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Research Article

DEVELOPMENT OF OXYGEN SEPARATION UNIT FOR EMISSION CONTROL IN IC ENGINE USING ZEOLITE 5A

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ABSTRACT

In IC engines, the combustion takes place through air and fuel mixture. The main aim of this unit is to separate the oxygen from the atmosphere and allow it to the combustion chamber of the IC engine. This has been made possible by the element called Zeolite. In the present work a setup has been designed and developed for four stoke single cylinder petrol engine and the emission rate has been control. The principle of rapid pressure swing adsorption system has been introduced for the oxygen production. By allowing the oxygen into the combustion chamber a complete combustion has been takes place resulting in increasing the efficiency of the engine. From the experiments conducted the emission has been decreased due to the action of oxygen enriched combustion which enables complete combustion.

INTRODUCTION

Now-a-days transportation becomes most essential part of life. The biggest problem is the growing of population and scarcity of clean air as the pollutants coming from the automobiles exhausts are continuously increasing. This is majorly because of the incomplete combustion that takes place in the cyclic process of an IC engine. For the purpose of making a good and an efficient engine and also to reduce the emission rate, the oxygen supplement unit has to be incorporated in the conventional Engine. The oxygen has to be produced in large volumes for complete combustion to take place in IC engines. An experimental setup has been proposed to enhance the oxygen production by adding an oxygen separation unit in the engine setup. It adsorbs the nitrogen molecule which is enormously present in the atmosphere. Adsorbing the nitrogen makes the air to have only oxygen which is second enormous amount in the atmosphere (Masoud, *et al.*, 2013). The principle used in this process is called Rapid Pressure Swing Adsorption (PSA) system. By allowing the oxygen to the combustion chamber there is a complete combustion takes place. As a result the Horse Power (HP) can be increased. By complete combustion the exhaust gases has been reduced while comparing to the conventional process. Hence the emission rate of an engine can be reduced.

Now-a-days it has been found that automobiles are producing more toxic pollutants in the ecosystem. In complete combustion, the reactant burns in oxygen, producing a limited number of products (Sharma and Wankat, 2009). 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, sulphur will yield sulphur dioxide, and iron will yield iron (III) oxide. Nitrogen is not considered to be a combustible substance when oxygen is the oxidant, combustion is not necessarily favourable to the maximum degree of oxidation, and it can be temperature dependent (Bonjour, *et al.*, 2002). For example, sulphur trioxide is not produced quantitatively by the combustion of sulphur.

The concept of oxygen enrichment aims at limited substitution of the nitrogen in air by oxygen to achieve low emission levels (Bonjour, *et al.*, 2002).

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Because of the increased oxygen content, additional fuel is burned. This has been made be possible by the element called zeolite. The zeolite molecule is the element has fine porous structure so that the larger molecules such as nitrogen, has been captured while the smaller molecule oxygen, has been freely passed through the zeolite molecule (Sircar, 1988). They contain tiny pores of a precise and uniform size, and are mainly used as an adsorbent for gases and liquids. 5A molecular sieves are used to dry natural gas, along with performing desulfurization and decarbonation of the gas.

EXPERIMENTAL STUDIES

The use of pure oxygen is an effective way of combustion, because the oxygen has the capacity to burn more than the air mixture in the atmosphere. The major advantage of the oxygen supply to the combustion chamber can lead to complete combustion takes place in the IC engine (Moghadazadeh, 2008). It can reduce the emission rate to a very low amount. The efficiency of the engine is better than the conventional engine with slight modification. The engine setup has to be established for complete combustion to takes place. The efficiency of such engine designed with slight modification would show better efficiency than the conventional engine.

The PSA process is one of the most popular methods used for the commercial production of oxygen gas (S.J. Lee et al., 2007). While cryogenic manufacture by the Joule-Thomson method (fractional distillation of air at low temperature and pressure) is suited to large scale operations (over 200 tonne of oxygen per day), PSA technology is suited to small and medium sized productions needs (Hidano, *et al*., 2011). Micro (suitcase sized) PSA plants have replaced heavy high pressure oxygen cylinders in the homes of asthma suffers. Small PSA plants have been built to replace large numbers of oxygen cylinders used in some industrial situation. The PSA process consists of pumping air through a bed containing a filter medium that preferentially adsorbs nitrogen, while allowing oxygen to pass through unrestricted. The separation of the oxygen from atmosphere is by the molecular sieve adsorbent zeolite 5A is carried out in the setup. The process used in the separation of oxygen using zeolite is Pressure Swing Adsorption (PSA).

Pressure swing adsorption (PSA) is a technology used to separate some gas species from a mixture of gases under pressure according to the species molecular characteristics and affinity for an adsorbent material (Jayaraman and Yang, 2005). It operates at near-ambient temperature and differs significantly from cryogenic distillation techniques of gas separation. Specific adsorptive materials (e.g., zeolites, activated carbon, molecular sieves, etc.) are used as trap, preferentially adsorbing the target gas species at high pressure. The zeolite 5A commercially available billets has been shown in the (Fig. 1),

Zeoloite can also be used to separate mixtures of oxygen, nitrogen and hydrogen, and oil-wax n-hydrocarbons from branched and polycyclic hydrocarbons (Jee and Lee, 2005; Lee, *et al*., 2007). 5A molecular sieves are stored at room temperature, with a relative humidity less than 90% in cardboard barrels or carton packaging. The molecular structure of the zeolite 5A moleculer structure has been shown in (Fig. 2).

The setup for producing oxygen from Zeolite consists of a nozzle like structured setup which act as a diffuser like inlet for air suction shown in (Fig. 3). The outer cylinder is made of stainless steel and the inlet cylinder is of perforated type. The perforated plate has zeolite 5A inside so that the air passing through the zeolite has been induced

Fig. 1 Zeolite 5A billets.

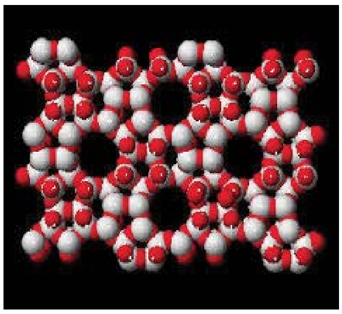

Fig. 2 Molecular structure of Zeolite 5A.

Fig. 3 Diffuser type inlet setup.

for adsorbent reaction to capture the nitrogen molecule. The inside cylinder is gas welded so that is attached to the outer cylinder. A rubber tube is attached to the top side of the setup has tightness for leakage proof of gases. The depressurization unit has been installed because to increase the life of the zeolite. The zeolite act as adsorber so that it would release the nitrogen molecule to the atmosphere by passing the compressed air from reverse direction. The depressurization makes the life of the zeolite to rapidly increase.

The perforated plate has been shown in the above (Fig. 4) which has zeolite 5A molecule. The perforated plate has been gas welded in the outer cylinder. The Specification of the inner and outer cylinder setup has been given in the Table 1. The suction side of the test engine is attached with oxygen separator to separate oxygen from air. The inlet temperature of air is measured with ambient temperature. It has a valve tube to fix the unit in the carburettor. It is used for the purpose of depressurization and to increase the life of the zeolites. There is a diffuser attached at the opposite side for creating more suction of atmospheric air.

The (Fig. 5) shows complete engine setup used in the present work. The setup has a perforated plate with zeolite 5A billets. The inner perforated cylinder is covered by a cylinder with conical outlet. The setup has a rubber tube for depressurisation. A conic outlet has been welded to increase the inlet air pressure to adsorb the nitrogen molecules. The conical chamber is made of Stainless Steel to avoid zeolite degradation. The zeolite inside the perforated

Fig. 4 Perforated plate inside cylinder setup.

Table 1. Specification of the cylinder set-up

Materials	Stainless Steel
Inner Cylinder Length	125 mm
Inner Cylinder Diameter	30 mm
Outer Cylinder Length	260 mm
Outer Cylinder Diameter	45 mm
Tube Material	Rubber
Inner Cylinder Type	Perforated Plate

Fig. 5 Experimental set-up.

plate readily adsorbs the nitrogen molecule by depressurizing and in turn the adsorbed molecule tends to lose zeolite material. At the suction stroke the engine sucks the atmospheric air to the engine via oxygen separation chamber unit before it enters into the engine. The air is sent through the setup is mostly pure oxygen which is supplemented for combustion. This is done by the rapid pressure swing adsorption process in the designed setup. The nitrogen molecule is adsorbed in the zeolite and makes the air which has mostly pure oxygen. This makes the engine to enable complete combustion. This makes the engine more effective and also emits less pollutant. The horse power can be increased through this process.

RESULTS AND DISCUSSION

The Experiments were carried out on the conventional setup and also by installing the setup. The emission test is taken by placing the setup in different positions (i) Installing the setup at the inlet manifold (ii) Installing the setup at the exhaust manifold. The emission test results have been taken for different location stated above and the report has been generated. The emission values of the setup at different places have been shown below in the Tables 2-4.

The emissions from the engine are decreased due to the action of oxygen enriched combustion so that the complete combustion has been takes place and the emission has been reduced. This makes the carbon monoxide emission with supplement of oxygen for better replacement of conventional method of combustion. The emission test has been taken for the engine setup with regulation norms at an emission testing centre and the results has been presented here. The emission norms of the engine have been noted with the smoke meter with and without emission setup. The setup has been installed in the inlet manifold and the readings have been noted similarly the setup has been installed in the exhaust manifold and the readings have been taken. The graph is the plotted by the value of carbon monoxide taken from the emission testing report at inlet and outlet manifolds. (Fig. 6) depicts the plot emission of CO for different location of oxygen separation unit. Similarly the (Fig. 7) depicts the plot for emission of HC for normal, Inlet and exhaust manifold. From the emission results it has been inferred that the zeolite setup is best suited at the inlet manifold. The emission was comparatively less when the zeolite unit was installed at the inlet manifold. The test reports the value of carbon monoxide and the hydrocarbons emission at the Inlet and exhaust manifold.

Table 2. Conventional engine without emission control set-up

Parameters	Regulation limit	Actual Emission
CO (% by Vol.)	3.5	3.5
HC (PPM)	4500	4500

Table 3. Conventional engine with emission control setup before inlet manifold

Parameters	Regulation limit	Actual Emission
CO (% by Vol.)	3.5	3.0
HC (PPM)	4500	3800

Table 4. Conventional engine with emission control setup before inlet manifold

Parameters	Regulation limit	Actual Emission
CO (% by Vol.)	3.5	3.2
HC (PPM)	4500	4000

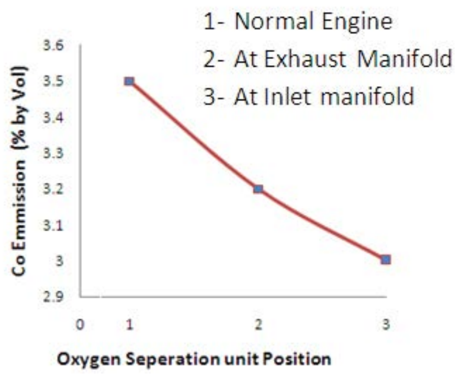

Fig. 6 Emission of CO at normal, Inlet and exhaust manifold.

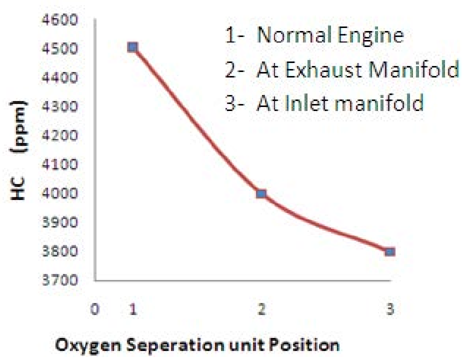

Fig. 7 Emission of HC at normal, Inlet and exhaust manifold.

CONCLUSION

In the process of conversion of the oxygen from the atmosphere, Heat integration can play an important role in regeneration of the zeolite to increase the life of it. The overall engine efficiency can be increased due to perfect combustion of fuel. Thus the emission can be reduced due to complete combustion and also to follow the correct emission norms. This setup would play a vital role in the automobile industry to control emission through complete combustion of fuels. The major benefits of this setup include the increased engine efficiency through complete combustion. Increase of the horse power. Favourable conditions for the formation of the carbon monoxide and unburned hydrocarbon is reduced by oxygen enrichment which is turns results in complete combustion of fuel. The advantages of complete combustion reaction avoid the release as harmful toxic pollutants such as aldehydes and ketones. Thus the emission has been reduced by addition of oxygen separation unit in this present work.

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