ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 9, Issue 6, June 2022

Automobile Exhaust Purification System

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Abstract*— In accordance with globalization, privatization etc., India is the 5th largest auto market in the world. Along with that, India ranks 3rd in carbon emission as per the data of 2020 proving, the total CO2 emission has been increased to 988.6 tonnes per year. Hence, there is a tremendous increase in air pollution. In some cities, 80% of air pollution is from automobile exhaust. Although coming is an era of e-mobility, the immediate transformation from internal combustion engine to electric vehicle seems to be hectic. This is because of many factors such as expense, charging facility, power etc. Analyzing the difficulty in the rapid face change, suitable techniques can be introduced which can purify and reduce the automobile exhaust minimizing the amount of harmful chemicals in it. The chemicals coming after EGR (Exhaust Gas Re-circulation) include CO2, SO2, NO2, CO and hydrocarbons which could generate particulate matter. These contaminants are a threat to the living beings as well as the archaeological monuments. There exists another fact that the arrival of the vehicle scrappage policy may be an unfortunate hit for the owners having vehicles older than 20 years. Due to the harmful exhaust gas, these are to be scrapped even though they have high performance at the scrapping time. Hence, this project discusses various techniques which can be employed to absorb the hazardous pollutants from the exhaust gas before releasing to the atmosphere. The project explains the various experimental methods including catalysis, honeycomb filtering, UV method etc., resulting in the design of an efficient tail gas purification system in a moving vehicle. Hence, through proper research if the project gives a good result in the purification process, this might be an excellent solution for the above addressed problems.

***Index Terms*— DOC, DPF, EGR, Emission Control System, PID Controller, RTD**

I. INTRODUCTION

Air pollution is accidental in todays' world since it is deteriorating the quality of living. It is a drastic issue which affects all the living beings in earth. The pollution from automobiles is a global concern as the number of vehicles on the road are increasing day by day. With this number the amount of air pollution is also surging. Today, many health problems along with natural hazards like acid rain, smog etc., are becoming common in metropolitan cities due to this spike in pollution.

The introduction of the vehicle scrappage policy is been on the roll, the implementation is very hectic as requires scrappage of old vehicles due to its pollution even though it is efficient in running. If this loss can be reduced by large amounts by introduction of devices, the system can save large amounts of money, work force and raw materials. Engine efficiency may get reduced after five years for a vehicle and therefore due to incomplete combustion the concentration of pollutants released directly to the atmosphere as exhaust increases.

There are methods like EGR (Exhaust Gas Recirculation) mechanism and a catalytic converter already present in vehicles in order to reduce pollution. EGR valve will recirculate the fuel-air mixture that have undergone incomplete combustion by mixing it with the fresh fuel-air mixture entering to the engine. By this mechanism a major concentration of oxides of nitrogen and sulphur are removed. After this process the final exhaust will enter in to the catalytic converter, where the honeycomb structured filters containing reducing agents like platinum, palladium etc., are placed. So, a reduction process takes place and as a result the elements from its oxides are adsorbed by these filters. Therefore, the concentration of that specific element in the exhaust decreases. Hence, the toxicity of the automobile exhaust directly released to the atmosphere can be reduced if it is integrated with a control system discussed in this paper.

II. METHODOLOGY

EGR (Exhaust Gas Re-circulation) is an important pollution reduction method in petrol and diesel engines. It regulates the subsequent mixing of the exhaust gas along with the intake air. After proper combustion using EGR, nitrogen oxide quantities can be reduced up to 70%. But at higher temperature these amounts increase rapidly. Hence simple EGR is no longer sufficient to fulfil emission standards as of now. Near to the cylindrical section on the exhaust pipe, a possibility of a control system is introduced which can analyse and purify the hazardous chemicals with several techniques. The main chemicals present in the automobile exhaust are: Oxides of nitrogen, carbon and sulphur. In order to reduce these chemicals, the following methods can be employed in the instrumentation part which are:

A. Catalysis

Catalysts such as Al_2O_3, TiO_2, SiO_2 along with porous honeycomb structures can provide more surface area for adsorption. The combination of these catalysts as filters and the combined honey comb structure can produce high reduction in the emission. The catalytic filters can absorb lot of chemicals from its molecules. Noble metals are better absorbers and certain arrangement methods like honeycomb

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arrangements can add on to the increased efficiency [1].

B. Filters

The filters with honey comb structures with activated catalysts or gas separating inner filters can be employed to adsorb chemicals from exhaust. The outcomes may still contain impurities like carbon components, which is very dangerous to human life and even can damage the ecosystem and hence the carbon filter using other materials like magnesium [2,9].

C. Collection of carbon

The carbon as a single component can be used to produce different types useful products, hence we aim to install a collector that accumulates the carbon and can be easily replaceable [3].

D. Measurement of carbon accumulated

Using the device, the calcium carbonate formed as a result of reaction can be collected and if it exceeds a level, it can be disposed using a valve controlled by a relay. If it is collected in a collection centre, it can be utilized to make other commercial products.

These methods may or may not be as ideal as expected and hence the parameters like temperature, pressure, etc., has to be measured continuously. So, gauges and thermometers can be installed to ensure the perfection of the device [Fig.1].

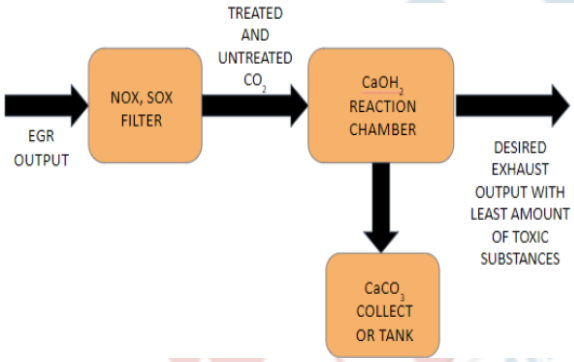

Fig.1 Block diagram of methodology

III. DESIGN

The product aims to reduce the pollutants coming out of the exhaust using a temperature controller system for maximum efficiency. At starting conditions, the temperature inside the devices will be very less and the reduction of CO_2 into $CaCO_3$ is an exothermic action. This heat produced can be used to increase the temperature of working of the initial filter, which will add on the efficiency. Along with the temperature increase the new design will maintain the same pressure.

The second filter is accompanied by a temperature control system. The temperature is controlled around 350°C where maximum efficiency is produced. The construction and temperature control will be dealt with in the second module.

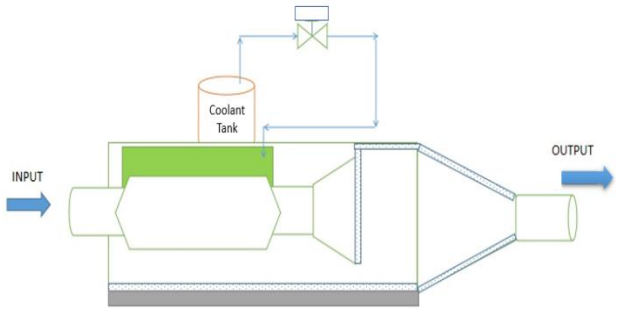

Fig.2 Design of the reaction chamber

The chamber is made of GI steel [Fig.2]. The chamber has an inlet which is directly connected to the filtering vessel. The output of the filtering vessel is expanded into the reaction chamber, here the chamber is fitted with mesh that is filled with $Ca(OH)_2$ gel/paste applied on them. The vessel is also fixed with a coolant chamber for controlling the temperature coming out of the vessel. The temperature from the outlet side is measured and is used to control the coolant flow in the coolant chamber.

The exhaust from the vessel which has high amounts of CO_2 reacts with $Ca(OH)_2$ producing $CaCO_3$ which is collected at the bottom. This reaction takes some time and hence the outlet valve is kept closed for a few seconds so that the time required for the process is easily available. The treated desired exhaust gas with the expectation of the least amount of non-toxic gasses will be given out of the outlet pipe of the chamber into the atmosphere which has to be measured for analysing the process. The collected $CaCO_3$ can be used in different industries such as cement industry for the production of gypsum and it can be used in floor tile manufacturing industries. And this also leads to the conversion of undesired waste to a desired product along with going eco-friendly.

The device was constructed as three stages: filtering vessel, reaction chamber and piping and instrumentation part. The filtering vessel is made up of mild steel of thickness of up to 3 mm thickness. The output side is fixed with nuts and bolts and can be opened to replace the filter. The length of the filter section is 31cm and the inside diameter is 15 cm. The connection part is of 10 cm and 15 cm in the input and the output of the section.

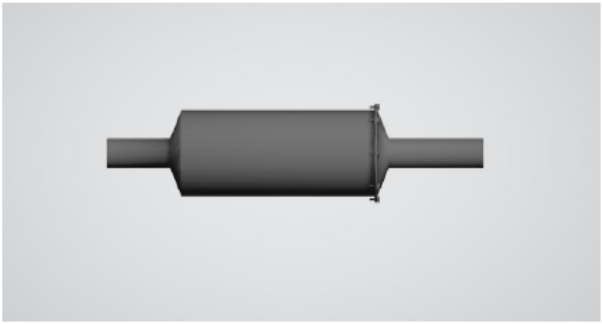

Fig.3 3D image of the vessel

ISSN (Online) 2456-1290

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A 3D design of the filtering vessel was to be designed to check for various requirements in gas flow [Fig.3]. An inlet and outlet for the gas to enter and exit was constructed. At the inlet side the flange is not permanently welded in order to ensure the replacement of used filters [Fig.4]. A conical shape at inlet and outlet sides are designed to compensate the pressure variations [4].

Fig.4 Filtering vessel designed in lathe

The chamber is made of GI steel [Fig.5]. The chamber has an inlet which is directly connected to the filtering vessel. The output of the filtering vessel is expanded into the reaction chamber, here the chamber is fitted with mesh that is filled with $Ca(OH)_2$ gel/paste applied on them. The vessel is also fixed with a coolant chamber for controlling the temperature coming out of the vessel. The temperature from the outlet side is measured and is used to control the coolant flow in the coolant chamber.

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The filters are made up of ceramic honeycomb structures which are filled with [Pt-Pd] combo and [Pt -Rd] which converts almost all the impurity components to carbon dioxide and nitrogen. Except CO_2 which will be dealt with in the second half of the purification system which will be done along with the temperature-controlled action. The reason is why the filters are honeycomb is because it provides a large surface area and it avoids any pressure variations [6,7].

Fig.5 Reaction Chamber

The electrical circuit uses a primary sensing element [RTD] that itself produces output in electrical form corresponding to the measurement [Fig.6]. The RTDs are available in different ranges and for the circuit, it uses a range of -50 to 450° C temperature range [11].

The output from the RTD is given to the PID controller which is capable of producing ON-OFF as well as throttled control action. The output of RTD is given to the controller that compares the set point provided by the operator. If the circuit is designed for PID control then the controller with the help of fuzzy logic selects a suitable gain for proportional, integral and derivative actions. The output is connected to a relay and acts as the manipulating mechanism in the measurement and control system. The output of the relay is variable AC and is connected into the electrically actuated solenoid valve [12].

The valve operates either in ON-OFF condition or in throttling valve conditions depending upon the selection of the valve. The output of the control valve is given to the coolant jacket placed inside the reaction chamber and on the filtering vessel. This is how the circuiting is done for the temperature control.

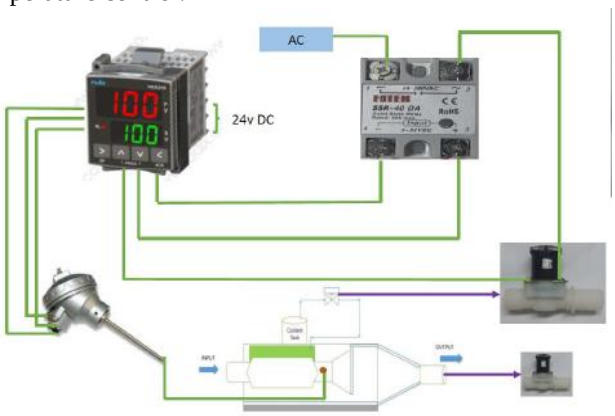

Fig.6 Electrical circuit design for temperature control

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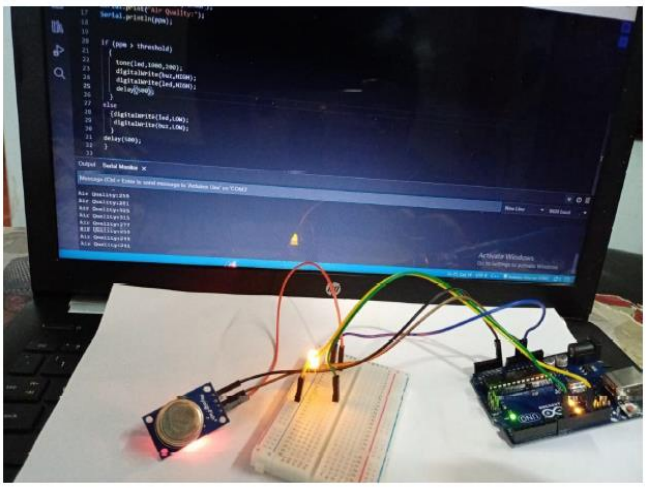

Fig.7 Pollution Testing device

A coolant tank is installed on top of the reaction chamber as the coolant reservoir. It has two ports, an outlet connected to the inlet of the coolant jacket and the inlet is connected to the outlet of the jacket so that there will be recirculation of coolant in order to minimize the exhaust temperature inside the chamber. The output of RTD determines how much coolant to be entered into the jacket and it is ensured by connecting a control valve between the inlet and outlet of jacket and tank respectively. If the flowrate from the jacket to tank is low, a pump can be installed for proper working. The reaction chamber should be sealed properly before experimentation and that can be done using a silicon sealant.

After implementation of every part, it is not worth enough to check for the progress in labs or PUC centres, it is not a cost-effective method and sometimes if the implementation is not perfect then the expensive sensors in the lab can get damaged. So, a pollution testing system using Arduino and MQ 135 pollution sensor is developed to check the pollution level before and after filter placements and also after reaction part [Fig.7].

IV. CONCLUSION

The pollution testing device indicated accurate values while experimentation. An ON-OFF controller was designed to control the temperature of the exhaust gas. At higher loads also, the controlling circuit served the purpose. The gauges and thermometers connected to the chamber ensured proper working of the instrument.

V. FUTURE SCOPE

The designed device can play a vital role in the automotive industry. The air pollution contribution from the automobile sector can be minimized by installing the device commercially. The vehicle scrappage policy implementation can be delayed which may be a relief for the stakeholders who have to scrap their vehicle for not following the pollution norms even if it contains a high-power engine.

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