IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 8, October 2014
www.ijiset.com
ISSN 2348 – 7968

Catalytic Reduction of CO_2 in Gasoline Passenger Car

S. Rajadurai[1], R.K Anulatha[2]

[1]President & CEO and Head-R&D, Sharda Motors Industries Ltd, Mahindra City, New Chennai
[2] Executive- Professional Management R&D, Sharda Motors Industries Ltd, Mahindra City, New Chennai

Abstract

Global warming resulting from the emission of greenhouse gases, especially CO_2, has become a wide spread concern in recent years. We have attempted to reduce carbon dioxide emission from gasoline-operated passenger cars using different catalysts. We have evaluated the absorption efficiencies of activated charcoals prepared from coconut shell as well as wood. The CO_2 reduction by physical absorption on coconut shell charcoal is approximately 6.8%, whereas the reduction of CO_2 on wood charcoal is approximately 9.2%. The physical absorption efficiency is purely a relative amount depending on the nature of the charcoal. In order to differentiate physical absorption and catalytic adsorption, we tried to reduce CO_2 on lithium silicate-coated honeycomb. The catalytic activity of lithium silicate-coated honeycomb is approximately 21.4%, which shows relatively higher CO_2 reduction performance. The catalyst layer of lithium silicate-coating on honeycomb is chosen in such a way that only chemical bonding and conversion occurs and clathration and absorption cannot take place. Chemical adsorption and catalytic reduction certainly is more efficient than mere physical absorption, as absorption is limited to physical nature of the catalyst. A detailed kinetic study of adsorption-conversion-desorption is required to understand the mechanism

Keywords:*Catalytic reduction of CO_2, Gasoline passenger car, Lithium silicate, Tubular honeycomb reactor, Wood charcoal, Coconut shell charcoal.*

1. Introduction

Increasing greenhouse gas emission due to industrialization is one of the major concerns faced by the current generation in the second decade of the 21st Century [1]. CO_2 is considered a major anthropogenic contributor to climate change. Carbon dioxide contributes approximately 76% of total anthropogenic greenhouse gases – a third of which comes from burning fossil fuels – to global warming because of its significant emission amount [2]. The formation of CO_2 increases exponentially due to industrialization, whereas the reduction of CO_2 by natural sources is not able to keep pace with the production due to a large amount of deforestation, etc. Consequently, a steady and continuous growth of CO_2 in the atmosphere is occurring. Figure 1 illustrates the growing gap between the twoprocesses and the increase in the residual CO_2 concentration in the atmosphere.

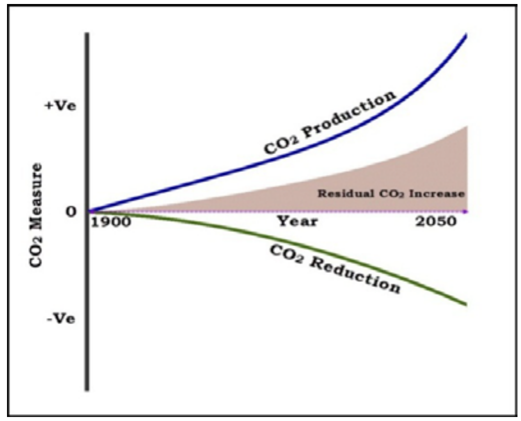

Fig. 1 The gap between CO_2 production and consumption

This demands the need for fixing CO_2 concentration in the atmosphere using artificial CO_2 reduction technologies. The concept of CO_2 capture and sequestration has recently attracted considerable interest in the reduction of CO_2 emissions [3-8]. Various CO_2 reduction technologies usedare listed in Figure 2.

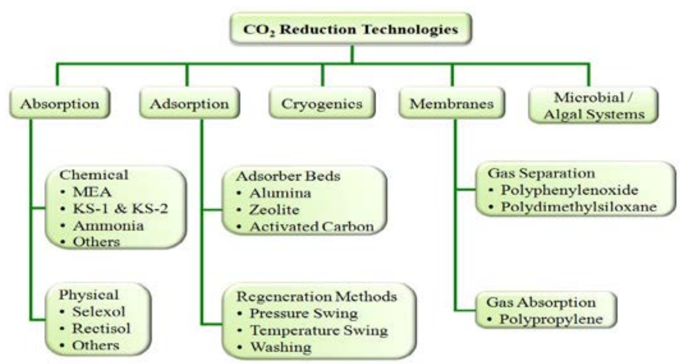

Fig. 2CO_2 Reduction Technologies

We have been continuously exploring CO_2 reduction by physical absorption and chemical adsorption technologies from different CO_2 sources using different catalysts and support materials [9-10]. The absorption process, in which carbon dioxide is physically absorbed and stored, is attempted using activated charcoals. The charcoals used in this study are prepared from different sources such as wood and coconut shell. In the current study, we have attempted to reduce CO_2produced from the gasoline-

ISSN 2348 – 7968

operated passenger car by sampling the exhaust gas at the tailpipe of the vehicle. Catalytic reduction by chemical adsorption is also attempted using lithium silicate catalyst loaded on metallic honeycomb. The shape selective catalyst layer of lithium silicate-coated honeycomb is chosen in such a way that only chemical bonding and conversion occur, and clathration and absorption cannot take place.

2. Schematic representation of CO_2reduction in gasoline vehicle

The gasoline-burnt internal combustion engines emit regulated gases such as CO, NOx, and HC. They are converted into CO_2, H_2O, and N_2 by three-way catalytic converter (TWC) as described in the equations.

$$2CO + O_2 \rightarrow 2CO_2 \quad (1)$$
$$2C_yH_n + \left(\frac{n}{2} + 2y\right) O_2 \rightarrow 2yCO_2 + nH_2O \quad (2)$$
$$2NO + 2CO \rightarrow N_2 + 2CO_2 \quad (3)$$

The products coming out of the three-way catalyst system contain CO_2, H_2O, N_2, O_2, etc. The slip stream of the exhaust gas coming out of the TWC, rich in CO_2, is then passed through a fixed-bed CO_2 absorption/adsorption catalyst chamber as shown in Figure 3.

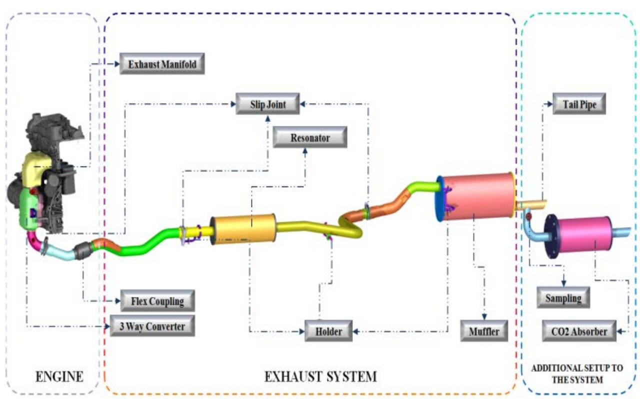

Fig.3 The Schematic of the CO_2 reduction in gasoline engine

Heterogeneous catalytic reactions are carried out in a tubular reactor of one type or another. Fixed-bed tubular reactor and tubular honeycomb structures are used in the current study. Lithium silicate-coated honeycomb is used in the first type and activated charcoal loaded in a tubular reactor is used in the second type. Two different types of granular charcoals, one from wood and the other from coconut shell, are prepared and loaded in a tubular reactor.

3. Lithium Silicate-coated Honeycomb Reactor

The tubular honeycomb catalytic reactor is fabricated as follows. A series of holes are made on the circular plates, and the plates are welded on the hollow pipe at equal distance to form a honeycomb. The honeycomb is cleaned with kerosene and washing soda, and is subsequently ready for catalyst coating.

The lithium silicate clear solution is prepared from lithium and silicon melts with Li:Si ratio 4:1. The clear solution is thoroughly mixed by continuous stirring. The liquid is uniformly sprayed through the fine nozzles on the honeycomb structure. The coated honeycomb is heat-treated at 450°C for 30 minutes and then dried in sunlight for two days. The honeycomb setup is kept inside the outer chamber. Flanges are welded on both ends of the assembly. The isometric view of the final assemblyof the catalytic reactor chamber is shown in Figure 4.

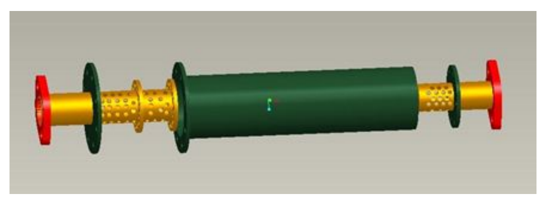

Fig 4. Catalytic reactor chamber

Positive flow exhaust gas from the automobile is fed from the inlet to the outlet of the honeycomb reactor assembly. In the second type of reactor, activated charcoal is loaded in the tubular reactor.

4. Activated Charcoal from Different Sources

Activated carbon is produced from a range of carbonaceous source materials such as nutshells, coconut shell, peat, wood, coir, lignite, coal, and petroleum pitch. Activated carbon is a micro-porous inert carbon matrix with a very large internal surface (700 to1500 m²/g).

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 8, October 2014
www.ijiset.com
ISSN 2348 – 7968

It is formed by thermal process at temperatures in the range of 600-900°C, in the absence of oxygen (usually in inert atmosphere with gases like argon or nitrogen). This material is further activated by being exposed to oxidizing atmospheres (carbon dioxide, oxygen, or steam) at temperatures above 250°C, usually in the temperature range of 600–1200 °C. Two types of activated charcoals are prepared from two different sources such as wood and coconut shell. A typical granular charcoal is shown in Figure 5.

Fig. 5 Type of activated charcoals

Experiments were carried out with the help of two catalysts, coconut shell-activated carbon and wooden coal-activated carbon. The catalysts were of granular form, with a size of approximately 300 micron. The mesh was made with a size of about 50 and 100 micron. The catalyst was packed inside the mesh and fixed in the tubular-fixed bed chamber for conducting experiments

5. Exhaust System with CO_2 Reduction System

Exhaust gas from gasoline engine is passed through three-way catalyst to convert NOx, HC, and CO. The gas coming of TWC, rich in CO_2, is passed through a CO_2 reduction catalyst chamber as shown in Figure 6. A constant volume sampling method is used to analyze the exhaust gas stream. The gas analyzer capable of analyzing CO, CO_2, HC, and NOx is used in this application. Results are reproduced by repeated experiments under identical test conditions; samples are taken before and after the catalytic chamber for quantitative measurement of CO_2 reduction.

6. Vehicle Test Assembly for CO_2 Reduction Study

The CO_2 reduction study performed from the exhaust gas at the tail pipe of the Maruti 800 passenger car is shown in Figure 6. The slip stream is taken for the experiments using a valve.

Fig. 6 CO_2reduction catalyst assemblyat the tail pipe

The quantitative reduction of CO_2 results of the absorption and adsorption efficiencies is calculated and summarized in Figure 7.

S. No	Catalyst	Concentration of CO_2 Before Catalyst (ppm)	Concentration of CO_2 After Catalyst (ppm)	CO_2 Reduction (%)
1	Activated charcoal from coconut shell	152000	142000	6.8
2	Activated charcoal from wood	152000	138000	9.2
3	Lithium silicate coated honeycomb	28000	22000	21.4

Fig.7 CO_2 reduction on different catalyst

As shown in Figure 7, the physical capture of CO_2 on charcoal from coconut shell is approximately 6.8%, whereas the absorption of CO_2on wood charcoal is about 9.2%. The catalytic adsorption and conversion in the lithium silicate-loaded honeycomb is about 21.4%. Chemical adsorption and catalytic reduction is more efficient than physical absorption as absorption is limited to physical nature of the catalyst. A detailed study of the kinetics of CO_2 reduction is planned to get the continuous adsorption and regeneration of CO_2. The efficiency of physical absorption taking place on soft charcoal (from coconut shell) is more than the absorption of CO_2 on hard charcoal (from wood).

7. Summary

Carbon dioxide emission reduction from gasoline-operated passenger cars is attempted using different catalysts. The absorption efficiencies of activated charcoals prepared from coconut shell as well as wood show the difference due to their physical characteristics. The CO_2 reduction by physical absorption on the coconut shell charcoal is approximately 6.8%, whereas the reduction of CO_2 on wood charcoal is approximately 9.2%. In order to differentiate physical absorption and catalytic adsorption, we tried to reduce CO_2 on lithium silicate-coated honeycomb. The amount and catalyst layer of lithium silicate-coated honeycomb is chosen in such a way that only chemical bonding and conversion occur, and clathration and absorption cannot take place.The catalytic activity of lithium silicate coated honeycomb is approximately 21.4%, showing relatively higher CO_2 reduction performance. Chemical adsorption and catalytic reduction certainly is more efficient than mere physical absorption, as absorption is limited to physical nature of the catalyst. A detailed kinetic study of adsorption-conversion-desorption is required to understand the mechanism

Acknowledgements

The authors acknowledge the support of Annai Vailankanni College of Engineering and Saveetha Engineering College students and management for their assistance. We sincerely thank the support of Gowtham and Sundaravadivelu at Sharda Motor R&D.

Reference

[1] S. Rajadurai, and R. Prashanthi, "Environmental Accountability for Sustainable Earth," Indian Journal of Science and Technology, 4, 350-355 (2011)

[2] IPCC "Carbon dioxide capture and storage". Special report of working group III of the IPCC, Cambridge university press, (2005)

[3] J. Figueroa, T. Fout, S. Piasyoski, H. Mcllvried, R. Srivastava, "Advances in CO_2 capture technology-the US department of energy's carbon sequestration program", Int. J. Greenhouse Gas Control,2 9-20, (2008)

[4] C. Stewart, M.A. Hessami, "A study of methods of carbondioxide capture and sequestration-the sustainability of a photo synthetic bio reactor approach", Energy convers. Manage. 46, 403-420, (2005)

[5] Bo Guo, Liping Chang and KechangXie, "Adsorption of Carbon Dioxide on Activated Carbon,"J.Natural Gas Chemistry, 15, 223-229 (2006)

[6] Jian-Rong Li a and YuguangMab, "Carbon dioxide capture-related gas adsorption and separation in metal organic frame works,"Coordination Chemistry Reviews, 255,1791-1823 (2011)

[7] M. AuliceScibioh and P.V Ragini, "Reduction of CO_2 by Nickel Macrocycle catalyst at HMDE,"Chem. Sci , 4 (2001)

[8] K. Rajalakshmi, "Photo catalytic Reduction of Carbon Dioxide in Conjunction with decomposition of water on oxide semiconductor surfaces, "Journal of electro analytical chemistry, 396,21-26 (2012)

[9] S. Rajadurai and R. K. Anulatha, "Carbon Dioxide Fixation – The Must and The Path, "International Journal of Science and Advanced Technology, Vol. 2, No 5 164 - 171 (2012)

[10] S. Rajadurai and R. K. Anulatha, "Catalytic reduction of CO2 in diesel engines - A lot with a Little," International Journal of Science and Advanced Technology, Vol. 2, No 5 164 - 171 (2014)

Biographies

First Author : Dr. S. Rajadurai, Ph. D.

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, and catalytic converter and exhaust system design 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 : R. K. Anulatha, B.E., M.B.A.

R.K. Anulatha, born in Chennai, 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. She graduated in Engineering from Vinayaka Mission University, Chennai, India (2009). She has completed her Post Graduate degree in Business Administration at the University of Madras, Chennai (2012). She worked in Professional Management Consulting from 2009 to 2012 co-coordinating professional and personal management activities, establishing end to end recruiting process, conducting training programs and interviews and providing counseling.

R. K. Anulatha is working with Dr. Rajadurai, Head of R&D, on emission control, NVH control and Program Management projects since 2012. She has been working on environmental research activities including understanding of global warming, identification of enhanced greenhouse gases, develop methods to reduce the enhanced green house gas effect. Her Earth day publication on “How to Save our Mother Earth” showed the ways to reduce green house gases and how to live green. She developed operational procedures for data base management, document control, and computer simulations.

R.K. Anulatha’s publication on “Carbon dioxide Fixation-The Must and the Path” and “Catalytic Reduction of CO_2 – A lot with a Little” are innovative and informative for climate control research programs. She had been co-ordinating student research projects at SRM University, Saveetha Engineering College and Annai Vailankannai College of Engineering for the last three years. Her keen interest in developing engineers for Sharda Motor R&D through college research projects produced more than 13 engineers in computational fluid dynamic, finite element analysis, program management and automobile exhaust system development concept engineering.