IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 5, Oct-Nov, 2014
ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

Development Of Oil Mist Separator And Evaluation With Oil Droplet Diameter Using Multiphase Simulation For Diesel Engine

Mr. Mangesh B. Dusane[1], Dr.M.R.Nandgaonkar[2]

[1]Mechanical engineering Depatment, College of Engineering, Pune, India.
[2]Associate Professor, Mechanical engineering Department, College of Engineering, Pune, India

Abstract— ***In crankcase ventilation system, the blow-by gases from the crankcase are routed to the intake manifold through Oil separator system. Both current exhaust emissions and continuously growing customer demand of less oil consumption drive the diesel engine manufacturer to develop more efficient crankcase ventilation and oil separation system. The oil carry over will ultimately affects the oil change interval and emission contents. The range of oil carry over nowadays followed is in between 0.2 to 0.4 g/hr. while designing, the various factors like cost, space, effect on the engine parameters, feasibility and reliability of the system are to be taken into consideration. At the same time, the crankcase pressures are taken into consideration as it will decide the life of all type of seals in the internal combustion engine. The feasible oil separators are modelled and with the help of 2-phase CFD using CFX software simulations are completed. The achieved target for oil carry over is reduced from 1.1 to 0.2 g/hr. The two phase i.e. Gas and oil, mixture CFD simulation for the percentage efficiency calculation at various blow by rates and its effectiveness at oil droplet diameters ranging from 1micron to 10 microns is done. Effect of oil droplet diameters on separation efficiency is calculated. Various calculations and results will show the optimum oil carry over for specified blow by rates. Certain assumptions made during simulation process as standard. Base oil carryover of engine separation system is compared with the modelled oil separators, which will give the better understanding of the efficiency of modelled system.***

Index Terms— ***CFD-Computational fluid dynamics, OMS-Oil mist separator.***

I. INTRODUCTION

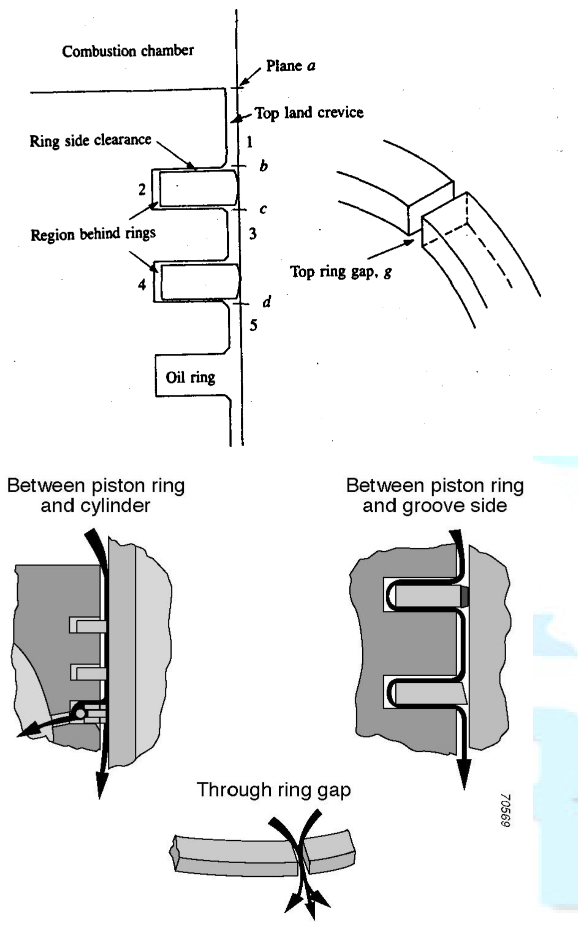
The objective of the diesel engine development is not only limited up to its performance, Efficiency but also related to meet current stringent emission norms applicable. Concentrating on the unburned emissions is more focused than that of the burnt gases. CO, HC, NOx and PM are the major contributor of emissions in Diesel engine. At the same time, control of NOx and PM is very difficult as they are dependent on each other. Increase of NOx will result in reduced PM and vice versa. So, either each one of the above has to be controlled during development phase. Oil is a major source of PM emissions. This oil contributes because of continuous flow of oil required for cooling purpose. The Blow by gas is results of the Piston ring gap. Combustion leaked gases from Piston rings to Crankcase are called as Blow by gases. Continuous leaked combustion gas flow into the crankcase will result in Pressured Crankcase. This Pressure relief is previously done by opening crankcase into the atmosphere called as Open crankcase ventilation system. This blow-by gases contains unburned gases, which are harmful to the atmosphere. Due to stringent emission norms, these gases cannot be sent to atmosphere. The origin of closed crankcase ventilation comes into picture. In closed crankcase ventilation system, these blow-by gases are sent back to intake system. The proposal for sending them to exhaust directly cannot be sophisticated, as it will further lead in increasing PM emissions.

The percentage of soluble organic fraction within particulates has increased to reach close to 50%. So, the reduction of oil consumption is an important subject today. Another challenge in the smaller engines is packaging boundary conditions and draining oil back to the sump. Since no standard validation procedure available in worldwide for blow by evaluation in engine, special validation setup and procedure to be established based on blow by forming mechanism and behavior of components at various operating conditions.

The crankcase of a combustion engine accumulates gases and oil mist called Blow by gases that can leak from several sources. Most of the combustion blow by occurs when the combustion pressure reaches to its maximum value, during its compression and expansion strokes. At high pressures, The gases leak to the crankcase around the piston rings and through piston ring gaps. Other important source includes the Turbocharger shaft, Air compressors and in some cases the valve stems. In total, these components can be responsible for as much as 30 – 40 % of the crankcase blow by. Crevice volume is major origin to the blow by gases.

A. Blow by mechanism

Crankcases in reciprocating engines have to be ventilated, because gases from the combustion chamber flow past the piston rings into the crankcase (blow-by). In addition, periodic volume changes in the crankcase caused by the kinematics of the crank mechanism must also be compensated. The piston movement produces high gas velocities inside the crankcase. Oil droplets are carried along by the gas, thus penetrating into the crankcase ventilation system. [1]



(a) Crevice volumes in the Piston rings

The major role is played by the Blow by gases. The mechanism of generation of the blow by gases is due to crevice volume. Gas flows into and out of these volumes during the engine operating cycle as the cylinder pressure changes. As the cylinder pressure rises during compression, unburned mixture or air is forced into each crevice region. Since these volumes are thin they have a large surface/volume ratio; the gas flowing into the crevice cools by heat transfer to close to the wall temperature. During combustion while the pressure continues to rise, unburned mixture or air, depending on engine type, continues to flow into these crevice volumes. After flame arrival at the crevice entrance, burned gases will flow into each crevice until the cylinder pressure starts to decrease. Once the crevice gas pressure is higher than the cylinder pressure, gas flows back from each crevice into the cylinder. The volumes between the piston, piston rings, and cylinder wall are shown schematically in Figure**.** These crevices consist of a series of volumes (numbered 1 to 5) connected by flow restrictions such as the ring side clearance and ring gap. The geometry changes as each ring moves up and down in its ring groove, sealing either at the top or bottom ring surface. The gas flow, pressure distribution, and ring motion are therefore coupled.

During compression and combustion, the rings are forced to the groove lower surfaces and mass flows into all the volumes in this total crevice region. The pressure above and behind the first ring is essentially the same as the cylinder pressure. There is a substantial pressure drop across each ring, however. Once the cylinder pressure starts to decrease gas flows out of regions 1 and 2 in Figure 1.1 into the cylinder, but continues to flow into regions 3, 4, and 5 until the pressure in the cylinder falls below the pressure beneath the top ring. The top ring then shifts to seal with the upper grove surface and gas flows out of regions 2, 3, and 4 (which now have the same pressure), both into the cylinder and as blow by into the crankcase. Some 5 to 10 percent of the total cylinder charge is trapped in these regions at the time of peak cylinder pressure. Most of this gas returns to the cylinder; about 1 percent goes to the crankcase as blow by. The gas flow back into the cylinder continues throughout the expansion process [1]. Normally, Blow by gases are 1-3% of the total volume and in the range of 40 to Maximum 150 lit/min (lpm). Measured Ring gap of the piston rings is ranging from 30 – 60 microns. Optimizing its ring gap is very difficult task as it is related to the Thermal expansion of the rings during combustion process.

B. Blow by characteristics

Until 1980,the blow by gases were evacuated by crankcase vent system to atmosphere. Because of the environmental concerns, the vehicle emission regulations changed and since then they are evacuated and has to be recirculated.

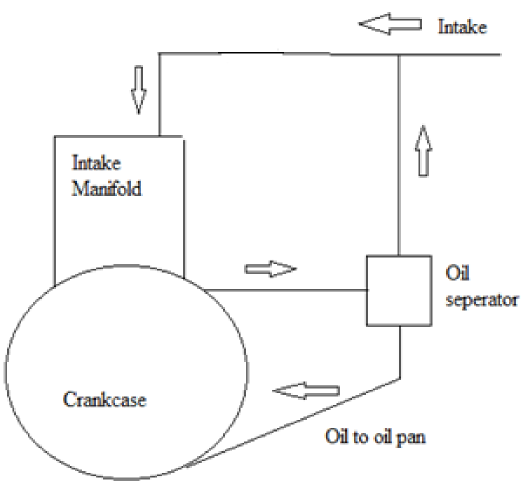
Recycling of blow by in the engine has several drawbacks associated because of presence of Oil mists:

1. *Fouling of the compressor*
2. *Catalyst poisoning*
3. *Disturbance of flow meter measurement*
4. *Increasing exhaust pollution, Blow by gases represent 20 – 30 % hydrocarbon in exhaust*
5. *Deposits in intercooler to intake valves*

In year 2000, legislations changed and it became further stringent. Therefore the blow by treatment must required before reinjection them into intake system. Filtration of the blow by gases has given further scope to control on the oil mist and diesel soot particles [2].

C. Oil separation system

It is also called as Positive crankcase Ventilation (PCV) system. PCV system consist of the area from which the blow by enters i.e. crankcase to the intake system where it is again fed to the combustion chamber. The blow-by gases will carry oil mist from chain cover through baffle plate and then to the oil separator. The oil separator will separate the oil mist with condensation into the droplets and return it to the oil sump through oil drain pipe. The blow-by with filtrated oil will passed to suction and then in the intake manifold. Due to pressure difference between the crankcase and the suction pressure after air filter, the crankcase gases will be sucked into the intake system.



(b) Closed crankcase ventilation system

D. Need of Efficient PCV system

There are certain parameters which are essential before study and optimization of PCV system. It is directly related to the emission parameters and Lube oil consumption.

a. Emission parameters

Blow by gases contains combustion products like HC, CO, NOx, PM which are regulated pollutants. In addition to that there is presence of Oil mist formed in crankcase due to regular dynamic motion of components and temperatures during cooling of engine. This oil if not separated from the blow by, directly goes to intake system and lead to significant contributor of PM emissions. It can lead maximum up to 20 % PM emissions which itself is very high value.

Nowadays, To reduce NOx emissions, EGR introduction is must and easiest way to achieve it. Due to high EGR rates, the Carbonate percentage in blow by further increases and lead to high viscous lube oil and reduced oil change interval. This has to be other difficulty while designing the filter associated with PCV system.

b. Lube oil consumption

The oil mist generated in crankcase during motion contains Lube oil droplets size ranging from 0.2-0.4 to 10 microns. During separation, this lowest particle size has to be taken into consideration. It is difficult to separate fine particles as any of the system incorporated for separation is not as efficient as it will fully clean the blow by from oil mist. Oil mist, which is not separated, will part of intake air and will combust in combustion chamber. So, it will consume more oil and ultimately increase oil change interval for Internal combustion engine [2].

E. Engine manufacturers requirements

The engine manufacturer's oil mist separation need is increasing (Table 1). The maximum allowed for oil carryover after separation system was around 1 to 1.5 g/h a few years ago and is now 0.2 to 0.5 g/h. This level of oil carry over has to be reached for any engine working conditions. It means that at idle, efficiency ha s to be 0 to 66% on an oil mist mean size of 1.2 micron. But it also means that efficiency has to be 75 to 95% at maximum horsepower working condition on an oil mist mean size distribution of 0.4 micron.

(1) Requirement of passenger car engines

Engine manufacturer	Oil carry over	Efficiency at max power	Crankcase pressure range
N 1 (Diesel)	0.5 to 1 g/h	75 to 87 %	-25 mbar to -5 mbar
N 2 (Diesel)	1 g/h	75 %	-20 mbar to 0 mbar
N 3 (Diesel & petrol)	0.2 to 1.5 g/h	70 to 95 %	-25 mbar to -5 mbar
N 4 (Diesel & petrol)	0.25 g/h	88 %	-25mbar to o mbar

On classical engine, Crankcase pressure is equal to intake pressure to separation system pressure drop. On Diesel engines, intake pressure is near zero at idle speed and low rotational speeds. As customers require that crankcase pressure remains below + 5 mbar, it means that separators pressure drop has to be lower than 5 mbar at idle and lower speeds but can have higher restriction at maximum horsepower condition. Pressure control valve (PCV) is required to avoid crankcase pressure below -20 to -25 mbar[2].

F. Types of oil mist separators

Before the development of the oil separator, it is necessary fact that what the kind of separation systems available are? There are various types of separation systems available which are evolved from industrial uses to automotive purpose. The selection criteria depends on the separation efficiency and the conditions of separation.

a. Cyclone separators

Basic principle behind the separation is centrifugal force occurring in eddy flow. Inexpensively manufactured and has least pressure drop across the system.

b. Fabric separators

Knitted steel fabric wires are used and blow by gases are allowed to go through this fabric. Large Diameter droplets are separated easily. Staple fiber nonwovens are also used for separation. It causes pressure drop across the system.

c. Diffusion Filters

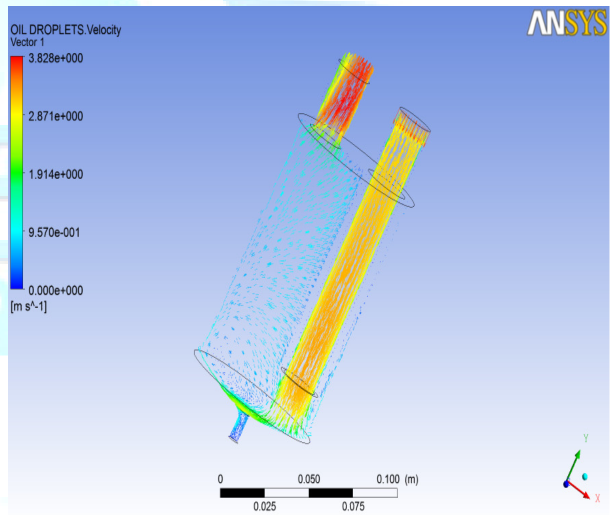
These are saturated filters and can be replaceable after certain maintenance routine [3].

G. Constraints while development of OMS system

There are many constraints which are to be considered while developing the oil mist separator. Main constraint is space associated with existing engine taken into consideration. The layout of inlet and return line is to be taken into account. The oil separated is circulated back to the oil sump for its further recirculation. Oil separator oil outlet is decided to locate above the oil level or below the oil level on the basis of the separator design. If not maintained as per specification, substantial oil through is seen from all feasible sources of leakage. The Oil separator gas outlet is located after the air filter and before the compressor in the turbocharged engine. The advantage of the system is that, the suction effect from intake system, automatically evacuate the crankcase blow by gases and helps in maintaining the crankcase always in negative pressures. The leak proof design is always preferable for OMS system. Any void opening will definitely affects the oil carry over in the engine, as it is always directly related to pressure differences. Void opening will result of atmosphere pressure interference in the system.

II. . DEVELOPMENT OF OIL SEPARATOR SYSTEM

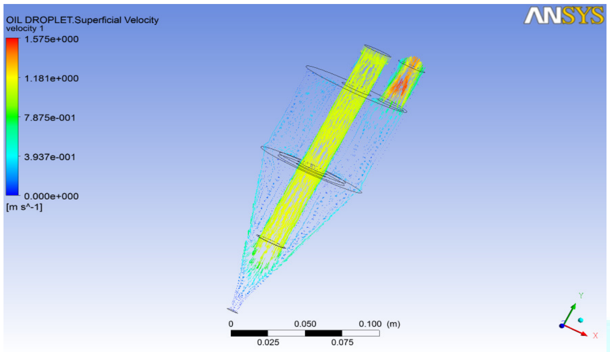
All constraints and criteria taken into consideration, we developed a sequential models for simulation and finally reach towards the efficient oil separator design for range of blow by flow rate. The separation principle of oil separator is impaction of oil droplets on the surface and maximum turbulence occurrence during the flow. So initially, considering these two fundamentals we arrived at the simple bottle type space constraint oil separator (Cylindrical separator). It is having one inlet and other outlet pipes in it as shown in Figure 3.



(c) Oil droplet velocity vectors for cylindrical separators

The inlet pipe is designed in such a way that the flow of blow by gases directly impacted on the surface and then turning 180 degree flows towards the outlet. The impaction of gas itself separating the oil droplets because of gravity forces and high dense fluid itself get separated from the low dense gases

Further turning of blow by flow will ease the separation phenomenon. In this process the least diameter droplets ranging from 0.1 to 0.4 micron are not efficiently separated and carried over by the gases. To avoid these, the further tuning in the model was required. The only way to do that is introduction of turbulence effect in the flow. This turbulence was achieved with the help of conical convergent at the downstream of the separator shown in Figure 4. It implements the convergence affect and higher pressure drop in the impaction area. The results obtained in the CFX multiphase simulation gives the better idea of the differences obtained between the different models.



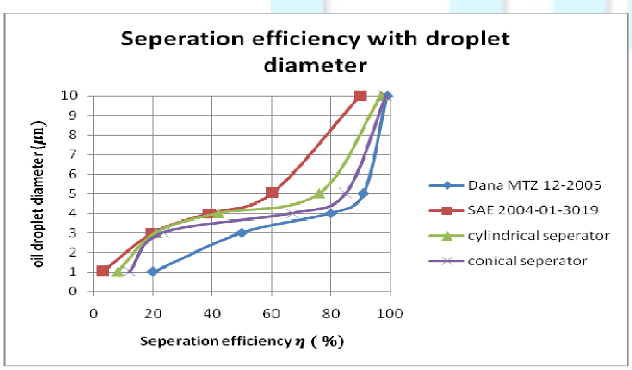
(d) Oil droplet velocity vectors for conical separators

It was further studied that whether there is possibility of obtaining more efficient system. It was tried with further baffle plate adoption in between. But because of high pressure drops, velocity of impaction changes the whole scenario and results in higher carry over.

III. RESULTS AND DISCUSSIONS

The modeled oil separators are simulated using Ansys CFX software. The separators are modeled using Pro-E software and meshed using ICEM software. During simulation, the blow by gases properties inclusive of lubrication oil properties considering in its mist form are properly taken and various research papers are studied for the boundary conditions. Each modeled separator is simulated for 1, 3, 4,5,10 micron oil droplet diameters.

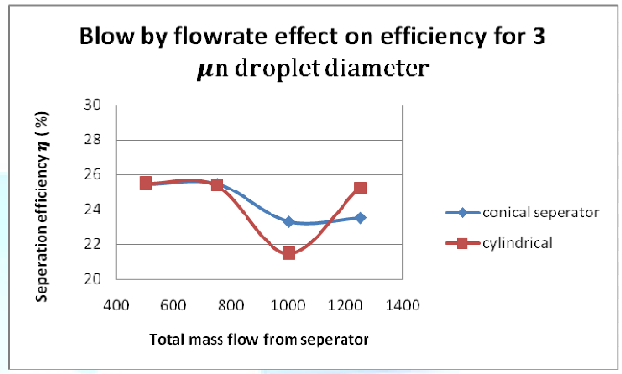
The separation efficiency calculation is done and been discussed in annexure. The efficiency of separation v/s oil droplet diameter is plotted shown in figure below. It was compared with two different research papers. Dana separator figures were obtained from MTZ journal [2]. The other resource was from SAE paper from year 2004 [3].



(e) seperation efficiency v/s Droplet Diameter

More the droplet diameter, more will be the separation. It is difficult to predict the percentage of the oil of specific droplet diameter in blow by gases at the entry of the separator.

The stability of the efficiency of separation is carried out for 3 micron droplet diameter is shown in figure below. It is observed that for variable blow by flow rate, conical type of separator is more stable.



(e) Total mass flow v/s Seperation efficiency

IV. CONCLUSIONS

The new modeled conical separator can be opted because of the best results obtained. The separator is simple in design and very reliable considering the all constraints. Only need of Pressure relief valve to be applied for idle condition of the engine to maintain the crankcase pressure. There is no such maintenance required periodically. The same configuration of separator can be applicable to different blow by flow engines. Calculated oil carry over for the conical separator is considered as least value. The separation efficiency is comparable with other oil mist separators.

REFERENCES

[1]. J.B. Heywood, ”Internal combustion engine “
[2]. Christophe G et al., “Blow by gases Coalescing Separation – Performances of the Rotating Solution”, SAE paper no. 2011-01-0409, 2011
[3]. Krause W, et al., “Oil separation in crankcase Ventilation – New concepts through system analysis and measurements”, SAE paper no.950939, 1995
[4]. Dr Pedro B. et al., “Air/oil separator with minimal space requirement in the crankcase venting system”, MTZ worldwide, volume 66, 2005
[5].Sydney T et al., “Prediction of the efficiency of an automotive oil separator: Comparison of Numerical Simulations with experiments”, SAE paper no. 2004-01-3019, 2004

Mangesh Dusane, Student of M.Tech (Automotive Technology), College of engineering, Pune, B..E. (Mechanical Engineering)Fr. C.R.I.T, Vashi

Dr. M.R. Nangaonkar, Associate Professor, College of Engineering, Pune, P.h.D in I C engines.