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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 of fuel increases the rate of evaporation, it is so because 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 de acceleration is high

2.3 Calculation

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

Abbreviations for units

L	Liter
M	meter
Kg	Kilogram
Bar	Bar
^0C	Celsius
Yr	Year

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
LS (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).

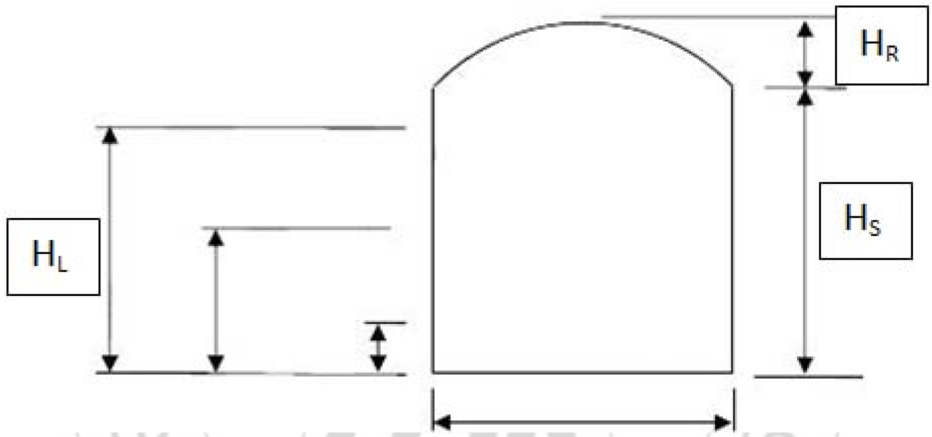


Figure 1: Fuel Tank Geometry

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).

PVA = stock true vapor pressure (Bar) at the average liquid surface temperature TLA

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 $PVA > 0.00698 K_E$ is given by expression:

$$KE = \frac{\Delta T_V}{T_{La}} + \frac{\Delta P_V - \Delta P_B}{P_A - P_{VA}}$$

Where
PVA is stock true vapor pressure (Bar)
Δ*TV* is max and min liquid temperature difference
TLA Daily average liquid surface temperature
Δ*PV* – Δ*PB* is the daily exceedance (bar) of the vapor space pressure range beyond the vent
Setting range

The daily vapor pressure range, ΔP_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:

$$\Delta P_B = P_{BP} - P_{BV}$$

ΔP_B = breather vent range (bar)
P_{BP} = breather vent pressure setting (bar)
P_{BV} = breather vent vacuum setting (bar)
vent valve with no pressure/vacuum
$P_{BP} = 0$
$P_{BV} = 0$

3.2.6 Stock Vapor Density *WV*

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

$$WV = \frac{M_V P_{VA}}{R T_{LA}}$$

Where
MV = stock vapor molecular
PVA is determined in Section 3.2.4
T_{LA} = 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:
$VQ = .0001698Q$
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:
$KN = 1$ for $N < 36$
$KN = (180 + N)/(6N)$ for $N > 36$
Where
The constant 180 has units of turnovers/yr.
N = stock turnover rate (turnovers/yr.
, *N* can be estimated as:
$N = .0001698Q / (\pi D2\ (HLX - HLN)/4)$

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:
$KC = 0.75$ for crude oil
$KC = 1.0$ for refined petroleum stocks
$KC = 1.0$ for single component petrochemical stocks

3.3.5 Vent Setting Correction Factor *KB*

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

If Δ*PB* is significantly greater than ±0.03 psig:
If $K_N \frac{P_{BX} + P_A}{P_O + P_A} < 1.0$
Then $K_B = 1.0$
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:

$$KB = \frac{\frac{P_O + P_A}{K_N} - P_{VA}}{P_{BX} + P_A - P_{VA}}$$

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:
a) The tank diameter *DV* = .49m
b) The shell height *HS* = .08m
c) The roof is flat, so $H_{RO}=0$

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 750 litres.
j) Stock temperature data is $T_{max}=40^0C$ and $T_{min}=30^0C, T_{avg}=35^0C$.
k) Time of year is April to October.

Solution
a) The daily maximum ambient temperature *TMAX* = 40 C
b) The daily minimum ambient temperature *TMIN* = 30°C

The daily average ambient temperature is:
TA= 35°C

The liquid bulk temperature *TB* may be estimated as:
$TLA= 35^0C$
$\Delta TV = 10^0C$

Standing Loss
The true vapor pressure *PVA* at the average liquid surface temperature *TLA*is
PVA =.4826 bar

The vented vapor saturation factor is:
$KS = 1/(1 + 0.053 PVA\ HVO)$
$KS = 1/(1 + 47.54(.48)(.04)) = 0.512$

The stock vapor density is:
$$WV = \frac{M_V P_{VA}}{RT_{LA}}$$

From calculation we get Wv=1.26 kg/m^3

$$KE = \frac{\Delta T_V}{T_{La}} + \frac{\Delta P_V - \Delta P_B}{P_A - P_{VA}}$$

From calculation we get K_E=.556

The standing loss is:
$LS = 365\ (\pi D2/4)\ HVO\ KE\ KS\ WV$
$LS = (365\ \text{days/yr.})(\pi.49^2/4)(.04)\ (0.556/\text{day})(0.512)(1.26) = 1.39$ Litre

Working Loss
Since Σ*HQ* is unknown, *VQ* is estimated as:
Q=Stock throughput
$VQ = 0.0001698Q = .12735$
K_N=1.0
Since the stock is Petrol, *KC* = 1.0
Since no vent setting has been used therefore
KB = 1.0

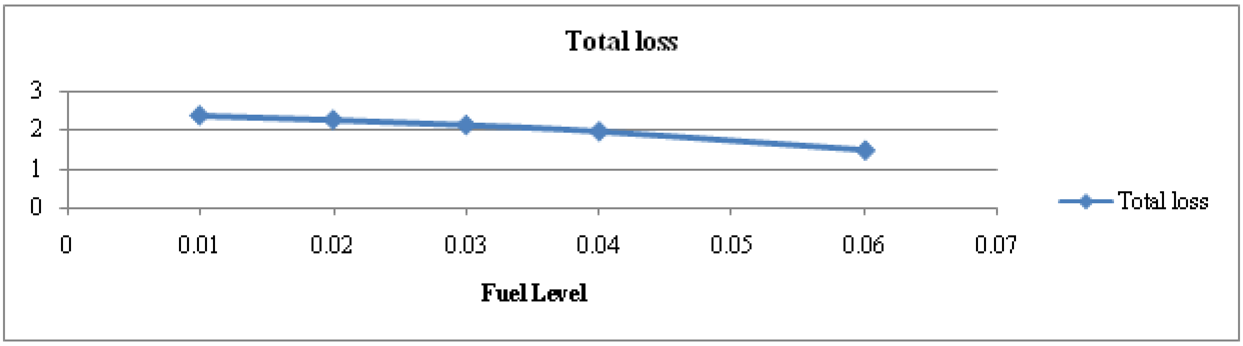
The back heat flow from engine and evaporation due to vehicle motion have been taken by factor K_O, whose value is 2.5

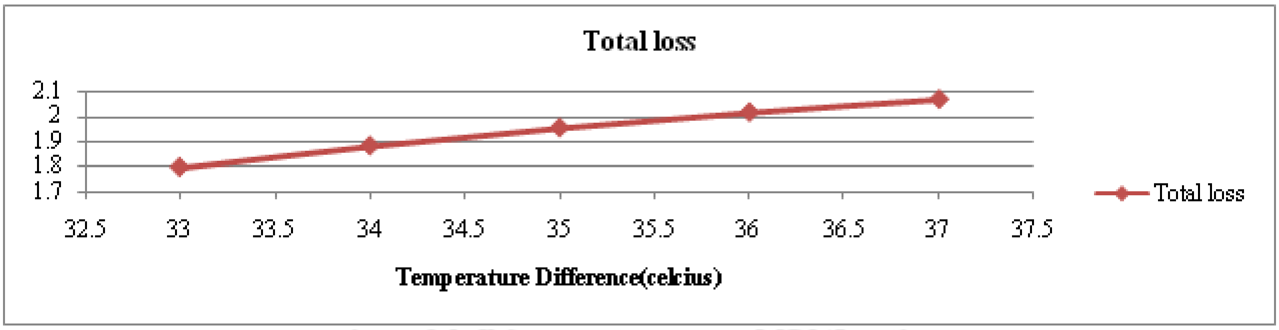
The working loss is:
$LW = VQ\ KN\ KC\ KBK_O WV$
$LW = (16{,}850{,}000)(1.0)(1.0)(2.5)(1.0)(1.26) = .557$ litre

Total Loss
The total loss *LT* is the sum of the standing loss *LS* and the working loss *LW*:
$LT = LS + LW$
$LT = 1.39+.557=1.95$ litre

4. Graph and Results

HS	HL	PVA	STOCI	Kn,	KO	VQ	TMAX	TMIN	TAV(	DELTA	HVO	KS	KE	WV	STANDIN(	WORKING	Total loss
0.08	0.06	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.02	0.685	0.556298	1.26	0.918159	0.557156	1.475315
0.08	0.04	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.04	0.521	0.556298	1.26	1.396937	0.557156	1.954093
0.08	0.03	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.05	0.466	0.556298	1.26	1.559588	0.557156	2.116744
0.08	0.02	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.06	0.421	0.556298	1.26	1.690835	0.557156	2.247991
0.08	0.01	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.07	0.384	0.556298	1.26	1.798972	0.557156	2.356128
HS	HL	PVA	STOCI	Kn,	KO	VQ	TMAX	TMIN	TAV(	DELTA	HVO	KS	KE	WV	STANDIN(	WORKING	Total loss
0.08	0.06	0.4826	750	1	2.5	0.127	44	30	37	0.14	0.02	0.685	0.648962	1.192	1.013202	0.52704	1.540241
0.08	0.04	0.4826	750	1	2.5	0.127	42	30	36	0.14	0.04	0.521	0.603917	1.225	1.474389	0.54168	2.016069
0.08	0.03	0.4826	750	1	2.5	0.127	40	30	35	0.14	0.05	0.466	0.556298	1.26	1.559588	0.557156	2.116744
0.08	0.02	0.4826	750	1	2.5	0.127	38	30	34	0.14	0.06	0.421	0.505878	1.297	1.582809	0.573543	2.156352
0.08	0.01	0.4826	750	1	2.5	0.127	36	30	33	0.14	0.07	0.384	0.452402	1.336	1.551656	0.590923	2.142579





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.

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