ,because through this vent a lot of fuel vapors gets lost to environment ,and this process takes place 24 hours continuously, sometimes loss of vapors is more for instance during a hot sunny day or after long ride
• Temperature and Atmospheric air saturation- temperature is one of the most determent factor in evaporative emission from fuel tank, temperature inside a fuel tank is always more than that of outside (3-5 C more) and since gasoline is such a volatile fluid rise in temperature increases the rate of

Evaporation to great extent, also if the air is dry and less saturated then evaporation rate increases

• Heat from engine- if the engine has been running for a long time then it is possible that heat from engine may reach to fuel tank as the tank is connected to manifold via fuel pipe and increase the process of evaporation

• Evaporation from air intake system-air intake system is system provided for suction of air from atmosphere, by the engine. During running condition air gets sucked in the engine, but as soon as engine is shut off, after a run, due to high temperature of engine fuel vapors starts evaporating through this air intake system .it have been seen that the loss is near about .1g/km

2.2 User Controlled Factors

During refueling (spitting loss)-during refueling al lot of fuel is lost; the loss is much more if the day is sunny so the refueling should be kept as less frequent as possible

Motion of fluid-as the vehicle moves so does the fuel and this movement cause the increase in are and kinetin energy of fuel ,this process further gets enhanced if the driving cycle is high, that is if number of acceleration and deceleration is high
2.3 Calculation

Assumptions
1-Shape of the fuel tank is cylindrical.
2-Capacity of fuel tank is 15 liter
3-Height of the fuel tank is .08 m
4-Top of the fuel tank is flat.

Abbreviations for units

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<td>L</td>
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3. Procedure for Estimating Loss

3.1 General

The total loss $LT$ ($l/yr.$) is the sum of the standing loss $LS$ and the working loss $LW$:

$LT = LS + LW$

$LW$ ($l/yr.$) is determined in Section 3.2, and $LW$ ($l/yr.$) is determined in Section 3.3.

3.2 Standing Loss $LS$

3.2.1 for fuel Tanks

The standing loss $LS$ ($l/yr.$) is given by expression:

$LS = 365(\pi D^2/4) HVO KS KE WV$

Where $D$, $HVO$, $KS$, $KE$, and $WV$ are determined in Sections 3.2.2 through 3.2.6, respectively.

The constant 365 has units of days/yr.

3.2.2 Tank Diameter $D$

The tank diameter $D$ (m) is:

a) For vertical tanks,

$D = DV$

Where $DV$ = cylindrical diameter of a vertical tank (m).

3.2.3 Vapor Space Outage $HVO$

The vapor space outage $HVO$ (m), the height of a cylinder of diameter $D$ whose volume equals the vapor space volume of a fuel tank, is:

a) For vertical tanks (see Figure 1): $HVO = HS - HL + HRO$

Where

$HS$ = tank shell height (m)
$HL$ = average liquid height (m)
$HL$ is unknown, use $HL = HS / 2$
$HRO$ = roof outage (m), the shell height equivalent to the volume contained under the roof.

1) For flat roofs: $HRO = 0$
2) For cone roofs: $HRO = HR / 3$
3) For dome roofs: $HRO = HR/2 + 2HR$

3.2.4 Vented Vapor Saturation Factor $KS$

The vented vapor saturation factor $KS$ (dimensionless) accounts for the degree of stock vapor saturation in the vented vapor:

$KS = 1/(1 + 47.54 PVA HVO)$

Where

$HVO$ is determined in Section 3.2.3
The constant 47.54 has units of $1/(Bar-m)$.

Figure 1: Fuel Tank Geometry

$PVA$ = stock true vapor pressure (Bar) at the average liquid surface temperature $T_{LA}$

True vapor pressure ($P_{VA}$) of gasoline stocks, at the daily average liquid surface temperature, can be determined using the following equation:

$P_{VA} = \exp [A - (B/T_{LA})]$

Where:

$\exp$ = exponential function
$T_{LA}$ = daily average liquid (gasoline) surface temperature.

Assumption: The RVP of gasoline for the summer months (April to October) is .482 bar and for the winter months (November to March) is .62 bar.

Liquid bulk temperature is based on the assumption that the product is in thermal equilibrium. The time required for the liquid bulk to achieve thermal equilibrium with ambient conditions, however, would result in the stock typically not being in thermal equilibrium for much of the period. Therefore, it is highly preferable to use measured values for the liquid bulk temperature.
3.2.5 Vapor Space Expansion Factor $KE$

The vapor space expansion factor $KE$ is nominally dimensionless but is assigned units of (1/day) because it describes the expansion of vapors in the vapor space that occurs due to the diurnal temperature cycle, and thus it pertains to a daily event.

a) For stocks with $PVA < 0.00689$ bar, the vapor space expansion factor $KE$ (1/day) is approximately:

$$KE = 0.04$$

b) For stocks with $PVA > 0.00698 K_L$, is given by expression:

$$KE = \frac{\Delta T_L}{T_L} + \frac{\Delta P - \Delta P_B}{P_A - P_A}$$

Where

- $PVA$ is stock true vapor pressure (Bar)
- $\Delta TV$ is max and min liquid temperature difference
- $TLA$ daily average liquid surface temperature
- $\Delta PV – \Delta PB$ is the daily exceedance (bar) of the vapor space pressure range beyond the vent

Setting range

The daily vapor pressure range, $\Delta P_v$, is calculated using the following equation:

$$\Delta P_v = P_{vX} – P_{vN}$$

Where:

- $P_{vX} =$ vapor pressure $P_{vA}$ at daily maximum liquid surface temperature, bar
- $P_{vN} =$ vapor pressure $P_{vA}$ at daily minimum liquid surface temperature, bar

Using the daily maximum and daily minimum liquid surface temperatures, the respective vapor pressures can be calculated as:

$$P_{vX} = \exp\{A-(B/T_{lx})\}, \quad P_{vN} = \exp\{A-(B/T_{ln})\}$$

The breather vent pressure setting range, delta $P_B$, is calculated using the following equation:

$$\Delta P_B = P_{dB} – P_{dV}$$

Where

- $P_{dB} =$ breather vent range (bar)
- $P_{dV} =$ breather vent vacuum setting (bar)

vent valve with no pressure/vacuum

$$P_{dB} = 0$$

$$P_{dV} = 0$$

3.2.6 Stock Vapor Density $WV$

The stock vapor density $WV$ (kg/m$^3$) is:

$$WV = \frac{M_V P_A}{R T_L}$$

Where

- $M_V =$ stock vapor molecular
- $PVA$ is determined in Section 3.2.4
- $T_L =$ daily average liquid (gasoline) surface temperature
- $R =$ ideal gas

3.3 Working Loss $LW$

3.3.1 General

Working loss occurs when the liquid level in the tank increases. The working loss $LW$ (l/yr) is:

$$LW = VQ KN KC KB WV$$

Where

- $VQ$, $KN$, $KC$, and $KB$ are determined in Sections 3.3.2 through 3.3.5, respectively, and $WV$ is determined in Section 3.2.6.

3.3.2 Net Working Loss Throughput $VQ$

The working loss throughput (m$^3$/yr) is:

$$VQ = 0.0001698Q$$

$Q =$ stock throughput (l/yr.).

The constant .0001698 has units of m$^3$/l.

3.3.3 Turnover Factor $KN$

The turnover factor (dimensionless) is:

$$KN = 1 \text{ for } N < 36$$

$$KN = (180 + N)/(6N) \text{ for } N > 36$$

Where

- $N =$ stock turnover rate (turnovers/yr).

$N$ can be estimated as:

$$N = 0.0001698Q/(\pi D_2 (HLX – HLN)/4)$$

3.3.4 Product Factor $KC$

The product factor accounts for the effect of different stocks on evaporative loss during tank working. The Product factor (dimensionless) is:

$$KC = 0.75 \text{ for crude oil}$$

$$KC = 1.0 \text{ for refined petroleum stocks}$$

$$KC = 1.0 \text{ for single component petrochemical stocks}$$

3.3.5 Vent Setting Correction Factor $KB$

If the breather vent pressure setting range $\Delta PB$ (determined in Section 3.2.5b)) is less than or equal to the typical range of ±0.03 psig, $KB = 1.0$.

If $\Delta PB$ is significantly greater than ±0.03 psig:

If $K_{Bb} = \frac{P_{bd} + P_A}{P_A} < 1.0$

Then $KB = 1.0$

Where

- $KN$ is determined in Section 3.3.3
- $PA =$ atmospheric pressure at the tank site
- $PBX =$ breather vent maximum pressure setting
- $PO =$ normal operating pressure

b) Otherwise, the vent setting correction factor (dimensionless) is:

$$KB = \frac{P_{bd} – P_A}{P_{bd} + P_A – P_A}$$

Where

- $PVA$ is determined in Section 3.2.4

Above accounts for vapor condensation before the vents open.

For of 2 wheeler fuel tank having a capacity of 15 litre and height of fuel tank is 8cm, with flat top roof and cylindrical in shape

Parameters

Estimate the total annual evaporative loss for a vertical fixed-roof tank with the following parameters:

- The tank diameter $DV = 49m$
- The shell height $HS = 0.8m$
- The roof is flat, so $HRO = 0$
d) The average liquid height is $H_S/2$.

f) The tank is painted white and its reflective condition is new.

g) The breather vent pressure/vacuum setting is 0.0 bar

h) The stock is gasoline fuel.

i) The throughput is 750 litres.

j) Stock temperature data is $T_{max}=40^0C$ and $T_{min}=30^0C$.

k) Time of year is April to October.

**Solution**

a) The daily maximum ambient temperature $T_{MAX}=40^0C$

b) The daily minimum ambient temperature $T_{MIN}=30^0C$

The daily average ambient temperature is:

$T_{AVG}=35^0C$

The liquid bulk temperature $T_{LA}$ may be estimated as:

$T_{LA}=35^0C + \Delta T V$

**Standing Loss**

The true vapor pressure $P_{VA}$ at the average liquid surface temperature $T_{LA}$ is

$P_{VA} = .4826$ bar

The vented vapor saturation factor is:

$K_{S} = 1/(1 + 0.053P_{VA} HVO)$

$K_{S} = 1/(1 + 47.54(.48)(.04)) = 0.512$

The stock vapor density is:

$W_{V} = \frac{M_{V} + P_{VA}}{RT_{LA}}$

From calculation we get $W_{V}=1.26$ kg/m$^3$

$KE = \frac{\Delta T_{V}}{T_{LS}} + \frac{4P_{V} - P_{A}}{P_{A} - P_{V}}$

From calculation we get $K_{E}=.556$

The standing loss is:

$LS = 365 \times (\pi D^2/4) HVO KE KS WV$

$LS = (365 \text{ days/yr.})(\pi 0.49^2/4)(.04) (0.556/0.512)(1.26) = 1.39$ Litre

**Working Loss**

Since $\Sigma HQ$ is unknown, $V_Q$ is estimated as:

$Q=Stock throughout$

$V_{Q} = 0.0001698Q = .12735$

$K_{N} = 1.0$

Since the stock is Petrol, $K_{C} = 1.0$

Since no vent setting has been used therefore $K_{B} = 1.0$

The back heat flow from engine and evaporation due to vehicle motion have been taken by factor $K_{O}$, whose value is 2.5.

The working loss is:

$L_{W} = V_{Q} K_{N} K_{C} K_{B} K_{O} W_{V}$

$L_{W} = (16,850,000)(1.0)(1.0)(2.5)(1.0)(1.26) = .557$ litre

**Total Loss**

The total loss $L_{T}$ is the sum of the standing loss $L_{S}$ and the working loss $L_{W}$:

$L_{T} = L_{S} + L_{W}$

$L_{T} = 1.39+.557=1.95$ litre

4. **Graph and Results**
5. Conclusion

Total loss in a year from whole country

It have been estimated that no. of 2 wheelers in while country is more than 11 crore (2012 statistics) and therefore fuel evaporated is about 11,00,00,000X1.95=21,450,000,000 litre of petrol ever year, this value have some serious impacts ,this amount of fuel goes into the atmosphere, causing air pollution, health problems, as petro vapors are big in size therefore they cause asthma and other lung problems. If this amount of fuel could be saved then, the impact on economy of the country and economy of the owner of the vehicle will be overwhelming.

6. Conclusion

The above calculated loss may seem to be less but if the contribution of complete life cycle of a 2 wheeler is taken along with the number of motorbikes, then we can have the bigger picture, and therefore it is necessary to implement control measures.

References

[2] Internal Combustion Engines – V. Ganesan