

A Review Paper on Emission Characteristics and Performance of Catalytic Converter

Meraman K. Modhavadiya¹, Prof. Vinod M.Makwana²

¹PG Student, Mechanical Engineering Department, GEC-Bhuj, meraman.modhavadiya15@gmail.com

²Assistant professor, Mechanical Engineering Department, GEC-Bhuj, makwana_vinod@yahoo.com

Abstract

In last few years, many techniques have developed to control emission from automobile like fuel treatment, engine modification, EGR and catalytic converter. catalytic converter is successful and widely used equipment. In this review paper various methods and techniques to improve performance of catalytic converter is discussed. According to literature survey change in design, shape and material the performance of catalytic converter is changed. It had found that hexagonal shape of monolith have better mechanical performance than square shape. Nickel based catalytic converter have reduced HC by 40 % and CO by 35%. Nobel metals are poisonous and expensive so we may use non noble metal like Cu, Ag, Au, Fe etc.

Keywords- Diesel engine, Engine performance, Emission, Catalytic Converter, IC Engine.

I. INTRODUCTION

A catalytic converter is a vehicle emissions control device that converts toxic pollutants of exhaust gas to less toxic pollutants by catalyzing a redox reaction (oxidation or reduction). Catalytic converters are used in internal combustion engines fuelled by either petrol (gasoline) or diesel—including lean burn engines.

The catalyst itself is most often a precious metal. Platinum is the most active catalyst and is widely used. However, because of unwanted additional reactions and/or cost, Palladium and rhodium are two other precious metals that are used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidization catalyst.

Exhaust emissions of much concern are Hydrocarbon (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NO_x) from the automotive vehicles. Catalytic converter oxidizes harmful CO and HC emission to CO₂ and H₂O in the exhaust system and thus the emission is controlled. There are several types of problems associated with noble metal based catalytic converter. These factors encourage for the possible application of non-noble metal based material such as copper, nickel, manganese based alloy, or combination as a catalyst.

Existing available catalytic converters suffer from various problems like; poisoning, fracture, melting & higher cost. so to develop cost effective catalytic converter like copper, nickel or manganese based or combination of this type of catalytic converter

II. LITERATURE REVIEW

Narendrasinh R. Makwana et al. [1] have developed cost effective Nickel based oxidation catalytic converter to use with four stroke diesel engine. This study introduces a simple low cost; non noble (nickel) based catalytic converter to reduce diesel engine exhaust emission. experiment has carried out using nickel based catalytic converter and performance is analysed. By using nickel based catalytic converter, HC reduces by 40% and CO reduces by 35%. So the nickel based catalyst can be effective approach in place of expensive noble metal based catalytic converter.

Chirag M. Amin et al. [2] have introduces copper as a catalyst for catalytic converter. Wire mesh copper
All Rights Reserved, @IJAREST-2015

catalytic converter is developed for a volume of 1.54 m³. The experimental study was conducted with the exhaust of a stationary, four stroke single cylinder, water-cooled, constant speed (1500 rpm) diesel engine with a power output of 3.5Kw. The optimum values of exhaust emissions found at full load are HC (130 ppm), CO (0.07 %). By using copper based catalytic converter it is found that HC is reduced by 38 % and CO by 33 % at full load. The efficiency of a catalytic converter is very much dependent on temperature. When a converter in good working order is operating at a fully warmed temperature of 300° C or above, it reduces HC by 38% and CO by 33%.

Shahrin Hisham Amirnordin et al. [3] has experimented on sub-grid scale modelling to predict the pressure loss of square- and hexagonal-cell-shaped honeycomb monoliths. This sub-grid scale modelling represents the actual variations in the pressure drop between the inlet and outlet for various combinations of wall thickness and cell density. This structure requires a high surface area for treating gases while maintaining a low pressure drop in the engine. Hexagon cell was more superior in terms of mechanical performance as it possesses low friction factor. At a constant cell density of 300 cpsi, superiority in terms of pressure loss is square > hexagonal > sinusoidal > triangular. At a constant hydraulic diameter of 1.26 mm, the trend is triangular > sinusoidal > square > hexagonal. [3]The results also show that a hexagonal-shaped cell gives a better mechanical performance (lower pressure drop) than a square-shaped cell. On the other hand, a square-shaped cell performs better chemically (higher specific surface area) a hexagonal-shaped cell. Overall, a hexagonal-shaped cell is more desirable than a square-shaped on because the former causes a 43% lower pressure drop.

P. karuppusamy et al. [4] designed and analysed various models with different wire mesh grid size combinations with appropriate boundary conditions and fluid properties specified to the system with suitable assumptions in CFD. The net work output per cycle from the engine is directly proportional to the backpressure. The backpressure is directly proportional to the catalytic converter design. Finally, the model with limited backpressure was fabricated and Experiments were carried out on computerized kirloskar single cylinder four stroke

diesel engine test rig with an eddy current dynamometer. The pressure drop in catalytic converters is associated with two major components: substrate and flow distribution device. The experimentation was conducted with the 150mm diameter catalytic converter fitted on the engine exhaust at the distance of 300 mm from the exhaust flange. Brake thermal efficiency decreased by 10 to 15 %, On other end BSFC increased by 15% when using catalytic converter. The increase in inlet cone angle increases the vorticity of the flow which leads to non-uniformity that reduces the conversion of the harm gases. The increase in inlet cone length reduces the backpressure and also reduces the recirculation zones.

P. V. walke et al. [5] designed and developed catalytic converter with different catalyst. The pellets are coated with copper oxide (CuO), cerium oxide (CrO₂) and zirconium dioxide (ZrO₂). Pellets are held together in a circular housing at two ends of the converter shell. Cylindrical spacer was used in between circular housing containing pellets to vary the distance and to reduce back pressure on the engine. Experiments were carried out on computerized kirloskar single cylinder four stroke (10 B.H.P, 7.4 KW) diesel engine test rig with an eddy current dynamometer. The converter was tested with different catalyst. There is considerable reduction in HC, CO and NO_x. Zirconium dioxide catalysts reduce HC emission. All three catalysts (zirconium dioxide, cerium oxide and copper oxide) reduce CO emissions. The catalyst (zirconium dioxide + cerium oxide), reduce NO_x emission. Brake thermal efficiency decreases with Catalytic converter. However, this decrease is marginal and it can be accepted in view of benefits on environment and health of human being.

Saugirdas pukalskas et al. [6] investigated catalytic converter operating effectiveness used in passenger cars. Already known determination methods of the effectiveness of catalytic converters are analysed. Experiment also consider the alternative verification methods of catalytic converters, whose validity has been verified through experimental studies. Therefore, simple and reliable verification method of operating effectiveness of catalytic converter is justified. Methods of efficiency evaluation are various and widely described. The main ways of evaluation of catalyst efficiency are as follows:

- By use of oxygen sensors (lambda sounds);
- By evaluation of amounts of NO_x, HC, & CO;
- By using temperature sensors.

Mohd fahrul Bin Hassan et al. [7] Spiral catalyst support is one of the substrate types for catalytic converter which reduces the harmful emissions from the combustion engines. The function of the catalyst support is to act as a carrier for the wash coat and for the noble-metal oxidizing catalyst. A good design of catalyst support can increase the performance of catalytic converter. Consequently, three patents developed in recent years for the development of spiral catalyst support, which produces a mandrel as an apparatus to provide a structure which prevents telescoping of the layers of a spiral catalyst support and two methods for manufacturing the spiral catalyst support, welding multi-

points and heat treatment of metals. The conceptual design was used to generate principle solutions and optimize the design concepts of an innovative spiral tool development as a forming tool to form a sheet metal in spiral form. The spiral form was successfully produced by an innovative spiral tool without considering the spring back behaviours.

P. purwanto et al. [8] studied the performance capabilities and effectiveness of Manganese coated Copper catalyst which are designed in such a way to obtain the appropriate shape and type of Catalytic Converter catalyst and suitable for premium fuel motor vehicles. Optimization of performance four model with different inside construction and variable cell size catalytic converter are fabricated. The experiment is carried out on stand Toyota 1500 CC machine with gas analyser Qrotech of type QRO-402 with tachometer. Model 2 gives the optimum result as it reduces the amount of CO by average 79.6%.

Julia widmann et al. [9] have studied impact of the inlet flow distribution on the light off behaviour of a 3-way catalytic converter. This paper presents a three-dimensional transient numerical study of the influence of the velocity distribution in front of the inlet face of the monolith during light off of a three-way catalytic converter. The difference in the thermal and chemical behaviour due to the shape of the velocity distribution is discussed in this paper.

Cathy chung et al. [10] has carried out investigation on CFD of thermal fluid flow and conversion characteristics of the catalytic converter. Their main objective was to predict the maximum operating temperature for appropriate materials and to develop a numerical model, which can be adjusted to reflect changes in the catalyst/wash coat formulation to accurately predict effects of flow, temperature and light off behaviour. They concluded that by changing the concentrations, the converter characteristics and steady state temperature could be changed.

Francisco payri et al. [11] has studied one-dimensional fluid –dynamic Model for catalytic converter in automotive engines. The main aim of this paper was to present a simple approach to the one dimensional modelling of the fluid dynamic behaviour of the catalytic converter. They developed a geometric model that was capable of completely representing the dynamic behaviour of the converter, that is, its reflection and transmission characteristics.

III. ANALYSIS

By study a literature review we conclude that performance of catalytic converter can be improved by changing materials of catalysts and changing cell shape. Performance of Catalytic converter can be improved by changing material in substrate and material alloy. Nickel based catalytic converter reduced HC by 40% and CO by 35%. Wire mesh copper catalytic converter is developed for a volume of 1.54 m³. The optimum values of exhaust emissions found at full load are HC (130 ppm), CO (0.07 %). HC reduced by 38% and CO by 33. when CuO, ZrO₂ and CrO₂ are used as catalysts they all reduced HC. ZrO₂

and CrO₂ combine reduced emission of NO_x. Manganese coated Copper catalyst used with Toyota 1500 CC engine it had reduced CO by 79.2 %. At a constant cell density of 300 cpsi, superiority in terms of pressure loss is square > hexagonal > sinusoidal > triangular. At a constant hydraulic diameter of 1.26 mm, the trend is triangular > sinusoidal > square > hexagonal. The experimentation was conducted with the 150mm diameter catalytic converter fitted on the engine exhaust at the distance of 300 mm from the exhaust flange. Brake thermal efficiency decreased by 10 to 15 %, on other end BSFC increased by 15% when using catalytic converter.

We can improve performance of catalytic converter by applying software analysis. CFD software can be helpful to predict performance of catalytic converter. Performance analysis by CFD can be validated with experiment result.

IV. CONCLUSION

When catalytic converter is used with Nickel based catalysts reduced HC by 40% and CO by 35%. Wire mesh copper catalytic converter had reduced HC reduced by 38% and CO by 33%. When CuO, ZrO₂ and CrO₂ are used as catalysts they all reduced HC. ZrO₂ and CrO₂ combine reduced emission of NO_x. Manganese coated Copper catalyst used with Toyota 1500 CC engine it had reduced CO by 79.2%. Different shapes of monolith have different characteristics like hexagonal shaped cell had good mechanical performance and square shaped cell and good chemical performance. The experimentation was conducted with the 150mm diameter catalytic converter fitted on the engine exhaust at the distance of 300 mm from the exhaust flange. Brake thermal efficiency decreased by 10 to 15 %, on other end BSFC increased by 15% when using catalytic converter. Au, Ag and stainless steel may be used to improve performance of catalytic converter in future.

REFERENCES

- [1] Narendrasinh R. Makwana, Prof. Chirag M. Amin, "Development and performance analysis of Nickel based Catalytic converter." , IJAET, Vol. IV, Issue II, April-June-2013
- [2] Chirag M. Amin, Prof. Pravin P. Rathod, Prof. Jigish J. Goswami, "Copper based catalytic converter", IJERT, Vol. 1 , Issue 3, May- 2012
- [3] Shahrin Hisham Amirnordin, Khalid Hasnan, "Pressure Drop Analysis of Square and Hexagonal Cells and its Effects on the Performance of Catalytic Converters", IJRET , Vol 2 , 2011
- [4] P.Karuppusamy, Dr.R.Senthil, " Design, Analysis of flow characteristics of catalytic converter and effects of backpressure on engine performance ", IJRET, Vol 1, issue 1, March 2003
- [5] P V Walke, Dr N V Deshpande, "Emission characteristics of a compression ignition engine using different catalyst", WCE, Vol 2, 2008
- [6] Saugirdas Pukalskas, Rytis Zautra, Saulius Nagurnas, "Research of efficiency of catalytic converters in automobiles with an Otto engine" ISSN 2029-2376, The 8th International Conference , May 2013
- [7] Mohd Fahrul bin Hassan DarwinSebayang, "Conceptual Design of a Spiral Catalyst Support ", ICME, May - 2008
- [8] P. Purwanto "Optimum Design of Manganese-Coated Copper Catalytic Converter to Reduce Carbon Monoxide Emissions on Gasoline Motor" Procedia Environmental Sciences 23 (2015) 86 – 92
- [9] Cathy Chung, Sivanandi Rajadurai and Larry GEE, "CFD Investigation of Thermal fluid flow and conversion characteristics of the catalytic converter", SAE 1999-01-0462, 1999.
- [10] Julia Windmann, Joachim Braun and Peter Zacke, "Impact of the inlet flow distribution on the light off behaviour of a 3-way catalytic converter", SAE-2003-01-0937.
- [11] Francisco Payri, Jesus Benajes, and Jose Galindo, "One-dimensional Fluid –Dynamic Model for catalytic converter in automotive engines", SAE-1999-01-0144.