REDUCTION IN EMISSION OF HARMFUL GASES FROM IC ENGINE BY ELECTROLYSIS

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Abstract

This paper is all about the reduction in the emissions of harmful gases from the IC engine. As we all know that the major problem in the world is air pollution. The significant portion of the air pollution is due to automobiles only. So, if we can control the emissions from engines that will lead to the gradual decrease in the overall pollution. The simplest method to decrease in the emission of harmful gases from the engine is by sending the pure oxygen into the cylinder. This is possible when we can purify the air by removing all the harmful gases from the air. This paper will explain that purifying method. This method will result in almost 60% reduction in pollution from current stage pollution if we put this method in practice. This method will also improve engine performance parameters. If we apply this method for every vehicle, then we can expect a pollution-free environment.

Keyword: Electrolysis, purifying method.

I. Introduction

The major problem in the world today is pollution. That was affecting a lot to human survival. The air which we are breathing is getting contaminated day by day. Breathing the contaminated air leads to many diseases to create in our body. The significant portion of the pollution is mainly due to automobiles only. So, if we can able to control the pollution due to vehicles, we can reduce nearly 60% of the current stage pollution.
Fig. 1: Yearwise pollution rate.

**Themajor Contributor to Air Pollution**

According to an analysis of the pollution, industries and automobiles are the major contributors. As we cannot avoid the pollution from industries altogether, but we can alter the pollution levels by reducing the emission of harmful gases from the automobiles.

**Engine**

It is a device which is used to convert chemical energy into mechanical energy.

Classification of engines:

1) Internal combustion engine
2) External combustion engine.

**Working of SI Engine**

It takes the fuel-air mixture from the carburettor during the second half of the revolution of the crank followed by compressing that mixture. The mixture is then ignited by the plug (SPARK) which will result in the combustion of fuel in the presence of oxygen. That will create a sudden increase in pressure and temperature resulting in the downward movement of the piston which will, in turn, rotates the crankshaft.

Thus, the chemical energy of fuel has got converted into mechanical energy.

**Composition of Atmospheric Air**

Atmospheric air contains

1) Nitrogen: 78% (nearly)
2) Oxygen: 21%
3) Hydrogen: 0.5%
4) Other gases: 1.5%
The Main Requirement for Combustion

The only required element for combustion is oxygen. However, our atmospheric air contains a mixture of all gases. The most unwanted gas is nitrogen for combustion process because it will result in the production of nitrous oxide (No\textsubscript{x}). So if we can able to reduce the unwanted gases in the air we can control the pollution levels.

Source for Pure Oxygen

The primary source is electrolysis of water
1. The chemical formula for water is H\textsubscript{2}O.
2. That means a water molecule contains two hydrogen atoms and one oxygen atom.
3. With the help of electrolysis, we can separate hydrogen and oxygen.

The Products of The Exhaust Gases

The main parameters that need to be taken care during the design of engine are:

• Performance parameters.
• Characteristics of the emissions.

The primary emissions from IC engines during combustion are:

1. NOx compounds
2. Hydrocarbons
3. Carbon monoxide
4. Carbon soot particle and the particulate matter.

Nitrogen Oxides (NO\textsubscript{x})

Nitrogen oxide emission is harmful emission from the IC engine, which makes the air to get polluted. The main reason for the productions of NO\textsubscript{x} compounds from the IC engine is the temperature in the cylinder, because during the combustion series of reactions will be taken place with release of enormous amount of energy which in turn increases the temperature of mixture to the maximum possible level where the triple bond between the nitrogen atoms will be broken up usually at the higher temperatures, i.e., above 1600 °C, molecular nitrogen (N\textsubscript{2}) and oxygen (O\textsubscript{2}) in the combustion air will get disintegrated into their atomic states and indulge in number of reactions.

The extreme reactions which are responsible for the production of NO\textsubscript{x} products during the combustion are:

\[ \text{N}_2 + \text{O} \rightarrow \text{NO} + \text{N} \]
\[ \text{N} + \text{O}_2 \rightarrow \text{NO} + \text{O} \]
\[ \text{N} + \text{OH} \rightarrow \text{NO} + \text{H} \]
Carbon Monoxide (CO)

The reason for carbon monoxide emission from the exhaust of the engine is due to incomplete combustion of the fuel (octane) inside the cylinder volume. The reason for incomplete combustion is the lack of oxygen supply, and the reaction can be represented as:

\[ C_2 + \frac{1}{2} O_2 \rightarrow CO \]

Hydro Carbon (HC)

Hydrocarbons are nothing but the fuel which we are using the engine, i.e., petrol, diesel …., all will come under hydrocarbons. In engine during combustion, some portion of the fuel will not burn, but it gets escaped into the atmosphere during the exhaust stroke, which makes the hydrocarbons to release into the atmosphere.

Carbon Soot Particles and Particulate Matter

These are the incomplete combustion products that will not be visible to the naked human eye. These particles will cause severe damage to the lungs. So the oxygen is very much important for the complete combustion of the fuel.

Combustion

Combustion or burning is the series of exothermic chemical reactions between an oxidant and fuel resulting in the production of a massive amount of heat energy and conversion of chemical species. The release of heat can produce light or illuminate in the form of a spark or like a glowing flame. Fuels which we are utilizing include organic compounds (mainly hydrocarbons) in any one form of three states of matter (i.e. gas, liquid and solid). Based on the by-products produced.

Classification of the Combustion

i.e., Complete and Incomplete combustion explanation towards complete and incomplete combustion

Incomplete combustion is the one in which the fuel will not burn to the full extent due to supply of lack of oxygen. Whenever we burn the hydrocarbon in the presence of \( O_2 \), the reaction will result in the production of carbon dioxide and water. Carbon will result in carbon dioxide, sulphur will result in sulphurdioxide,

Iron gives rise to ironoxide. Nitrogen is a gas which cannot burned when oxygen is used as oxidant, But small quantities of different nitrogenoxides (commonly represented as NOx species) appears in the combustion process because of atmospheric air utilization. Combustion is a process which depends on the temperature to a certain extent. For example, SO\(_3\) is the one such which cannot be yielded by the combustion of sulphur. NOx species appear in significant amounts above 2,800 °F (1,540).

II. Literature Survey

They have done the experiments on a compression ignition engine by sending a different
Amounts of oxygen from the inlet putting an increment of 2% from 21% to 27%. The main point which made them in conducting this experiment is that, if the amount of oxygen content which we are sending into the engine is more then it will result in the better performance of the engine and we can expect the complete combustion of the fuel. However, in the real-time engine, the air at the available at the suction stroke is atmospheric air, which contains the maximum percentage of the nitrogen and less portion of oxygen, which makes the combustion incomplete. Sending more amount of oxygen into the cylinder can reduce harmful products from the engine. With the increase in percentage of oxygen, it was observed that burning of fuel reaches to the maximum extent. Moreover, it will result in reduction of carbon monoxide. The analysis system consists of a naturally aspirated single cylinder engine. To measure the load a dynamometer has employed.

To analyse the exhaust gases, a device called krypton gas analyser has employed.

They have concluded with the following outputs:

- The more oxygen content at the inlet of the engine at low speeds has increased the thermal brake efficiency and brake power compared to atmospheric air that we sent into the cylinder, but at higher speeds, there is not that much change in the brake power.
- The amount of fuel required is less if we send the enriched oxygen into cylinders at the lesser speeds.
- The amount of fuel required to produce unit brake power is less at the lower speeds if we send enriched oxygen at the inlet. So, specific fuel consumption mainly depends on the air to fuel ratio.
- The exhaust fuel which is spelling out of the cylinder without complete combustion can let minimised by sending more amount of oxygen at the inlet such that combustion will occur properly.
- CO drops to very less percentage because of involvement of pure oxygen in the process.

They have done multiple tests on a single-cylinder diesel engine with pure oxygen as oxidant. More amount of oxygen implies the less ignition delay period, and for the given stoichiometry the combustion efficiency in case of more oxygen at the inlet is high compared to atmospheric air at the inlet.

The proper combustion of fuel and oxidant will result in less effect on the atmosphere, and at the same time, it does not contribute anything to the greenhouse effect. An experiment was conducted on the engine to evaluate the engine parameters:

1) Ignition delay period,
2) Combustion time,
3) Heat release and Cylinder pressure.

They have sent the pure oxygen by using a cylinder which contains oxygen which will be mixed with the atmospheric air in a chamber. We can achieve this mixing of air by invoking small mixing chamber before the entrance. Now, the test has been done with different quantities of oxygen levels and the load on the engine.
III. Electrolysis

• Electrolysis of water (aq) is the decomposition of water into oxygen and hydrogen gas due to the passing of electric current through the water. The chemical reaction has a standard potential of −1.23 Volts, meaning it ideally requires a potential difference of 1.23 volts to split water into oxygen and hydrogen.

• Chemical reaction is:

  \[ 2 \text{H}_2\text{O(laq)} \rightarrow \text{O}_2(\text{gas}) + 4 \text{H}^+(\text{aq}) + 4\text{e}^- \]

![Fig. 2: Diagrammatic representation.](image)

Working Procedure

• We have the container filled with water.
• Pure water does not conduct electrolysis very quickly.
• So, some acidic medium is necessary for making the reaction faster.
• For that purpose, we are adding sodium chloride; it makes the reaction to happen fast. For this water, we are giving an electric current with the help of a battery.
• This current will electrolyse the water into oxygen and hydrogen at the respective electrodes.
• Later we will collect these gases in the test tube and will be diverted into the cylinder (in case of compression ignition engines) with the help of high-pressure tubes.
• This whole mechanism will take place during the suction stroke of the cylinder. In this process, electrodes will play a key role in making the reaction a little bit faster.
• Generally, we prefer graphite electrodes based on the cost criteria.
• Instead of using graphite, we can make use of titanium electrodes but which are little bit cost-effective.
Combustion Process

- Combustion is the reaction between a fuel(hydrocarbons) and an oxidant accompanied by the release of a large amount of heat:

  \[ \text{Fuel} + \text{Oxidant} \rightarrow \text{Products} + \text{Heat} \]

- Combustion rate mainly depends on the air to fuel ratio.
- More supply of oxygen makes the combustion efficiency.
- Presence of nitrogen will significantly affect the combustion.

Reactions Involving the Combustion of Petrol Under Ideal Conditions

- Under ideal conditions, during combustion, only hydrocarbon and oxygen are present, the chemical reaction commonly called combustion or burning produces only water, carbon dioxide, and energy as the following essential equation shows.

  \[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{ENERGY} \]

- In the above ideal reaction, the energy obtained from the reaction is greater than the energy given to the reaction; it is common knowledge that a spark is needed to make a hydrocarbon burn in case of the petrol engine. The spark represents the energy needed to break the carbon-carbon and carbon-hydrogen bonds of the hydrocarbon molecule as well as the oxygen-oxygen bond of the oxygen molecule. The typical C-C bond requires 350 kJ/mol of energy to break, the typical C-H bond requires 413 kJ/mol of energy and the O-O bond requires about 498 kJ/mol of energy.

- Gasoline (Fuel or hydrocarbons) undergo reaction with the oxygen resulting in the release of water vapour (H2O) and Carbon monoxide (CO). Octane is obtained after several stages in the fractional distillation from the crude oil. Since major percentage of gasoline contains octane, we chemically say that gasoline comprises of octane. The chemical formula of it is \( \text{C}_8\text{H}_{18} \). The Perfect stoichiometric reaction for octane as shown in the below. The Reaction of octane with oxygen is exothermic (that means, it releases energy). The burning of 1 Gram of octane will produce the energy of 44,400 joules.

  \[ \text{C}_8\text{H}_{18} + 12.5 \text{O}_2 \rightarrow 8 \text{CO}_2 + 9 \text{H}_2\text{O} + 44,000 \text{joules} \]

- 1 mole of gasoline requires 12.5 moles of oxygen to undergo perfect reaction. 12.5 moles of oxygen weighs 400 grams. Since molecular weight of oxygen is 32.

- Since air contains 21% of O2, there will be an Octane reaction which is of exothermic.

- The below calculations are made with respect to the weights of the molecules. we can say the weight of \( \text{C}_8\text{H}_{18} \) for 1 mole is equal to the 114 Grams.
IV. Calculations

Calculations (By Sending Atmospheric Air):

• Based on the above fuel oxidant reaction, we can say that we unnecessarily consuming 47 moles of nitrogen into the combustion chamber. The weight for 47 moles of nitrogen is sum up to 1316 Grams. Since one mole of oxygen is equal to the 3.756 moles of nitrogen.

• From the above reaction, we can say that we require 1716 grams of oxygen and nitrogen if we are using atmospheric air for complete combustion of the octane. The weight 1716 is obtained by summing up the individual weights of nitrogen and oxygen in the atmospheric air.

• So, The required air-fuel ratio for proper combustion of the octane as per the availability of air is 15. It is obtained by dividing the molar weight of the air and fuel. However, most of the industries prefer to take the air-fuel ratio of 14.7.

• The above statement implies that we require 15 Grams of atmospheric air to undergo reaction with octane (for one mole).

• Since they have chosen the cylinder whose stroke volume is 200 cubic centimetre (cc), it can also written as one-fifth of liter.

• They found the weight of the air which is exactly fit for the 200 cc volume.

• We know that The molar weight of air is 28.8 Grams. We can get this from:

\[
\begin{align*}
1) & \quad 0.21 \times 32 = 6.72 \\
2) & \quad 0.79 \times 28 = 22.12
\end{align*}
\]

Therefore total weight is equals to 28.8 grams.

• The volume occupied by one mole of gas at STP is 22.4 iters.

That is,

\[1 \text{ mole of air (28.8 Grams)} \Rightarrow 22.4 \text{ L}\]

Now, the weight of the air in a volume of 1/5 L is given below.

Since, the volume of the engine which is under test is 200 cc.

• For one gulp, the amount of the air required weights to 0.257 grams. The Calculations are shown as:

\[\text{Weight} = \frac{0.257 \times 28.8}{24} = 0.257 \text{ grams}\]

• They found the weight of the air, at the same time they need to find the amount of fuel required as per the air sent into the cylinder. So, The weight of the fuel is given as:

\[\text{Weight of fuel} = \frac{0.257}{15} = 0.0171 \text{ g}\]

• The reaction between fuel and oxidant will result in the production of 790 joules. As we know that the energy possessed by 1 mole of octanes is 44,400 joules. Since it is taking 0.0171 grams of fuel during the suction stroke which made the production of energy as the 790 joules.

• The energy released per explosion for the lean mixture that we have sent into the cylinder. We have to inject enough amount of fuel during the fuel injection time.
in case of diesel engine. If we send the more fuel than required it will yield in the incomplete combustion of the furl because of insufficient Oxygen.

- The RPM that they have chosen is 6000 for the current experiment.
- Since we know that for a four-stroke engine there is one power stroke for every crank revolution.
- If we run the engine at 6000 RPM, It implies that there are 50 power strokes per second.
- With this information, we can find the power produced. Power is defined as the work done per unit time.

\[
\text{Power} = 50 \times 790 = 37,950 \text{ J/s}
\]

- We can represent J/s as watts. The value of one horsepower is equal to 746 watts.
- Therefore, the power produced by the engine at 6000 which is highest rpm is 50.9 Hp.

\[
\text{Horsepower of engine} = \frac{37,950}{746} = 50.9
\]

- From where we got 200 cc?
- We got the volume of the engine from the dimension of the engine cylinder.
  1) Cylinder diameter = 6.3 cm.
  2) Stroke length = 6.4 cm
  3) Piston area = \( \pi \times \frac{6.3 \times 6.3}{4} \)

\[
= 31.2 \text{ cm}^2
\]

- The stroke volume of the engine can be calculated with the formula as shown:

\[
\text{Volume} = \text{area} \times \text{length}
\]

In our case

\[
\text{Area} = 31.2 \text{ cm}^2
\]

Length = 6.4 cm

So, volume = 200 cm³

- Here are a few methods to get more energy for one explosion in the engine:

  1) More displacement—which implies the bigger engine.
  2) Higher starting pressure in the cylinder inlet—it can be made possible by providing supercharger using an air compressor on intake.
  3) Lat method is sending 100% oxygen into the cylinder without any traces of Nitrogen.

Calculations (by Sending Pure Oxygen):

The chemical equation is

\[
C_8H_{18} + 12.5 O_2 \rightarrow 8 CO_2 + 9 H_2O + 44,000 \text{ joules.}
\]
it is the basic equation between fuel and oxidant which implies that for complete combustion of 1 mole of octane we require 12.5 moles of oxygen and it results in the release of 44,000 joules of energy.

- From the process of electrolysis, we will separate oxygen and hydrogen by creating a potential difference as shown above.
- This pure oxygen has to be sent into the cylinder without any traces of nitrogen.
- The below calculations are made with respect to the weights of the molecules. We can say the weight of C8H18 for 1 mole is equal to the 114 Grams.
- The weight of one mole of oxygen is 32 grams.
- Dimensions of the cylinder:

We got the volume of the engine from the dimension of the engine cylinder.

Cylinder diameter = 6.3 cm.
Stroke length = 6.4 cm
Piston area = \( \pi \times \frac{6.3}{2} \times \frac{6.3}{2} \)
= 31.2 cm²

- The stroke volume of the engine can be calculated with the formula as shown:

\[
\text{Volume} = \text{area} \times \text{length}
\]
In our case, \( \text{Area} = 31.2 \text{ cm}² \)
\( \text{Length} = 6.4 \text{ cm} \)
So, volume = 200 cm³

- For perfect reaction we require 12.5 moles of oxygen which weighs to 400 grams.
  \( 12.5 \times 32 = 400 \text{ grams} \).
- Required air fuel ratio:
  \( \text{Air-fuel ratio} = \frac{400}{114} = 3.5 \).
- The volume occupied by one mole of gas at STP is 22.4 liters.

That is,

1 mole of \( \text{O}_2 \) (32 Grams) \( \rightarrow 22.4 \text{ L} \)

\( ? \rightarrow \frac{1}{5} \text{ L} \)

Since the volume of the engine which is under test is 200 cc.

- For one gulp, the amount of the oxygen required weight to 0.266 grams. The Calculations are shown as:

\[
\text{Weight} = \frac{0.266 \times 32}{24} = 0.266 \text{ grams}
\]
- we found the weight of the oxygen, at the same time we need to find the amount of fuel required as per the oxygen sent into the cylinder. So, the weight of the fuel is given as:

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\[\text{D. Satyanarayana et al}\]
The reaction between fuel and oxidant will result in the production of 3374.4 joules. As we know that the energy possessed by 1 mole of octane is 44,400 joules. Since it is taking 0.076 grams of fuel during the suction stroke which made the production of energy as the 3374.4 joules.

\[
\text{Energy released} = 0.076 \times 44,400 = 3374.4 \text{ joules}
\]

The RPM that they have chosen is 6000 (since we have taken 6000 in previous case).

Since we know that for a four-stroke engine there is one power stroke for every crank revolution.

If we run the engine at 6000 RPM, It implies that there are 50 power strokes per second.

With this information, we can find the power produced. Power is defined as the work done per unit time.

\[
\text{Power} = 50 \times 3374.4 = 168,720 \text{ KW}
\]

We can represent J/s as watts. The value of one horsepower is equal to 746 watts.

Therefore, the power produced by the engine at 6000 which is highest rpm is 226 Hp.

It is obtained from:

\[
\text{Horsepower of engine} = \frac{168,720}{746} = 226.
\]

**Table 1: Comparison between usage of atmospheric air and pure oxygen.**

| Atmospheric Air | Pure Oxygen |
|-----------------|-------------|
| Weight of 1 mole of air = 1716 grams | Weight of 1 mole of oxygen = 400 grams |
| Weight of 1 mole of octane = 114 grams | Weight of 1 mole of octane = 114 grams |
| Air – fuel ratio = 15 | Air – fuel ratio = 3.5 |
| Weight of air for one gulp = 0.257 grams (since, engine is 200 cc) | Weight of O₂ for one gulp = 0.266 grams (since, engine is 200 cc) |
| Weight of fuel for one gulp = 0.0171 grams | Weight of fuel for one gulp = 0.076 grams |
| Energy per explosion | Energy per explosion = 3374.4 joules |
V. Conclusion

As we have seen in the above calculations that the atmospheric air contains 78% of nitrogen and 29% of oxygen which makes the amount of fuel to be sent less in a stroke for a given CC cylinder which will in turn reduce the efficiency. But with the help of this method we can send the more fuel as per the requirement of oxygen content in a given CC cylinder. So, by sending pure oxygen into the cylinder will drastically decrease the Nox emissions and it will increase the efficiency of the engine. Application of this principle will result in a significant reduction of pollution. One thing to notice that is we have to carry some water along with us for enhancing results.

References

I. 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 (IOSRJMCE),e-ISSN: 2278-1684, p-ISSN: 2320–334X, PP.30-33

II. K.Rajkumar, P. Govindarajan, “ExperimentalInvestigation of Oxygen Enriched air intake onCombustion Parameters of a Single Cylinder DieselEngine” - International Journal of Engineering Science and Technology, Vol. 2(8), 2010, PP 3621-3627

III. GarimaShakya,” Problems in Computational Mechanism Design” Doctoral Consortium AAMAS 2019, May 13-17, 2019, Montréal, Canada.

IV. http://www.petroleum.co.uk/how-hydrocarbons-burn.