Journal of Advances in Mechanical Engineering and Science, Vol. 2(3) 2016, pp. 21-28

REVIEW ARTICLE

Prevention of Exhaust from Gasoline and Diesel Engines

[*]J Abitha[1]
[1]Udaya School of Engineering, Kanyakumari, Tamil Nadu, India.

Received-11 May 2016, Revised-7 June 2016, Accepted-15 June 2016, Published-28 June 2016

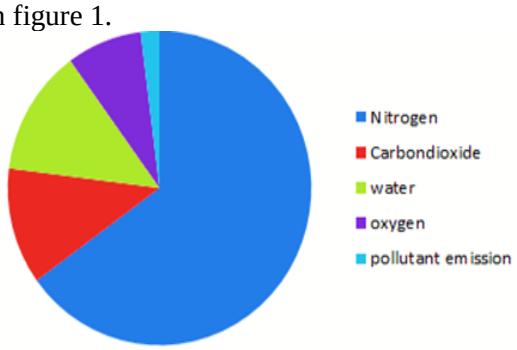
ABSTRACT

Typical road, rail, air and water transport results in exhausts that are harmful to living beings. Hence the pollutants must be filtered before it is released into the atmosphere. Various filtering methods are implemented to decontaminate the pollutant substances such as nitrogen, sulphur and carbon. Several approaches are enacted by the government too where the vehicles are permitted to discharge the exhaust within the specified limits. When these limits are strictly followed, air pollution can be limited to a certain extend. Still these approaches may not be utmost effective, unless the exhausts are filtered and thus this article deals with the available filtering techniques. Since nitrogen oxide is the most pollutant substance among other emissions, methods like Exhaust Gas Recirculation (EGR), Selective Catalytic Reduction (SCR), Diesel Particulate Filter (DPF), Lean Nitrogen Oxides Trap (LNT) techniques etc. are carried out to eliminate it.

Keywords: Pollutants, Motor vehicles, Environment degradation, EGR, SCR, LNT.

1. INTRODUCTION

[1] Diesel engines are preferred because of their cost effectiveness, efficiency and durability. Due to the advantages of diesel engines, they are mostly preferred for heavy duty vehicles. Although the merits are many, it results in the emission of pollutant substances including nitrogen, sulphur dioxide and carbon dioxide. Since there are no proper methods to filter out the emission of sulphur dioxide, ultra-low sulphur diesel is the type commonly used to arrest its outflow. The diagrammatic representation of the exhaust mixture is noted in figure 1.



Adapted from [1]

Figure 1.Diesel exhaust gas

[2] To reduce the release of exhaust gases, a lot of methods are undertaken since they cause several health issues by polluting the environment. The level and average amount of particles released are calculated and filtering techniques are adopted accordingly. By filtering the pollutants such as carbon monoxide, hydrocarbons and nitrogen oxide, the outcome of engines would not be harmful and thus air pollution can be minimised. It is stated that the emission from vehicles is the root to global warming. It substantially increases the degree of greenhouse gases and a serious issue to be focussed is the minimization of exhaust gases. Unless there is a reduction, the complications in global warming owing to environmental pollution would be grave. Hence these effluents are treated prior to their discharge into the atmosphere. Some of the control technologies of particulate matter from diesel engine are given by diesel oxidation catalyst, diesel particulate filters and closed crankcase ventilation.

[3] The usage of motor vehicles is constantly increased since people often travel

*Corresponding author. Tel.: +919442058557
Email address: sharonabitha@gmail.com (J.Abitha)
Double blind peer review under responsibility of DJ Publications
http://dx.doi.org/10.18831/james.in/2016031003

using private vehicles rather than preferring public mode of transports. As long as these vehicles are escalated, the emission from engines will be increased as well. The emission includes non- methane hydro carbon composition as well. Thus air pollution due to the effluent release is said to be high compared to other sources of air pollution and it is estimated that around 5 million people are severely affected every year throughout the world. The pollutant emission is also responsible for acid rain and ozone layer depletion. Similar to other fossil fuels, the main components of diesel are carbon and nitrogen. The resultant should be of carbon dioxide and moisture mixture, but this is not the case as it exhausts carbon-monoxide, hydro carbons, particulate and nitrous oxides. This variation occurs due to proportion of air and fuel mixture along with combustion temperature and pressure. The emission of gasoline and diesel engines varies and therefore different after-treatment systems are to be followed.

2. FILTRATION TECHNIQUES

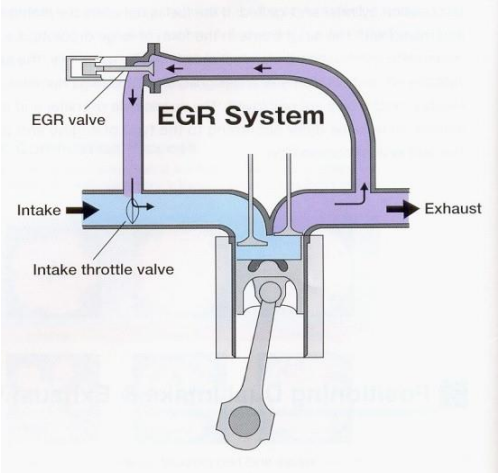
[4] The pseudo-electret fibres are well known for its efficiency which filters the micron-sized exhaust particles even at extreme temperatures. It works on the basis of di-electrophoretic force. The filter is made of several layers of fibres consisting of a pair of conductors which is developed in such a way that the micron particles get retained while applying direct current. [5] A non-thermal plasma and chemical hybrid process are performed to eliminate the oxides of nitrogen and sulphur. This process converts nitric oxide to nitrogen dioxide which is further converted to soluble compound in-turn to nitrogen.

3. STRATEGIES TO CONTROL DIESEL EXHAUST

[6] Incomplete internal combustion results in the release of oxides of carbon, nitrogen and sulphur, hydrides of carbon and particulate matter. These pollutants from diesel engines are more compared to petrol engines. Still diesel engines are employed more owing to their fuel and torque efficiencies. Installation of filtering equipment within the vehicle may occupy a lot of space and so in-cylinder solutions are favoured which is also cost effective. [7] Many vehicles are subjected to tests under normal driving conditions to calculate the amount of emission out-letting the stream under portable emission measurement system equipment. [8] Though hydro carbon, particulate matter and carbon monoxide emissions are low during engine idling state, exhaust of nitrogen oxides are measured to be high. Hence auxiliary power units, direct fire heater and thermal power storage are used to reduce fuel intake and idling emissions as engine idling condition does not favour efficiency.

3.1. Exhaust gas recirculation

Exhaust gas recirculation method is one of the filtering techniques used to control the emission of exhaust. Still, it is unsuitable for heavy engines because usage of EGR may reduce oxides of nitrogen but increases the exhaust of particulate matter in-turn. To perform EGR, this technology itself consumes a lot of fuel leading to lower efficiency. Therefore in-cylinder solutions such as modified injection system and lower compression methods are also carried out while adopting EGR. The basic EGR system is given in figure 2.



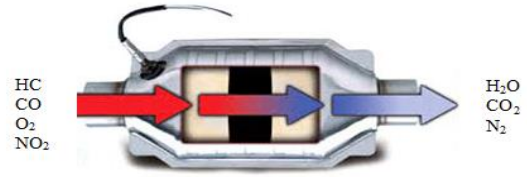
Adapted from [9]

Figure 2.Exhaust gas recirculation

3.2. Catalytic converter

Catalytic converter is the technique used to control emission which reduces the toxicity of unfavourable gases emerging from engines. Three way catalytic converters are used in emission control procedures in many countries since it offers an effective way in reducing the pollutants of nitrous oxide. [10] Optimization of results can be achieved using three-way catalytic converter in low emitting vehicles. Conventional three-way catalysts cannot aid in removal of nitrogen oxides. To

avoid such circumstances, other catalytic methods have to be carried out. The basic catalytic converter is given in figure 3.



Adapted from [11]

Figure 3.Catalytic converter

3.3. Diesel oxidation catalyst

[12] Diesel oxidation catalyst is a significant remover of particulate emission from diesel motor. It shows higher durability. Figure 4 describes the basic structure of DOC. It oxidises unburned hydrocarbons and the oxides of carbon and hydrogen. The outlet of the vehicle where the exhaust emerges is been equipped with an upstream cerium and zeolite catalytic mixture which lowers the quantity of particulate substance. The filtering device is said to be wall-flow filters. Another method of DOC consists of two layers. Inner core is made of palladium and gold and outer core is of platinum in which, when the diesel exhaust is passed through, it cleans up the particulate matter from the emission.

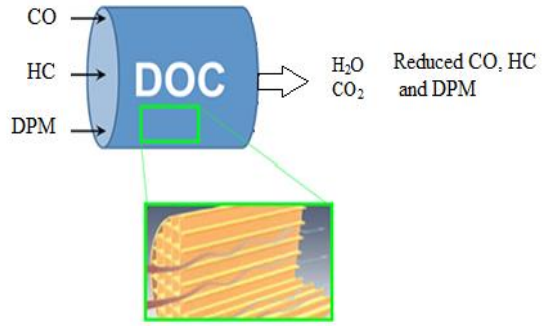


Figure 4.Basic DOC process

3.4. Lean nitrogen oxide trap

[13] The exhaust is allowed to pass through lean nitrogen oxide trap to reduce the outcome of nitrogen oxides present in the exhaust. The experiments result in higher efficiency when higher rate of exhaust gas recirculation is performed. Hence the effectiveness lies with respect to the EGR proficiency. [14] The procedure to limit nitrogen oxide is done using in-cylinder control strategy where air-ratio is adjusted by using engine management system. [15] It uses multi-layer filtration to enhance the performance of filter which is combined with monolith reactor. The efficiency of LNT technique is improved by the presence of oxidised catalytic layer. This enhances nitrogen oxide filtration at particularly lower temperatures.

3.5. Selective catalytic reduction

[16] One of effective removal of nitrogen oxide from diesel exhaust is selective catalytic reduction method. It uses the catalytic composition of cerium, tungsten and titanium by homogeneous precipitation technique. [17] SCR uses zeolite catalyst by nitric oxide reduction and ammonia oxidation activities. Since SCR is used to treat the oxides of nitrogen, other techniques of emission control such as particulate filter and oxidation catalyst are also included to prevent the emission of particulates and carbon particles respectively. [18] A catalytic filter, $Pd/LaMnO_3$ is used to filter hydro carbons and the oxides of carbon and nitrogen.

3.6. Diesel particulate filter

DPF has been used for the removal of particulate matter from the diesel exhaust stream. One of the approaches is categorised by means of two honey comb structure which filters the exhaust gas. [19] It also prevents solid particles emitting from the exhaust stream by various physicochemical processes. [20] The factors of fuel injection rate, inlet location, temperature and exhaust flow rate are to be considered. This technique may emit nitrous oxide during fuel injection. [21] The system with nano-metric composite materials of ionic conductors is used to eliminate diesel particulates. It suggests to under-go several basic tests prior to the implementation of filters to determine its efficiency.

[22] Diesel particulate filter is been used along with partial flow filter which lowers the fuel intake. The results by changing the space velocity under exhaust flow rate and particulates are examined. The investigation shows higher efficiency when partial flow filter is used. [23] While using DPF, the sediments which retains in the filter may cause back pressure and therefore the filter is required to be checked frequently to remove the filtered sediments. This is done by a mathematical operation of multiple regression theory which enhances fuel economy as well.

3.7. Biodiesel blend

[24] Diesel can be replaced with bio fuel namely, biodiesel. Although the usage of bio diesel considerably reduces the emission of carbon monoxide, hydro carbons, solid particles, nitrogen oxides emission, fuel consumption is comparatively more and hence blended biodiesel is preferred for the method of dynamic blend estimation by an extended kalman filter. Biodiesel production is costlier and can be produced by microemulsion, thermal cracking and transesterification methods.

3.8. Hydrated lime filter

[25] For the oxidation of nitric oxide, non-thermal plasma combustion procedure is applied which deals with the problem of diesel exhaust. This procedure is followed by hydrated lime filter to prevent the emission of toxic nitric oxide to the environment.

3.9. Plasma reactors and soot oxidation

[26] Plasma reactors are constructed for the removal of nitrogen oxides emission from the diesel exhaust where the exhaust is passed through the reactors axially or radially. [27] Non-thermal plasma technique is one of the effective methods to eliminate nitrogen oxides from the exhaust. This technique includes homogeneous nucleation and condensation along with NH_4NO_3 vaporisation. Perhaps, the tests are carried out under high temperature to maximise its efficiency. [28] The method is comprised of a transformer and an ignition coil to generate high frequency AC voltage and pulse accordingly where a cascaded plasma-adsorbent method is used to maximise the efficiency. [29] Soot oxidation is done by using a DC corona discharge and oil bath mechanism. After a series of experiments and procedures, it is noted that the oil used in the study absorbs considerable quantity of unburned carbon or soot particles.

4. TECHNIQUES TO CONTROL PETROL EXHAUST

Petrol exhaust can be treated using alumina-platinum-halogen catalyst. The temperature point has to be checked before exposing it to the catalytic filter. The filter is placed in between the gasoline container and the exhaust stream where the solid particles are evaporated. This can be made of glass or any other material and the filtering aid requires to be kept cleaned and checked often to prevent the stagnant of disposal materials in-turn to maintain its efficiency. [30] Lean burn petrol engines are efficient where elimination of nitrogen oxides from the emission requires certain type of catalyst which deals with sulphur poisoning and thermal deterioration. Particulate matter filter consists of porous substrate which filters the solid particles emitting from the stream.

[31] Conventional gasoline can be replaced with reformulated gasoline which reduces smog and this is been made compulsory in many places. Sulphur contents must be excluded and gold based contact materials are favoured to noise free signals.

4.1. Gasoline particulate filter

[32] Gasoline particulate filter reduces black carbon mass effectively in gasoline direct injection and port fuel injection vehicles. Carbon particles are emitted more when the engine is started at ambient temperature. Such types of engines should be equipped with particulate filter that prevents the outcome of exhaust.

[33] The emissions of gasoline vehicles are sampled using a constant volume sampler. A number of vehicles are used for this purpose and it is found to be non-volatile. It is investigated that quartz filters are capable to filter out the emission of low duty gasoline vehicles.

4.2. Soot oxidation and three-way catalyst

[34] It is found that by using a three-way catalyst over gasoline exhaust stream, fuel intake is minimised leading to higher efficiency as well. The combustion mechanism is enhanced with higher absorption of soot particulates.

4.3. Active carbon filter

[35] The atmosphere is contaminated due to the evaporation of unburned fuel and the ejection of gaseous exhaust. The polluted airflow, its speed and the treatment process are studied. It states that around 70% of exhaust is purified by using active carbon filter.

5. DRAWBACKS OF CATALYST USAGE

[36] Usage of gasoline catalyst of Pt-Pd-Rh and Pd-Rh and diesel engine catalyst of platinum shows negative aspects. The analysis is determined by plasma mass spectrometry

and the impact of using petrol engine is higher compared to diesel engine.

6. FUTURE SCOPE

A mobile apparatus is been devised which absorbs the polluted outcome of solid particulates, unburned coal, dust, nitrogen, carbon and sulphur oxides. The collected exhaust are treated and disposed frequently at different times of use. The apparatus may include a purifying unit to convert carbon monoxide and nitrogen oxide into carbon and nitrogen dioxides accordingly. It also includes a washing section and a catalytic filter where these converted dioxides are purified using hydroxyl ions followed by filtration.

[37] A novel real time, cost effective emission control method is described. Among various pollutants of hydro carbons, nitrogen oxides and particulate matter, emission of nitrogen oxides is more destructive. Hence this approach would be constructive and should be promoted for future use. [38] The prevention methods include receptor modelling methods which estimates the source emission of Nano particles. [39] At present, many vehicles are being equipped with catalytic filters to reduce these toxic emissions.

7. CONCLUSION

The article reviews the filtering techniques and the control methods to prevent combining of contaminated gases with atmospheric gases. Without utilizing the filtering techniques, general emission standards as allotted by the government cannot be fulfilled. Biodiesel blend can be used as an alternative fuel for diesel engines. [40, 41] Emission of Nano solid particles affects human systems. Studies show that all internal combustion engines without filtering components emits toxic materials. Older engines emit more of these exhausts. [42] Gaseous emissions are more harmful than particulate substances and hence treating of carbon products with standard technology should be made compulsory as it directly affects the human cells. [43, 44, 45] It is analysed that the exhaust causes toxicity, pulmonary malfunction, inflammation and DNA manipulation. The other effects such as cardiac and pulmonary mortality due to the exposure of such poisonous exhausts are reviewed. Since older engines are more prone to such defects, these engines must be serviced regularly. [46] Investigations are done on the effects of wood combustion and ship engines. Due to various harmful effects, filtering technologies must be developed to meet the standard emission norms. Copper and iron composition of zeolite base is used widely which considerably reduces nitrogen oxides. It is highly preferred as it is thermally stable, active and less prone to deactivation. Though cost effective units are preferred, installation of emission techniques should not be avoided even if the processing methods are costlier.

REFERENCES

[1] Ibrahim Aslan Resitoglu, Kemal Altinisik and Ali Keskin, The Pollutant Emissions from Diesel-Engine Vehicles and Exhaust After-Treatment Systems, Clean Technologies and Environmental Policy, Vol. 17, No. 1, 2015, pp. 15-27, http://dx.doi.org/10.1007/s10098-014-0793-9.

[2] Timothy R.Dallmann, Thomas W.Kirchstetter, Steven J.DeMartini, and Robert A.Harley, Quantifying On-Road Emissions from Gasoline-Powered Motor Vehicles: Accounting for the Presence of Medium- and Heavy-Duty Diesel Trucks, Environmental Energy Technologies, Vol. 47, No. 23, 2013, pp. 13873–13881, http://dx.doi.org/10.1021/es402875u.

[3] P.F.Nelson and S.M.Quigley, The Hydrocarbon Composition of Exhaust Emitted from Gasoline Fuelled Vehicles, Atmospheric Environment, Vol. 18, No. 1, 2003, pp. 79-87, http://dx.doi.org/10.1016/0004-6981(84)90230-0.

[4] I.Inculet, P.Castle, M.Slanina and M.Duca, Pseudoelectret Filter for Micrometer-Sized Particles in Exhaust Gases at 210°C, IEEE Transactions on Industry, Vol. 38, No.1, 2002, pp. 64-68.

[5] Hashira Yamamoto, Yuri Yamamoto, Tomoyuki Kuroki and Kota Yoshida, Pilot-Scale Exhaust Gas Treatment for A Glass Manufacturing System using a Plasma Combined Semi-Dry Chemical Process, Industry Applications Society Annual Meeting, Addison, 2015, pp. 1-7.

[6] P.Brijesh and S.Sreedhara, Exhaust Emissions and its Control Methods in Compression Ignition Engines: A Review, International Journal of Automotive Technology, Vol. 14, No. 2, 2013, pp. 195-206.

[7] Jerzy Merkisz and Jacek Pielecha, Passenger Cars Exhaust Emissions under Real Driving Conditions, Automotive Engineering, 2016, pp. 127-139, http://dx.doi.org/10.1007/978-3-319-27276-4_12.

[8] S.M.Ashrafur Rahman, H.H.Masjuki, M.A.Kalam, M.J.Abedin, A.Sanjid and H.Sajjad, Impact of Idling on Fuel Consumption and Exhaust Emissions and Available Idle-Reduction Technologies for Diesel Vehicles-A Review, Energy Conversion and Management, Vol. 74, 2013, pp. 171-182.

[9] Ming Zheng, Graham T.Reader and J.Gary Hawley, Diesel Engine Exhaust Gas Recirculation–A Review on Advanced and Novel Concepts, Energy Conversion and Management, Vol. 45, No. 6, 2004, pp. 883–900.

[10] M.Ranganathan, S.A.Renald Remo, U.Kishore, S.Yuvaraj and S.Arun, Development and Performance Analysis of New Catalytic Converter, International Journal of Engineering Research and Science and Technology, Vol. 1, No. 3, 2015.

[11] G.C.Koltsakis, P.A.Konstantinidis and A.M.Stamatelos, Development and Application Range of Mathematical Models for 3-Way Catalytic Converters, Applied Catalysis B: Environmental, Vol. 12, No. 2-3, 1998, pp. 161-191, http://dx.doi.org/10.1016/S0926-3373(96)00073-2.

[12] Russella and William S.Eplinga, Diesel Oxidation Catalysts, Catalysis Reviews: Science and Engineering, Vol. 53, No. 4, 2011, pp. 337-423, http://dx.doi.org/10.1080/01614940.2011.596429.

[13] Mostafa Koochak, Ayatallah Gharehghani and Mahdi Shahbakhti, Experimental and Simulation Study of In-Cylinder Strategies for Regeneration of Lean Nitrogen Oxide Traps in a High-Speed Direct-Injection Diesel Engine, Journal of Automobile Engineering, 2013, http://dx.doi.org/10.1177/0954407013504751.

[14] Joo Wung Yoon and Simsoo Park, Investigation of the Nitrogen Oxide Reduction Characteristics and In-Cylinder Controls of the Regeneration Mode of a Lean Nitrogen Oxide Trap Catalyst in a Light-Duty Diesel Engine, Journal of Automobile Engineering, Vol. 227, No. 7, 2013, http://dx.doi.org/10.1177/0954407012475272.

[15] Marek Vaclavik, Vladimr Novak, Jan Brezina, Petr Koci, Greigory Gregori and David Thompsett, Effect of Diffusion Limitation on the Performance of Multi-Layer Oxidation and Lean Nox Trap Catalysts, Catalysis Today, Vol. 273, 2016, pp. 112–120.

[16] Wenpo Shan, Fudong Liu, Hong He, Xiaoyan Shi and Changbin Zhang, A Superior Ce-W-Ti Mixed Oxide Catalyst for the Selective Catalytic Reduction of NOx with NH3, Applied Catalysis B: Environmental, Vol. 115–116, 2012, pp. 100–106, http://dx.doi.org/10.1016/j.apcatb.2011.12.019.

[17] Ja Hun Kwak, Diana Tran, Janos Szanyi, Charles H.F.Peden and Jong H.Lee, The Effect of Copper Loading on the Selective Catalytic Reduction of Nitric Oxide by Ammonia Over Cu-SSZ-13, Catalysis Letters, Vol. 142, No. 3, 2012, pp. 295-301, http://dx.doi.org/10.1007/s10562-012-0771-y.

[18] Mohammad Hossein Saberi, Abbas Ali Khodadadi and Yadollah Mortazavi, Selective Detection of Unburned-Hydrocarbon in the Exhaust Gas Using Catalytic Filter, IEEE Sensors Proceedings, Valencia, 2014, pp. 1839-1842.

[19] Grigorios Koltsakis, Onoufrios Haralampous, Christopher Depcik and J.Colter Ragone, Catalyzed Diesel Particulate Filter Modeling, Reviews in Chemical Engineering. Vol. 29, No. 1, 2013, pp. 1–61, http://dx.doi.org/10.1515/revce-2012-0008.

[20] T.Tang, D.Cao, J.Zhang and Y.Zhao, Experimental Study of Catalyzed Diesel Particulate Filter with Exhaust Fuel Injection System for Heavy-Duty Diesel Engines, SAE Technical Paper, 2014, http://dx.doi.org/10.4271/2014-01-1496.

[21] Jerzy Merkisz, Pawel Fuc, Piotr Lijewski and Andrzej Ziolkowski, The Application of Nano-metric Composite Materials in a Diesel Engine in the Aspect of Improvement of Deep Bed Filtration in a Diesel Particulate Filter, World Automotive Congress, Vol. 189, 2012, pp. 767-778.

[22] Isaline Lefort, Jose Herreros and Athanasios Tsolakis, The Use of a Partial Flow Filter to Assist the Diesel Particulate Filter and Reduce Active Regeneration Events, SAE International Journal of Engines, Vol. 7, No. 4, 2014, http://dx.doi.org/10.4271/2014-01-2806.

[23] Fu Jun Gong Jinke, Yuan Wenhua and Yu Mingguo, Study on the Exhaust Back-pressure Threshold-value MAP for the Diesel Particulate Filter Regeneration, Third International Conference on Measuring Technology and Mechatronics Automation, Shangshai, 2011, pp. 557-560.

[24] David B.Snydera, Ray W.Herrick, Gayatri H.Adia, Michael P.Buncea and Carrie M.Halla, Dynamic Exhaust Oxygen Based Biodiesel Blend Estimation with an Extended Kalman Filter, Proceedings of the American Control Conference, Baltimore, 2010, pp. 3009-3014.

[25] T.Goto and R.Ohyama, An Experimental Study on Neutralization of Non-Thermal Plasma Oxidized Diesel Engine Combustion Exhaust Nox Gases with Hydrated Lime Filter, Electrical Insulation and Dielectric Phenomena, USA, 2004, pp.114-117.

[26] Sankarsan Mohapatro and B.S.Rajanikanth, Studies on Removal from Diesel Engine Exhaust Using Duct-Type DBD Reactor, IEEE Transactions on Industry, Vol. 51, No. 3, 2015, pp. 2489-2496.

[27] Kenji Yamada, Kaname Mitsuyoshi and Masayuki Itoh, Improvement of NOx Reduction Efficiency in High Temperature System by Aerosol Assisted Non-Thermal Plasma Technique, IEEE International Conference on Plasma Science, Monterey, 2005, pp. 322.

[28] Sankarsan Mohapatro and B.S.Rajanikanth, Portable HVAC and Pulsed Plasma Sources for Control of NOx in Diesel Engine Exhaust, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 18 , No. 6, 2012, pp. 1821-1828.

[29] Y.Tashiro, Kanazawa, Y.Honda, K.Hayashi and T.Yoshioka, Removal of Soot in Diesel Exhaust Gases by a Combination of DC Corona Discharge and Oil Bath, IEEE Conference on Plasma Science, Canada, 2002.

[30] Masahiko Takeuchi and Shinichi Matsumoto, NOx Storage-Reduction Catalysts for Gasoline Engines, Topics in Catalysis, Vol. 28, No. 1, 2004, pp. 151-156.

[31] E.Smith and Deringer Ney, Contact Systems for Use in Sulfur Containing, Reformulated Gasolines, Proceedings of the 50th IEEE Holm Conference on Electrical Contacts and the 22nd International Conference on Electrical, USA, 2004, pp. 289-296.

[32] Tak W.Chan, Eric Meloche, Joseph Kubsh, and Rasto Brezny, Black Carbon Emissions in Gasoline Exhaust and a Reduction Alternative with a Gasoline Particulate Filter, Environmental Science and Technology, Vol. 48, No. 10, 2014, pp. 6027–6034, http://dx.doi.org/10.1021/es501791b.

[33] Andrew A.May, Albert A.Presto, Christopher J.Hennigan, Ngoc T.Nguyen, Timothy D.Gordon and Allen L.Robinson, Gas-Particle Partitioning of Primary Organic Aerosol Emissions: (1) Gasoline Vehicle Exhaust, Atmospheric Environment, Vol. 77, 2013, pp. 128-139, http://dx.doi.org/10.1016/j.atmosenv.2013.04.060.

[34] Bogarra-Macias, M.Herreros-Arellano, J. Tsolakis and A.York, Reformate Exhaust Gas Recirculation (REGR) Effect on Particulate Matter (PM),

Soot Oxidation and Three Way Catalyst (TWC) Performance in Gasoline Direct Injection (GDI) Engines, SAE International Journal of Engines, Vol. 9, No. 1, pp. 305-314, 2016, http://dx.doi.org/10.4271/2015-01-2019.

[35] Lepadatu, Ioan, Ciocanea and Adrian. The Efficiency of Street Car Pollution Reduction Equipments, Hidraulica, No. 4, 2013, pp. 85-90.

[36] M.Moldovana, M.Gomeza, G.Morrisonb, S.Rauchb, C.McLeodc, R.Mac, S.Carolid, F.Petruccid, B.Boccad, P.Schramele, M.Zischkae, U.Wassg and J.Santamariaj, Environmental Risk of Particulate and Soluble Platinum Group Elements Released from Gasoline and Diesel Engine Catalytic Converters, Science of the Total Environment, Vol. 296, No. 1-3, 2002, pp. 199–208.

[37] S.Jaganth Nivasan, S.V.Jegan, R.Ramkumar and Sanjoy Deb, Real Time Air Pollution Monitoring and Control System for Diesel Engine, Journal of VLSI Design and Signal Processing, Vol. 2, No. 1, 2016.

[38] Prashant Kumar, Liisa Pirjola, Matthias Ketzel and Roy M.Harrison, Nano Particle Emissions from 11 Non-Vehicle Exhaust Sources-A Review, Atmospheric Environment, Vol. 67, 2013, pp. 252-277, http://dx.doi.org/10.1016/j.atmosenv.2012.11.011.

[39] Virginia Routley, Motor Vehicle Exhaust Gas Suicide, Crisis, Vol. 28, No. S1, 2007, pp. 28-35.

[40] Yan-Lin Zhang, Kimitaka Kawamura, Tomomi Watanabe, Shiro Hatakeyama, Akinori Takami and Wei Wang, New Directions: Need for Better Understanding of Source and Formation Process of Phthalic Acid in Aerosols as Inferred from Aircraft Observations over China, Atmospheric Environment, Vol. 140, 2016, pp. 147-149.

[41] Mayer, A.Czerwinski, J.Kasper and M.Ulrich, Metal Oxide Particle Emissions from Diesel and Petrol Engines, SAE Technical Paper, 2012, http://dx.doi.org/10.4271/2012-01-0841.

[42] Lucky Joeng, Shahnaz Bakand and Amanda Hayes, Diesel Exhaust Pollution: Chemical Monitoring and Cytotoxicity Assessment. AIMS Environmental Science, Vol.2, No.3, 2015, pp. 718-736.

[43] Mohan Durga, Soundararajan Nathiya, Abbu Rajasekar and Thiyagarajan Devasena, Effects of Ultrafine Petrol Exhaust Particles on Cytotoxicity, Oxidative Stress Generation, DNA Damage and Inflammation in Human A549 Lung Cells and Murine RAW 264.7 Macrophages, Environmental Toxicology and Pharmacology, Vol. 38, No. 2, 2014, pp. 518–530.

[44] Lucky Joeng, Amanda Hayes and Shahnaz Bakand, Validation of the Dynamic Direct Exposure Method for Toxicity Testing of Diesel Exhaust In Vitro, Hindawi Publishing Corporation, ISRN Toxicology, Vol. 2013, pp. 1-11, http://dx.doi.org/10.1155/2013/139512 .

[45] Doug Brugge, John L.Durant and Christine Rioux, Near-Highway Pollutants in Motor Vehicle Exhaust: A Review of Epidemiologic Evidence of Cardiac and Pulmonary Health Risks, Environmental Health, Vol. 6, No.23, 2007, http://dx.doi.org/10.1186/1476-069X-6-23.

[46] Zimmermann, R.Buters, S.Dietmar, T.Paur, H.Dilger, M.Mülhopt, S.Harndorf, H.Stengel, B.Rabe, R.Hirvonen, J.Hiller and K.Sapcariu, A Comprehensive Study on the Chemical Composition, the Physical Properties and the Molecular Biological and Toxicological Effects on Human Lung Cells of Aerosols from a Ship Diesel Engine Operated with Heavy or Light Diesel Fuel Oil, American Geophysical Union, 2013.