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Carbon Dioxide Reduction in Diesel Power Generator using Modified Charcoal

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***Abstract*—Natural calamities and catastrophes are frequently occurring due to climate change caused by global warming. Carbon dioxide is one among the greenhouse gases responsible for enhanced greenhouse effect. Fossil fuel combustion produces maximum amount of CO_2.Reduction of CO_2 from internal combustion engines is mandated to control CO_2 emission. As a part of our continued effort to control atmospheric CO_2, we have undertaken a study of CO_2 absorption using modified charcoals. The results of CO_2 reduction from diesel operated generator using charcoal derived from different sources such as coconut shell, coconut trunk, coconut stem and wood are summarized. CO_2 absorption on charcoal from coconut shell is 9.8%, where as that on charcoal from coconut trunk and coconut stem are found to be 8.4% during engine zero load condition. CO_2 absorption efficiency on all coconut charcoals is less than 10% due to low pore volume (<surface area 50 m^2/g). CO_2 absorption at 20% engine load condition is found to be lower than that of the zero engine load condition due to low resident time for absorption caused by high mass flow rate. The potassium hydroxide loaded charcoal shows additional efficiency (30%) due to increased adsorption along with absorption. The activated wood charcoal (surface area > 500 m^2/g) shows higher absorption efficiency of CO_2 (65%) due to high porosity.**

***Keywords*—Carbon dioxide, Absorption, Adsorption, Activated Charcoal, Charcoal, Coconut stem, Coconut trunk, Coconut Stem.**

I. INTRODUCTION

The planet is getting warmer day by day. Most climatologists regard the final decade of the twentieth century as the warmest in the past millennium. Even minor alterations in global temperature will trigger a series of weather extremities and alter the climatic patterns of the planet. Global warming effects on earth are caused by several factors. To understand the overall effects of global warming on earth, we have to understand the contributions and effects of each component of the planet. The gases produced from vehicles, power plants and other sources are building up in the atmosphere, acting like a thick blanket over our planet.

Climate change can be reduced by decreasing the emission of heat-trapping gases particularly CO_2 to the atmosphere[1-5]. The production of CO_2 from various sectors and consumption of CO_2 through natural process are not proportional leading to an unbalanced residual growth of CO_2 in the atmosphere as shown in Figure 1.

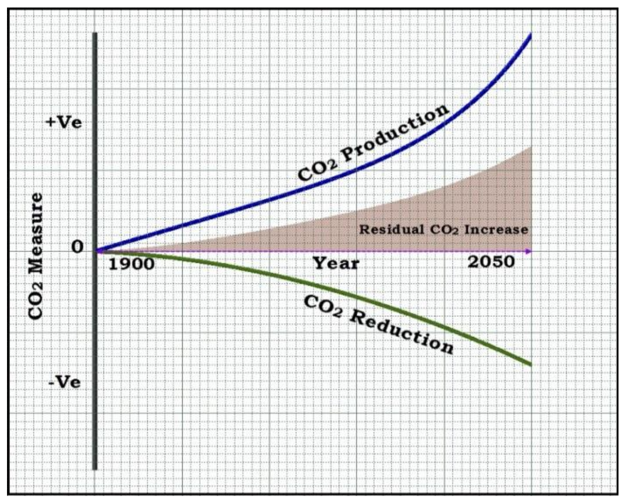

Figure 1. Carbon Dioxide Production and Reduction

It has been clearly identified that additional effective technologies are needed to control CO_2 in the atmosphere [6-13]. In the current study, absorption of CO_2 is achieved in a diesel genset using charcoal derived from different sources such as coconut shell, trunk, and coconut stem. The reduction of CO_2 by absorption on charcoal and activated charcoal and absorption/adsorption on potassium hydroxide loaded charcoal are compared.

II. SCHEMATIC REPRESENTATION OF CO_2 REDUCTION IN DIESEL GENSET

The diesel genset exhaust gas is passed through after treatment system to remove CO, NO_X, HC and PM as per the following equations.

$$2CO + O_2 \rightarrow 2CO_2$$

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$$2C_yH_n + \left(\frac{n}{2} + 2y\right) O_2 \rightarrow 2yCO_2 + nH_2O$$

$$2NO + 2CO \rightarrow N_2 + 2CO_2$$

$$PM \rightarrow Trapped\ and\ removed$$

The after treatment system (ATS) containing diesel oxidation catalyst(DOC) and diesel particulate filter (DPF) is directly connected to the diesel generator. The products coming out of the exhaust after treatment system contains CO_2, H_2O, N_2 and O_2 etc. This gas stream is then passed through a fixed bed CO_2 absorption chamber as shown in Figure 2.

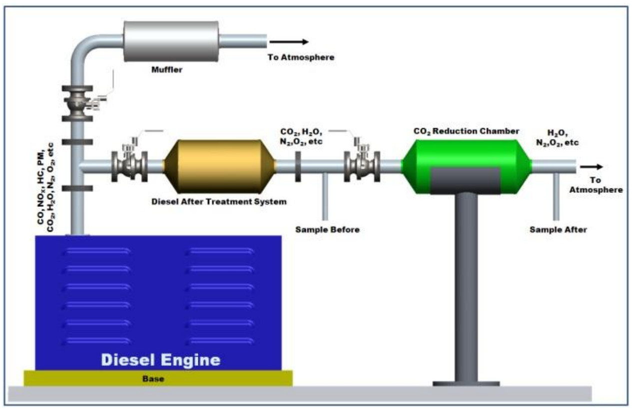

Figure 2. Schematic Representation of CO_2 Absorption System

Carbon dioxide reduction is a process which is used to capture the carbon dioxide emission from the engine using the CO_2 absorption chamber.

III. MATERIALS USED FOR CO_2 REDUCTION

The materials used for CO_2 reduction is chosen to have the absorption and adsorption characteristics. Catalysts are usually loaded on high surface area porous support materials. Charcoal, clay, alumina, zeolite and clathrates are few materials supports.

1) Charcoal

Charcoal from coconut shell, coconut trunk, coconut stem and wood are prepared by controlled firing of the raw materials. Figures 3a, 3b show the raw coconut shell and the charcoal from coconut shell, figures 4a, 4b show the raw coconut trunk and the charcoal from coconut trunk and figures 5a, 5b show the raw coconut stem and the charcoal from coconut stem.

Figure 3a. Raw Coconut Shell

Figure 3b. Coconut Shell Charcoal

Figure 4a. Coconut Trunk

Figure 4b. Coconut Trunk Charcoal

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Figure 5a. Coconut Stem

Figure 5b. Coconut Stem Charcoal

IV. Activated Wood Charcoal

Wood charcoal is porous and can absorb liquids and gases on its porous surface. Therefore, it is used in water filters, gas masks and ant gastric tablets for people suffering from indigestion. Wood charcoal is also used as a decolorizing agent as it can adsorb coloring matter. Activated wood charcoal is a form of carbon that has been processed with oxygen to create million of tiny pores between the carbon atoms. This increases the surface area of the substance from 500 to 1500 m^2/g. One pound of activated charcoal has the surface area equivalent of six football fields. A representative sample of the high surface area activated wood charcoal is shown in Figure 6.

Figure 6. Activated Wood Charcoal

V. CO_2 Absorption Chamber

The CO_2 absorption studies are carried out using the absorption chamber filled with the charcoal material. Absorption chamber is chosen to minimize charcoal abrasion. The size of the chamber is taken about 100 mm diameter pipe and length about 300mm. Charcoal is filled in a wire mesh housing as shown in figure 7a. The charcoal filled wiremesh housing is inserted inside the chamber shown in figure 7b. The chamber with two outlet flanges is attached to the diesel generator for performance evaluation.

Figure 7a. Wiremesh Housing with Charcoal

Figure 7b. CO_2 Absorption Chamber

VI. Working Of Diesel Genset

The diesel engine is mounted on the ground. Eddy current dynamometer was connected to the engine. Loading on the engine was done electrically with rheostat. Exhaust gas analyzer connected to the exhaust pipe for measuring the HC, CO, NO_X and CO_2. The engine was started and warmed-up to establish the recommended oil pressure and was checked for any fuel, oil and water leaks. After completion of the warm-up procedure, the engine was run on no load condition and speed was adjusted to 1500 rpm by adjusting the fuel injection pump.

For each load condition the engine was running at a minimum of 5 minutes and data were collected during the last 2 minutes of the operation.

Simultaneously, engine exhaust emission (NO_x, CO, HC and CO_2) was measured. Exhaust gas analyzer is used to measure directly the exhaust gas emission such as CO_2 in terms of volume %, CO in terms of % by volume, HC in terms of ppm and NO_x in terms of ppm.

The exhaust gas coming out of the engine is made to pass through the chamber with the help of feedback system. The gas which has particulates along with other emissions is passed through the ATS system to remove CO, HC, NOx and PM. Then, the carbon dioxide rich gas is passed through the CO_2 absorption chamber containing charcoal. The exhaust temperature is noted and ensured that it is below 250^{0}C at 1bar pressure (Figure 8).

Figure 8. Diesel Genset Mounted with CO_2 Absorption Chamber

VII. Results And Comparison

The results of CO_2 absorption efficiency on charcoals are summarized in Figure 9.

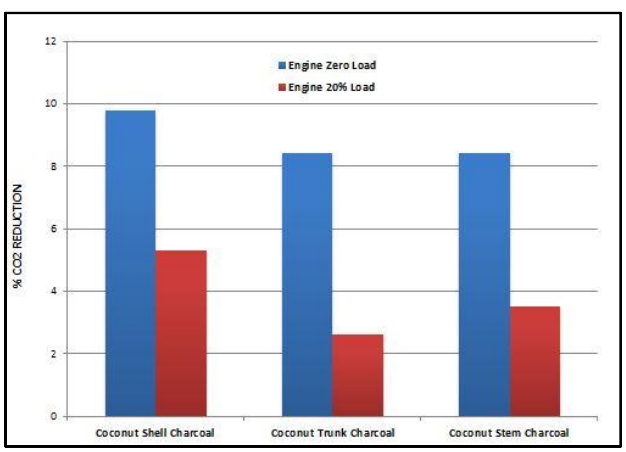

Figure 9. CO_2 Absorption Efficiency of Charcoals

The absorption efficiency of CO_2 on the charcoals of coconut shell, trunk and stem are less than 10%, may be due to low porosity. CO_2 reduction on the conventional charcoal from coconut shell, activated wood charcoal and potassium hydroxide loaded charcoal are compared in Figure 10.

CO_2 REDUCTION USING DIESEL OPERATED GENERATOR		
S.No.	**Material**	**Engine at Zero Load**
1	Charcoal from Coconut Shell	9.8%
2	KOH Loaded on Charcoal	30%
3	Activated Wood Charcoal	64%

Figure 10. Reduction of CO_2 on Different Supports

VIII. Summary

The results of CO_2 reduction from diesel operated generator using charcoal derived from different sources such as coconut shell, coconut trunk, and coconut stem, wood are summarized. CO_2 absorption on charcoal from coconut shell is 9.8% whereas that on charcoal from coconut trunk and coconut stem are found to be 8.4% and 8.4% during engine idling. The CO_2 absorption performance of CO_2 is less than 10% due to low pore volume of the charcoal derived from coconut raw materials. CO_2 absorption at 20% engine load is found to be 5%, for all the different charcoals which is much lower than that of the zero engine load condition. The substantial reduction of CO_2 absorption efficiency may be due to low resident time for absorption caused by high mass flow rate. The potassium hydroxide loaded charcoal shows additional efficiency (30%) due to increased adsorption. The activated wood charcoal (surface area > 500 m^2/g) shows higher absorption efficiency of CO_2 (65%) due to high porosity.

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AUTHOR'S PROFILE

First Author: Mylaudy Dr. S. Rajadurai

Dr. S. Rajadurai, born in Mylaudy, Kanyakumari District, Tamil Nadu, India, received his Ph.D. in Chemistry from IIT Chennai in 1979. He has devoted nearly 36 years to scientific innovation, pioneering theory and application through the 20th century, and expanding strides of advancement into the 21st century. By authoring hundreds of published papers and reports and creating several patents, his research on solid oxide solutions, free radicals, catalyst structure sensitivity, carbon dioxide reduction and emission control has revolutionized the field of chemistry and automobile industry.

As a corporate executive in the United States and India for over three decades, Dr. Rajadurai managed strategy on power train development and emission control for low, ultra low, super ultra low and partial zero-emission systems. From 1990-1996, he was the Director of Research at Cummins Engine Company.. He was the Director of Advanced Development at Tenneco Automotive between 1996 and 2002 and subsequently Emission Strategist and Director of Emissions at ArvinMeritor until 2004. From 2004-2009, he was Vice-President of ACS Industries and since 2009 as President &CEO and Head of R&D Sharda Motor Industries Ltd.

Dr. Rajadurai has held leadership positions on the Board of Directors for the U.S. Fuel Cell Council, Manufacturers of Emission Control Association (MECA), Chairman of MECA Committee on Advanced Technologies and Alternate Fuels and Walker Exhaust India. He is an active participant in Clean and Green Earth Day demonstrations since 1997 and US Clean Diesel School Bus Summit (2003). He was a panelist of the Scientists and Technologists of Indian Origin, New Delhi 2004. He is a Fellow of the Society of Automotive Engineers. He was the UNESCO representative of India on low-cost analytical studies (1983-85). He is a Life Member of the North American Catalysis Society, North American Photo Chemical Society, Catalysis Society of India, Instrumental Society of India, Bangladesh Chemical Society and Indian Chemical Society.

Second Author: J.Maya

J. Maya, born in Piracode, Kanyakumari District, Tamil Nadu, India is a Professional Management Executive working at Research and Development, Sharda Motor Industries Ltd., a global automotive component development and manufacturing Industry. Maya graduated in Electronics and Communication Engineering from Annai Vailankanni College of Engineering, Kanyakumari, TamilNadu, India (2015). She had undertaken a special project on "Value implementation of tube mill operations and it's control system - a TPM approch" for yield improvement at Sharda Motor Industries. She had attended National Workshop on "Role of control system on Engineering" at DMI College, Aralvaimozhi (2014) and "Competency Development" at Annai Vailankanni College of Engineering (2015). Maya is working with Mylaudy Dr. Rajadurai, Head of R&D, on emission control projects. She is working on environmental research activities including understanding of global warming, climate change, carbon dioxide control etc.. She had been co-ordinating student research projects at SMIL with Universities and Colleges. She also shows keen interest in developing engineers through professional training and support.