International Letters of Chemistry, Physics and Astronomy
ISSN: 2299-3843, Vol. 48, pp 37-49
doi:10.18052/www.scipress.com/ILCPA.48.37

Online: 2015-03-25

Engine enhancement using enriched oxygen inlet

P. Shivakumar Singh*

Dept. of PG Studies and Research in Botany, MVS Govt. UG & PG College,
Mahabubnagar - 509001. Telangnana, India

*E-mail address: shivakumarsinghp@gmail.com

ABSTRACT

An internal combustion engine essentially requires a fuel which must have sufficient calorific value to produce enough power, and oxygen for the combustion of fuel. In normal vehicles fuel will be supplied from a fuel tank equipped with it. And oxygen will be taken from the atmospheric itself. Under normal conditions the percentage of oxygen present in atmospheric air will be around 21% of the total volume.

Studies shows that by increasing the oxygen percentage in the inlet air increases engine performance and reduces emission produced by the engine.

Keywords: Nitrogen oxides; Carbon monoxide; Hydro carbon; Engine enhancement

1. INTRODUCTION

Today the most important things to take care of while designing an engine are,

- Performance
- Emission characteristics

The Emission in the case of IC engines are mainly due to

1. NOx
2. CO
3. HC
4. Carbon soot particle

1.1. Nitrogen oxides (NO_x)

Nitrogen oxides emission is one of the most important emission that must be take care of. The main cause of NO_x emission in engine is because of the engine temperature during the working (combustion of fuel). When the combustion takes place, temperature inside the engine cylinder increases rapidly, this reaches a high temperature that meets the requirement for the breaking of strong triple covalent bond of Nitrogen (N_2). At high temperatures, usually above 1600 °C (2900 °F), molecular nitrogen (N_2) and oxygen (O_2) in the combustion air disassociate into their atomic states and participate in a series of reactions.
The three principal reactions producing thermal NO_x are:

$$N_2 + O \rightarrow NO + N$$

$$N + O_2 \rightarrow NO + O$$

$$N + OH \rightarrow NO + H$$

1.2. Carbon monoxide (CO)

Carbon monoxide is mainly produced due to the incomplete combustion of fuel, which is the result of lack of enough oxygen inside cylinder.
The reaction can be represented as,

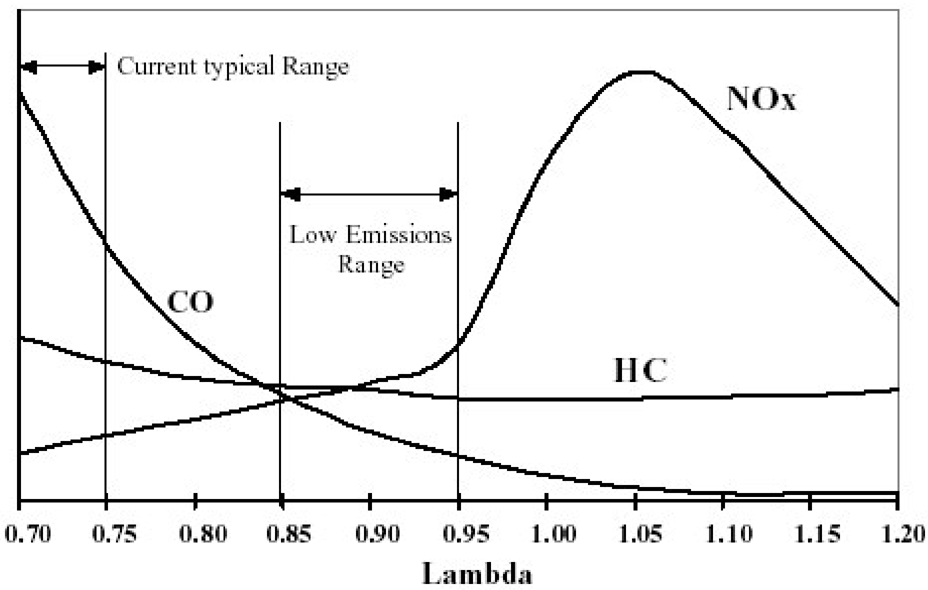
$$C_2 + \frac{1}{2} O_2 \rightarrow CO$$

1.3. Hydro carbon (HC)

Hydro carbon is actually the fuel that we use to run the engine. When the fuel is escaped to atmosphere without combustion it contribute to the engine emission.

1.4. Carbon soot particles

Carbon soot particles are also produced due to incomplete combustion, which mean due to the lack of enough oxygen



2. COMBUSTION

Combustion or burning is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. The release of heat can produce light in the form of either glowing or a flame. Fuels of interest often include organic compounds (especially hydrocarbons) in the gas, liquid or solid phase.

According to the byproducts produced the combustion can be broadly classified in to two Complete and Incomplete combustion

2.1. Complete combustion

In complete combustion, the reactant burns in oxygen, producing a limited number of products. When a hydrocarbon burns in oxygen, the reaction will primarily yield carbon dioxide and water. When elements are burned, the products are primarily the most common oxides. Carbon will yield carbon dioxide, sulfur will yield sulfur dioxide, and iron will yield iron (III) oxide. Nitrogen is not considered to be a combustible substance when oxygen is the oxidant, but small amounts of various nitrogen oxides (commonly designated NOx species) form when air is the oxidant. Combustion is not necessarily favorable to the maximum degree of oxidation, and it can be temperature-dependent. For example, sulfur trioxide is not produced quantitatively by the combustion of sulfur. NOx species appear in significant amounts above about 2,800 °F (1,540 °C), and more is produced at higher temperatures. The amount of NOx is also a function of oxygen excess.

2.2. Incomplete combustion

In most industrial applications and in fires, air is the source of oxygen. In air, each mole of oxygen is mixed with approximately 3.71 mol of nitrogen. Nitrogen does not take part in combustion, but at high temperatures some nitrogen will be converted to NOx (mostly NO, with much smaller amounts of NO. On the other hand, when there is insufficient oxygen to completely combust the fuel, some fuel carbon is converted to carbon monoxide and some of the hydrogen remains unreacted. A more complete set of equations for the combustion of a hydrocarbon in air therefore requires an additional calculation for the distribution of oxygen between the carbon and hydrogen in the fuel. Thus the incomplete combustion produces all the unwanted emissions.

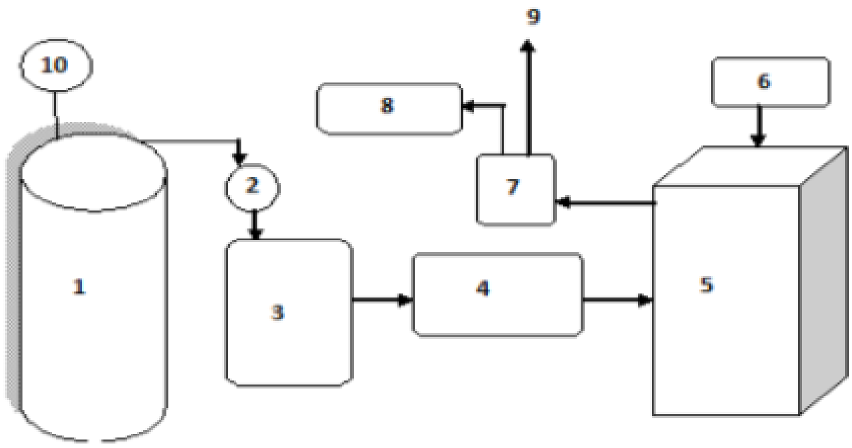
The only way to make sure that only complete combustion takes place is by providing only Oxygen in to the intake system of engine. By that way the fuel get enough oxygen to react with and hence complete combustion takes place.

3. LITERATURE SURVEY

Bharath.P [1] ***et al*** studied about break thermal efficiency and oxygen in exhaust using oxygen enriched air in CI engines. They had done on their experiments on a compression ignition engine by providing various percentage of oxygen at the inlet varying from 21% to 27% with an interval of 2%. The basic concept which lead them to this experiment is that enriched oxygen inlet will result in better engine performance and reduced emissions.

In a normal engine it will be running on atmosphere air inlet which contains 78% of nitrogen which might produce pollutant like NOx. On increasing the percentage oxygen actually the percentage of nitrogen get reduced and that might result in reduced NOx emissions. As the oxygen percentage increases it advances the complete combustion process. And it will further results in reduced carbon monoxide and hydrocarbon emissions.

Experimental setup consists of a single cylinder, naturally aspirated, air cooled, and constant speed Greaves engine, an eddy current Dynamometer was used as the Loading device and a Krypton gas analyzer was used for the study of the exhaust gases.



(1) Oxygen cylinder; (2) Flow meter; (3) Flame trap; (4) Engine; (5) Engine; (6) Loading Device; (7) Exhaust gas; (8) Krypton gas analyzer; (9) To Atmosphere

And they have concluded on the following points,

- Brake thermal efficiency at low loads for enriched oxygen intake increases the brake power compared to the normal air intake but when load increases the Brake power remains normal.
- Fuel consumption rate decreases for higher oxygen percentage in the intake air.
- The amount of fuel consumed for unit brake power is high at minimum load, and reduces when the load increases and this happens for all oxygen percentages in the intake air.
- Oxygen which is coming out of the exhaust also increases with respect to the percentage of oxygen in the intake air but the percentage of oxygen burnt inside the cylinder increases with respect to the supplement of oxygen inducted into the cylinder.
- CO drops a very high percentage with respect to oxygen induction in the intake as oxygen helps in better combustion.

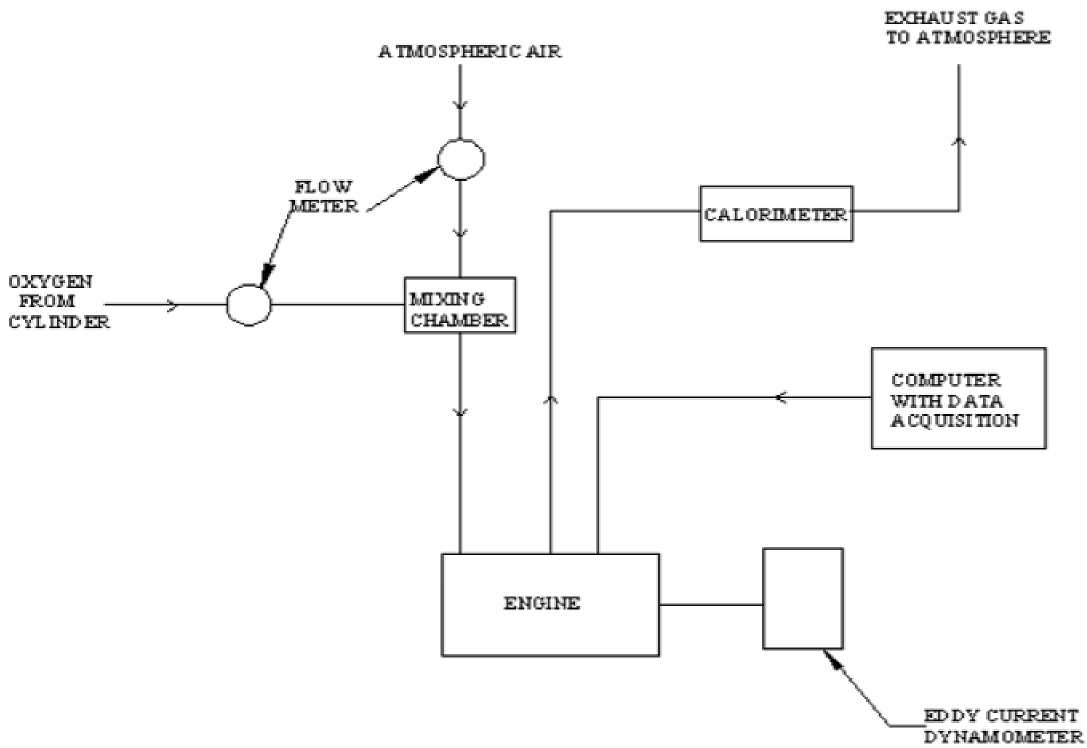
K RAJKUMAR [2] ***et al*** had done several experiments on single cylinder diesel engine by providing oxygen enriched air inlet. Increasing the oxygen content with the air leads to faster burn rates and the ability to burn more fuel at the same stoichiometry. Added oxygen in the combustion air leads to shorter ignition delays and offers more potential for burning diesel. Oxy-fuel combustion reduces the volume of flue gases and reduces the effects of greenhouse effect also. Engine test has been carried out in the above said engine for different loads and the following combustion parameters like Ignition delay, Combustion duration, Heat release and Cylinder pressure was discussed in this.

They have provided enriched oxygen by using a oxygen cylinder which mixes with the current air. For that purpose a small mixing chamber was provided before inlet manifold. Then oxygen enriched air was compared with different load with different level of oxygen enrichment to evaluate the combustion parameters.

Experimental setup:

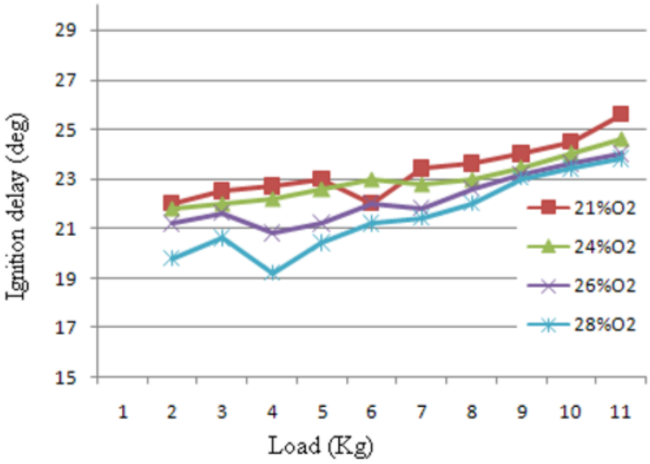
MAKE	Kirloskar
BHP	5HP
SPEED	1500 to 2000 rpm, governed speed of 1500 rpm for CI operation
No. OF CYLINDERS	One
COMPRESSION RATIO	17:1
BORE	80 mm
STROKE	110 mm
TYPE OF IGNITION	Cpmpression Ignition
METHOD OF LOADING	Eddy Current Dynamometer
METHOD OF STARTING	Manual Crank Start
METHOD OF COOLING	Water

Working diagram

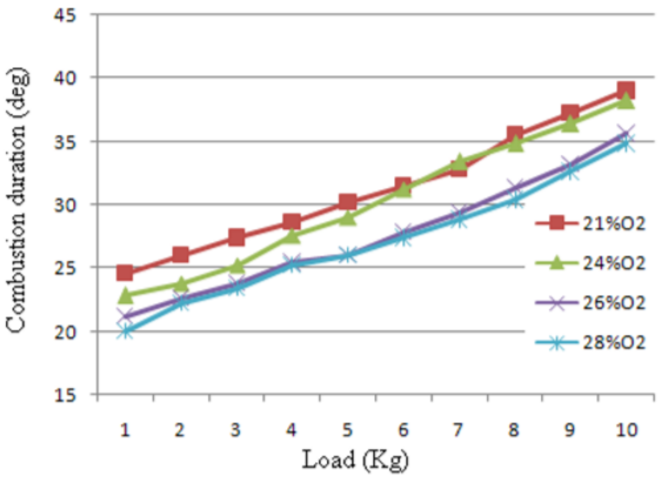


Results and discussions

	Ignition delay (deg)			
Load	21%O2	24%O2	26%O2	28%O2
1	22	21.8	21.2	19.8
2	22.5	22	21.6	20.6
3	22.7	22.2	20.8	19.2
4	22	22.6	21.2	20.4
5	19.8	23	22	21.2
6	23.4	22.8	21.8	21.4
7	23.6	23	22.6	22
8	24	23.4	23.2	23
9	24.5	24	23.6	23.4
10	25.6	24.6	24	23.8



	Combustion duration (deg)			
Load	21%O2	24%O2	26%O2	28%O2
1	24.6	22.8	21.2	20
2	26	23.8	22.6	22.2
3	27.4	25.2	23.8	23.4
4	28.6	27.6	25.4	25.2
5	30.2	29	26	26
6	31.5	31.2	27.8	27.4
7	32.8	33.4	29.4	28.8
8	35.5	34.8	31.4	30.4
9	37.2	36.4	33.2	32.6
10	39	38.2	35.6	34.8



- A maximum of 6% decrease in ignition delay period was obtained for the enrichment level of 28% Oxygen.
- An average increase of 50% in the heat release can be obtained from the oxygen enriched combustion technology for the enrichment level of 28%.
- 12% increase in peak pressure was obtained for the maximum level of oxygen enrichment.
- An average decrease of 8% to 23% in combustion duration for the enrichment range of 24% to 28% of Oxygen

WHY NOT USING AN OXYGEN CYLINDER

One of the effective way to provide complete combustion is by providing an additional oxygen cylinder with in the engine.

So why don't cars carry around pure oxygen? The problem is that oxygen is pretty bulky, even when you compress it, and an engine uses a LOT of oxygen. A gallon of gasoline weighs 6.2 pounds, so the engine needs 86.8 pounds of oxygen (6.2 x 14) per gallon of gasoline. Oxygen is a gas, so it is extremely light. One pound of oxygen fills 11.2 cubic feet of space, so a gallon of gasoline needs 972.16 cubic feet of oxygen to go with it. If your gas tank holds 20 gallons of gasoline, you would have to carry almost 20,000 cubic feet of oxygen with it! This is a lot of oxygen - so much that it would fill a 2,500 square foot house.

Even if you compress the oxygen to 3,000 psi (pounds per square inch), it will still take 100 cubic feet to store it. To put that into perspective, a standard scuba tank holds about 80 cubic feet of gas, so it would take 250 scuba tanks to hold all that oxygen.

Because oxygen is so bulky, what people use instead is nitrous oxide. In the engine, nitrous oxide turns into nitrogen and oxygen, and it's the oxygen that people are after. Nitrous oxide easily liquefies under pressure, so you can store a lot more of it in a bottle than you can gaseous oxygen, which does not liquefy. Even so, a typical system will supply only one to three minutes of nitrous to the engine. In the process, it adds about 100 horsepower to a typical big block engine. The biggest problem is that the extra gasoline that the nitrous allows in the cylinder increases pressure in the engine so much that it can do some real damage, unless the engine is designed to handle it. That would be the same problem you would have with an engine breathing pure oxygen. It would have to be quite beefy to handle the load.

Separation of Oxygen from atmospheric air

We know that proving an oxygen cylinder along with the engine is not economic, hence the only way is by proving oxygen from atmosphere itself.

Table 1. Composition of air.

Standard Dry Air Composition:				
Gas	% by Volume	% by Weight	Parts per Million (V)	Chemical Symbol
Nitrogen	**78.08**	**75.47**	**780805**	$\mathbf{N_2}$
Oxygen	**20.95**	**23.20**	**209450**	$\mathbf{O_2}$
Argon	**0.93**	**1.28**	**9340**	**Ar**
Carbon Dioxide	0.039	0.0606	390	CO_2
Neon	0.0018	0.0012	18.21	Ne
Helium	0.0005	0.00007	5.24	He
Krypton	0.0001	0.0003	1.14	Kr
Hydrogen	0.00005	Negligible	0.50	H_2
Xenon	8.7×10^{-6}	0.00004	0.087	Xe

There is two methods to separate oxygen from atmospheric air

Cryogenic liquefaction process

Pure gases can be separated from air by first cooling it until it liquefies, then selectively distilling the components at their various boiling temperatures. The process can produce high purity gases but is energy-intensive. This process was pioneered by Dr. Carl von Linde in the early 20th century and is still used today to produce high purity gases. The cryogenic separation process requires a very tight integration of heat exchangers and separation columns to obtain a good efficiency and all the energy for refrigeration is provided by the compression of the air at the inlet of the unit.

To achieve the low distillation temperatures an air separation unit requires a refrigeration cycle that operates by means of the Joule–Thomson effect, and the cold equipment has to be kept within an insulated enclosure (commonly called a "cold box"). The cooling of the gases requires a large amount of energy to make this refrigeration cycle work and is delivered by an air compressor. Modern ASUs use expansion turbines for cooling; the output of the expander helps drive the air compressor, for improved efficiency. The process consists of the following main steps:

1. Before compression the air is pre-filtered of dust.

2. Air is compressed where the final delivery pressure is determined by recoveries and the fluid state (gas or liquid) of the products. Typical pressures range between 5 and 10 bar gauge. The air stream may also be compressed to different pressures to enhance the efficiency of the ASU. During compression water is condensed out in inter-stage coolers.

3. The process air is generally passed through a molecular sieve bed, which removes any remaining water vapor, as well as carbon dioxide, which would freeze and plug the cryogenic equipment. Molecular sieves are often designed to remove any gaseous hydrocarbons from the air, since these can be a problem in the subsequent air distillation that could lead to explosions. The molecular sieves bed must be regenerated. This is done by installing multiple units operating in alternating mode and using the dry co-produced waste gas to desorb the water.

4. Process air is passed through an integrated heat exchanger (usually a plate fin heat exchanger) and cooled against product (and waste) cryogenic streams. Part of the air liquefies to form a liquid that is enriched in oxygen. The remaining gas is richer in nitrogen and is distilled to almost pure nitrogen (typically < 1ppm) in a high pressure (HP) distillation column. The condenser of this column requires refrigeration which is obtained from expanding the more oxygen rich stream further across a valve or through an Expander, (a reverse compressor).

5. Alternatively the condenser may be cooled by interchanging heat with a re-boiler in a low pressure (LP) distillation column (operating at 1.2-1.3 bar abs.) when the ASU is producing pure oxygen. To minimize the compression cost the combined condenser/re-boiler of the HP/LP columns must operate with a temperature difference of only 1-2 degrees Kelvin, requiring plate fin brazed aluminum heat exchangers. Typical oxygen purities range in from 97.5% to 99.5% and influences the maximum recovery of oxygen. The refrigeration required for producing liquid products is obtained using the JT effect in an expander which feeds compressed air directly to the low pressure column. Hence, a certain part of the air is not to be separated and must leave the low pressure column as a waste stream from its upper section.

6. Because the boiling point of argon (87.3 K at standard conditions) lies between that of oxygen (90.2 K) and nitrogen (77.4 K), argon builds up in the lower section of the low

pressure column. When argon is produced, a vapor side draw is taken from the low pressure column where the argon concentration is highest. It is sent to another column rectifying the argon to the desired purity from which liquid is returned to the same location in the LP column. Use of modern structured packing's which have very low pressure drops enable argon purities of less than 1 ppm. Though argon is present in less to 1% of the incoming, the air argon column requires a significant amount of energy due to the high reflux ratio required (about 30) in the argon column. Cooling of the argon column can be supplied from cold expanded rich liquid or by liquid nitrogen.

7. Finally the products produced in gas form are warmed against the incoming air to ambient temperatures. This requires a carefully crafted heat integration that must allow for robustness against disturbances (due to switch over of the molecular sieve beds). It may also require additional external refrigeration during start-up.

8. The separated products are sometimes supplied by pipeline to large industrial users near the production plant. Long distance transportation of products is by shipping liquid product for large quantities or as Dewar flasks or gas cylinders for small quantities.

2. Non-cryogenic processes

Pressure swing adsorption provides separation of oxygen or nitrogen from air without liquefaction. The process operates around ambient temperature; a zeolite (molecular sponge) is exposed to high pressure air, then the air is released and an adsorbed film of the desired gas is released. The size of compressor is much reduced over a liquefaction plant, and portable units can be made to provide oxygen-enriched air for medical purposes. Vacuum swing adsorption is a similar process, but the product gas is evolved from the zeolite at sub-atmospheric pressure.

Membrane technologies can provide alternate, lower-energy approaches to air separation. For example, a number of approaches are being explored for oxygen generation. Polymeric membranes operating at ambient or warm temperatures, for example, may be able to produce oxygen-enriched air (25-50% oxygen). Ceramic membranes can provide high-purity oxygen (90% or more) but require higher temperatures (800-900 dig C) to operate. These ceramic membranes include Ion Transport Membranes (ITM) and Oxygen Transport Membranes (OTM). Air Products and Chemicals Inc. and Praxair are developing flat ITM and tubular OTM systems, respectively.

Clearly both these methods can't be adopted in a moving automobile.

We could not achieve 100% pure oxygen by the following method but since even in slight change in oxygen alters engine characteristics we can adopt the following method to increase the concentration of oxygen in the intake air.

The FILTER concept

We know that separating oxygen by any of the above mentioned methods are not practically possible on an automobile and even slight increase in the percentage of oxygen increases engine performance greatly. Hence like the difference in boiling point property used for Cryogenic liquefaction process we can try the density difference to separate the oxygen as in a cyclone separator.

THEORY

The molar masses of different constituents of atmospheric air are shown in the table 2

Table 2. Molar masses of atmospheric gases.

Composition of Dry Air near Sea Level		
Component*	**Content (mole fraction)**	**Molar Mass**
Nitrogen	0.78084	28.013
Oxygen	0.20948	31.998
Argon	0.00934	39.948
Carbon dioxide	0.000375	44.0099
Neon	0.00001818	20.183
Helium	0.00000524	4.003
Methane	0.000002	16.043
Krypton	0.00000114	83.80
Hydrogen	0.0000005	2.0159
Nitrous oxide	0.0000005	44.0128
Xenon	0.000000087	131.30

From the table it is clear that the density of oxygen and nitrogen are not same, they are apart by 0.2 kg/m^3. Due to the low difference in density it is not that much easy to separate oxygen by simple methods. We need to provide more additional power than the default suction force of engine.

MODEL 1

Model 1 consist of a simple hollow type cylinder in which atmospheric air is forced to flow in circular direction. The passage of the inlet air is so designed that while the air enters in to the cylinder air executes a circular motion. When the air is forced to execute circular motion the molecules which got higher mass will get away from radial direction. That is when air is forced to execute circular flow the element which got higher density (oxygen in our case) will occupy the extreme end i.e. nearer to the cylinder wall and other elements to inside according to the density difference.

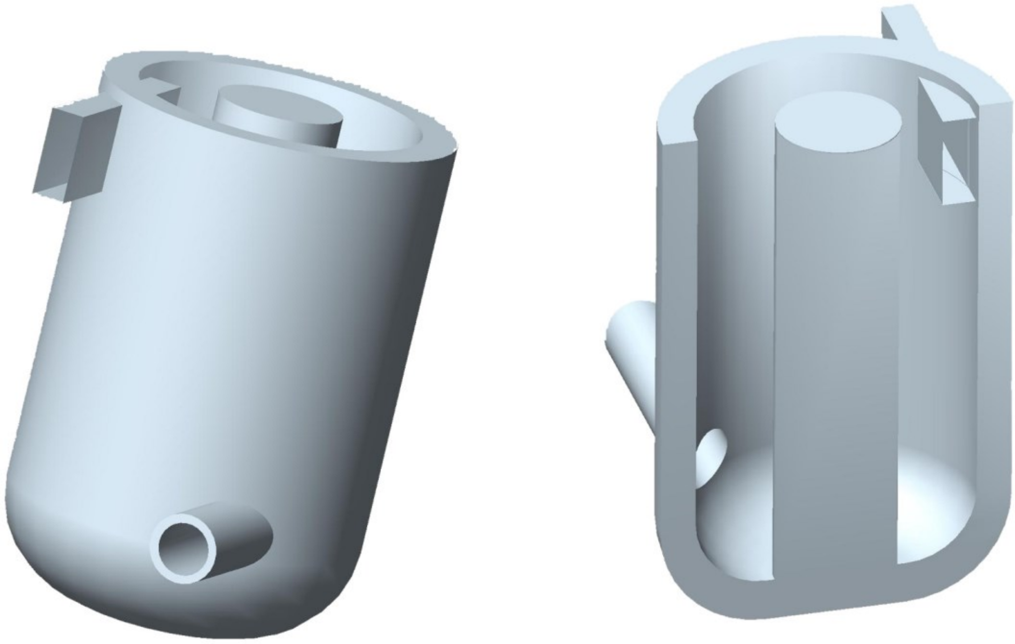


Fig. Model 1.

From the figure the atmospheric air is intaken through the circular tube at the bottom and the air is forced to rotate inside the cylinder. As the air reaches upper side by continues rotation the oxygen may be located to the extreme end and it can be collected by the arrangement as shown in the figure.

But providing the power required to separate oxygen effectively is not possible by this model. So we move on to the next model.

MODEL 2

The main disadvantege of model 1 is the inability to provide required velocity to the circulating air. And there is a possibility for the air to get mixed while rotating inside the cylinder, so inorder to prevent this the circular camber is replaced by a hollow tube coiled like a spring and air separating arrangement at one end of the tube.

In model 2 atmospheric air forcefully given to one end of the tube (in the lower end by as in figure) and it is allowed to circulate through the tube. After complecting the loops like wise happened in model 1 the elements that got more mass get pushed away in radial direction and it can be separated out by collecting only the air at extreme end.

The efficiency of the filter can be increasedby increasing the velocity of air flow, increasing the length of metal tube, decreasing the diametre of coil.

Model 2 is shown below

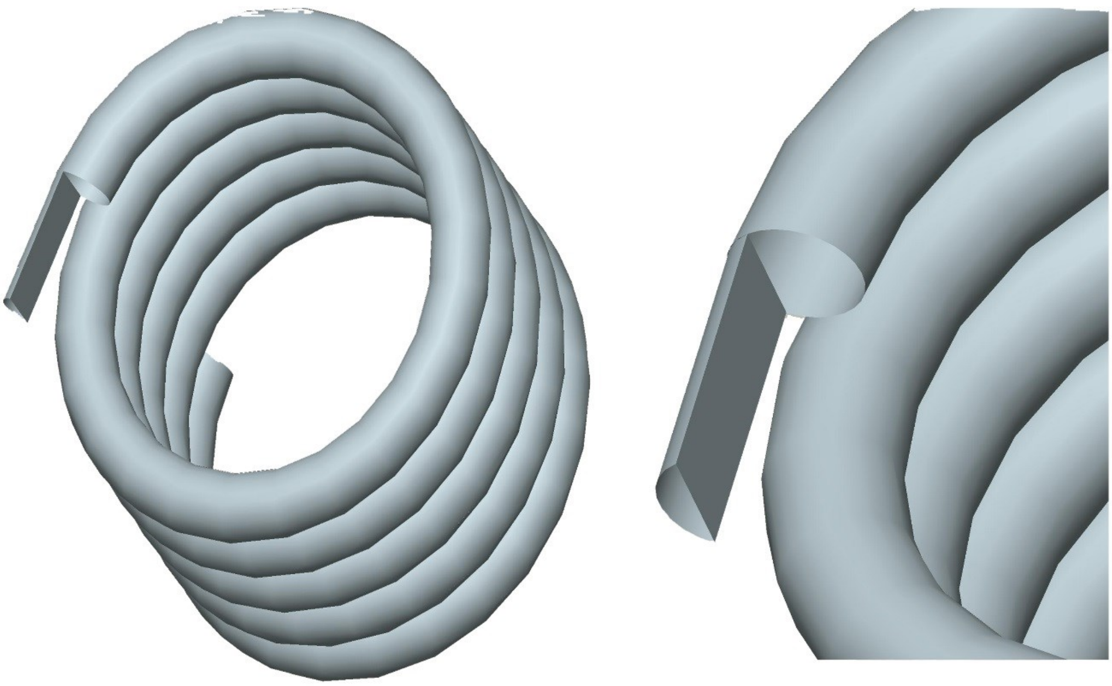


Fig. Model 2.

The position of separator at the end of coil as shown in model 2 is should be calculated by theoretically. It is influvenced by,

1. Length of coil
2. Velocity of air intaken
3. Diameter of coil and diamere of tube

4. ADVANTAGES AND DISADVANTAGES

Advantages

- Low NO_X emission compared to normal engine.
- Complete combustion of fuel hence there is no formation of carbon monoxide and carbon soot particles.
- Low fuel consumption and better mileage.
- Engine size can be reduced
- Economic and less maintains cost

Disadvantages

- Less power

Decrement in power is due to the lack of enough gas in the engine cylinder. Power will certainly reduce if we are providing the same amount of oxygen from the atmosphere to the same engine. Actually the power is developed by the shock waves that are created due to the explosion (combustion) of fuel inside the engine cylinder. When we provide the same amount of oxygen we are actually reducing the entire volume of inlet air to 20% (if only oxygen is allowed to pass to engine-theoretical concept) thus the medium which carry the shock waves reduces and hence the less power output.

How to overcome *Less power* problem?

1. One way is by reducing the engine size by 5 times (calculated by theoretical values). Thus we are reducing the volume of engine and hence increasing the air density inside engine cylinder. By this way we get Same power of normal engine by an engine that is only 1/5 of normal engine
2. Other way is by increasing the amount of oxygen to the engine cylinder by 5 times. That is provide the same volume of oxygen as that of normal air. This can be done by means of the *blower.*

- Need additional blower to supply air.
- Once we set the separator at the end of tube which is pre calculated considering the length of tube and velocity of inlet air, we only get a constant flow of air. So if we need more air while we accelerate we can't simply count on it. So in order to prevent this we can introduce a simple chamber which stores the excess oxygen and supplies to the engine directly. So if we need excess oxygen the chamber can provide it as long as we want and the chamber is air tight and is filled continuously by filter.

Reference

[1] Bharath.P, Kamalakkannan.K, "Analysis of Brake Thermal efficiency and Oxygen in exhaust using oxygen enriched air in Compression Ignition engine"- *IOSR Journal of Mechanical and Civil Engineering* (IOSR-JMCE), e- ISSN: 2278-1684, p-ISSN : 2320–334X, PP. 30-33

[2] K.RAJKUMAR , P. GOVINDARAJAN , "Experimental Investigation of Oxygen Enriched air intake on Combustion Parameters of a Single Cylinder Diesel Engine" - *International Journal of Engineering Science and Technology*, Vol. 2(8), 2010, PP 3621-3627

(Received 08 February 2015; accepted 20 February 2015)