https://doi.org/10.48047/AFJBS.6.12.2024.1799-1810

African Journal of Biological Sciences
Journal homepage: http://www.afjbs.com
Research Paper Open Access

Improving CRDI Engine Efficiency: Utilizing Waste Plastic Oil and Innovative Catalytic Converter Design for CFD Analysis to Enhance Emission Performance

A.Abdul munaf[1], Dr. A. Velmurugan[2], Dr. M.Loganathan[3],Dr P.Premkumar[4], R.Ravi[5]

[1]Research Scholar, Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalainagar-608001.

[2,4]Associate Professor, Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalainagar-608001.

[3]Professor, Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalainagar – 608001

[5]Professor, Department of Chemical Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalainagar – 608001

Munaf.rafan@gmail.com[1],velathi.lec@gmail.com[2],logu692002@rediffmail.com[3], ppklmeau@gmail.com[4],lect_ravi@yahoo.com[5]

Article History
Volume 6, Issue 12, 2024
Received: 30 May 2024
Accepted : 25 June 2024
Doi:
10.48047/AFJBS.6.S12.2024.1799-1810

Abstract - Catalytic converters are indispensable components in the automotive industry, tasked with thecrucial mission of curbing harmful emissions and enhancing air quality. This study conductsan in-depth exploration of catalytic converter design, employing cutting-edge computational methodologies, including SOLIDWORKS and ANSYS FLUENT. The primary objective is tocomprehensively assess fluid dynamics within both conventional and innovative catalytic converter configurations, with a particular focus on crucial parameters such as velocity distribution, dynamic pressure, and turbulent intensity contours. The outcomes of this rigorous analysis reveal compelling insights. The avant-garde catalytic converter design showcases aplethora of advantages over its conventional counterparts, manifesting in a uniform velocitydistribution, diminished turbulence, and a substantially reduced backpressure profile. Theseinrightful findings highlight the enormous potential of ground-breaking catalytic converter designs to revolutionize exhaust system efficiency and make considerable progress in reducing vehicle missions and their effects on the environment. This research not only underscores the criticality of optimizing catalytic converter performance but also emphasizes the pivotal role of state-of-the-art computational tools in devising emissions control strategies. By bridging the gap between theoretical scrutiny and real-worldapplications, this study makes an indispensable contribution to the advancement of emissionscontrol and catalytic converter design, with far-reaching implications for the global pursuit ofcleanertransportation. Data envelopment analysis a multi-response linear programming optimization tool was employed to assess the output and emissions of DI diesel engines using waste plastic oil mixtures.

Keywords - Catalyticconverter, MRLP (multi-response linear programming),Emissionscontrol, and computational Fluid Dynamics.

1.Introduction

Internal combustion engines play a pivotal role in powering various modes of transportationandmachinery,contributingsignificantlytomodernsociety'sproductivityandmobility. However, these engines are not without their inefficiencies andenvironmental concerns,particularly related to the gas exchange process involving the exhaust of burnt gases and thefresh charges being admitted into the engine's cylinder. Due to the energy needed to transfergases from a lower inlet pressure to a higher exhaust pressure, this process results in a loss ofpower. This loss, known as exhaust stroke loss, has a direct impact on the engine's volumetricefficiency, a critical factor in engine performance. The engine’s volumetric efficiency in turn,greatly influences its overall performance, emphasizing the importance of optimizing thisaspect. The pressure rises due to the cylinder moving to the top dead center from the bottomdead center during the exhaust stroke, which results in the displacement of burn gases fromthe top of the cylinder to the exhaust pipe. This results in exhaust stroke loss since it takesenergy to push the exhaust gases out.Backpressure, which directly relates to the pressure drop through parts like the catalytic converter and other components in side the exhaust system, is one of the main factors impacting exhaust stroke loss. Therefore, designing exhaust system components with minimal backpressure is essential to maximizing engine output. In this context, the present work aims to address exhaust emissions by proposing a catalyst using copper without compromising engine performance. The primary objective is to enhance fluid flow through the catalytic converter, ultimately improving its overall efficiency. This involves introducing a new design for the commonly used monolith in catalytic converters and optimizing the catalytic converter'shoneycomb structure to minimize backpressure'simpact onengineperformance.

The growing number of motorized vehicles has a substantial negative impact on the environment, particularly due to the emission of exhaust gases. (1) Growing global concern over vehicle emissions' environmental contamination has led to the implementation of more stringent regulations on hazardous components like CO, NOx, and HC, which are present in hazardous exhaust gases and have adverse effects on human health and the environment. Evaluate the effectiveness of the catalytic converter in reducing these deleterious gases by measuring CO and HC emissions at various engine velocities (1000 rpm, 2000 rpm, 3000 rpm, 4000 rpm, and 5000 rpm) using a five-gas analyzer. (2) Pollutant reduction is contingent upon exhaust emissions treatment, and catalytic converters are among the most effective remedies for reducing engine emissions.

Vehicle emissions become more environmentally friendly when technologies like metallic catalytic converters (MCC) reduce CO and HC emissions by converting them into less harmful compounds. [3] The catalytic converter's unique integral honeycomb structure design increases the contact area between the exhaust gas and the catalyst. This enables faster conversion reactions and more effective control over the amount of emissions. (4) Research has shown that metallic oxides like copper oxide and silver oxide have promising catalytic properties that can replace expensive noble metals like platinum and palladium in catalytic converters. (5) Catalytic converters are crucial for reducing hazardous emissions, with a focus on improving cold-start efficiency due to harmful emissions being highest during this phase. The efficiency of catalytic converters depends on the substrate's temperature and thermal response, with conventional converters often having low conversion efficiency due to slow temperature increases, resulting in cold-start issues and increased emissions. (6)

Mathematical models are essential for approximating the ultimate outcome of system layout and control strategies, which assist in the transition from design specifications to on-road testing. Fast mathematical models, such as the Filling-and-Emptying (FE) and Quasi-Steady Flow (QSF) approaches, frequently develop 0D, aggregated parameter models for intake and exhaust systems, in-cylinder processes, and real-time simulations. Despite the complexity of chemical and physical processes in the cylinder, 'fast' models efficiently depict combustion and pollutant formation reactions using simplified 0D single-zone approaches [7]. Computational Fluid Dynamics (CFD) is in high demand for catalytic converter analysis and design in order to minimize the time and cost associated with experimentation. The objective of this investigation is to optimize the design of automotive three-way catalytic converters by modifying the substrate length in order to reduce emission concentrations and improve conversion efficiency. (8)

A three-dimensional steady-state analysis is conducted using Ansys Fluent software and a finite volume approach. Research indicates that a 20° diffuser angle results in a decrease in pressure drop, a decrease in peak pressure, and an increase in the uniformity index (9). The investigation focuses on the use of computational fluid dynamics (CFD) to analyze and optimize catalytic converter design, with the goal of minimizing the time and costs associated with experimentation. (10) Optimizing a variety of physical and chemical parameters is a multifaceted process involved in the design of catalytic converters. Numerical simulation is suggested as a viable method for predicting catalyst performance and investigating catalytic properties. The study models the oxidation of hydrogen, carbon monoxide, methane, and C3H6 using a detailed surface reaction model and a two-dimensional flow field description. The analysis is based on the change in the ratio of precious metal (Pt/Rh) and its impact on pollutant emissions as a function of temperature. The research's objective is to verify the computational fluid dynamics (CFD) analysis through experimental analysis from a reference paper, underscoring the importance of understanding the behavior of catalytic converters in the context of emission mitigation. (11)

The research involves utilizing CAD software to design and modify the catalytic converter.Reference is taken from conventional catalytic converters to assess the impact of designparameter changes. Specific modifications include altering the honeycomb structure, shiftingtheinletpipetothecenterforbetterflowdistribution,andcreatingaconicalsectionattheentryand exitof the casingto avoid sudden expansion and contraction effects.These designenhancementsaimtoachievemoreuniformflowdistributionandreducepressurelosseswithinthe catalytic converter. This endeavor aligns with broader efforts to reduce exhaust emissionsfrom internal combustion engines, aligning with stringent environmental regulations. Thecatalyticconverter,asapivotalcomponentinemissioncontrol,playsacrucialroleinachievingthese goals. Therefore, this research seeks to contribute to the development of more efficientcatalytic converters that can help mitigate the environmental impact of engine exhaust whilemaintainingor enhancingengine performance.

Pyrolysis is a thermalprocessthatbreaksdownlong-chainpolymermoleculesintosimplercompoundsundercontrolled temperature and pressure conditions, producing oil, gas, and char as byproducts.Research indicates that PET waste can yield oilranging from 23% to 40%throughpyrolysis,makingitasuitablecandidateforthisprocess.HDPE(High-densitypolyethylene), known for its strength and durability, is commonly used in products like milkbottles and toys. Studies have shown that HDPE waste can yield oil up to 80.88% throughpyrolysis, demonstrating its potential as a feedstock for fuel production. On the other hand,PVC (Polyvinyl chloride), composed primarily of chlorine and carbon, poses challenges dueto the release of toxic substances at high temperatures during pyrolysis. However, someresearcheffortshaveexploredthe conversionofPVCwaste intooil, albeitwithlimitations.(12)

To provide context and build upon existing knowledge in this field, the followingsections will delve into a literary survey, detailed descriptions of catalytic converters, theircomponents, and the experimental setup used in this research. Furthermore, this work willexploretheachievementsandlimitationsofcatalyticconverters,sheddinglightonthechallengesand opportunitiesinthis criticalareaof automotivetechnology. (13)

2.Mathematic modeling

The commercial Ansys Fluent CFD application is employed to model the flow through the catalytic converter. Darcy's law [14] is used to define the inertial and viscous terms of the monolith, which are derived by conducting discrete channel simulations for a single monolith flow channel at the specified range of flow conditions. The monolith is classified as a porous zone.

$$\rho\frac{Du}{Dt} = -\frac{\partial p}{\partial x} + dtv(\mu gradu) + Smx \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\rho\frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + dtv(\mu gradv) + Smy \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\rho\frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + dtv(\mu gradw) + Szx \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Governing equations of the flow of a compressible Newtonian fluid

$$Continuity\frac{\partial p}{\partial x} + dtv(\rho u) = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$1) x - \ momentum$$

$$\frac{\partial(\rho u)}{\partial x} + div(\rho uu) = -\frac{\partial p}{\partial x} + div(\mu gradu) + Smx \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$2) y - \ momentum$$

$$\frac{\partial(\rho v)}{\partial x} + div(\rho vu) = -\frac{\partial p}{\partial y} + div(\mu gradv) + Smy \qquad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$3) z - momentum$$

$$\frac{\partial(\rho w)}{\partial z} + div(\rho wu) = -\frac{\partial p}{\partial y} + div(\mu gradw) + Smz \qquad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$4) Energy$$

$$\frac{\partial(\rho i)}{\partial t} + div(\rho iu) = -\frac{\partial p}{\partial y} + div(kgradT) + \varphi + Sl \qquad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

3. ExperimentalWork

Thisresearchinvestigationfocusesonassessingtheperformanceofthecatalyticconverter anditsdesignmodificationsusingacombinationofCAD(Computer-Aided Design)simulationsandreal-worldexperiments.Thisworkprovidesadetailedaccountoftheexperimentalprocedures,methodologies,and findings.

3.1 DesignofCatalyticConverterUsingCAD

3.2 CAD Design, Geometry and Modification in base design.

TheinitialdesignofthecatalyticconverterwascreatedusingSOLIDWORKS,withreferenceto conventional catalytic converters. The purpose was to assess the impact of designmodifications on various parameters. The basic design served as a foundation for simulation,and major dimensions were determined. **Fig. 1** and 2 portraits the catalytic Converter andmodified Honeycombstructure developed using SolidWorks. Several modifications weremadetothebasedesigntoimprovethecatalyticconverter'sperformance.Thesemodifications included changes to the honeycomb structure, diameter of holes, thickness ofthe honeycomb, and the addition of conical sections at the inlet and outlet. The shape of thecatalytic converter was also altered from the traditional circular shape to an oblong or ovalshape. This change was made to enhance the efficiency of the converter in reducing harmfulemissions.Thedeveloped wireframemodelis alsodisplayed inFig. 3

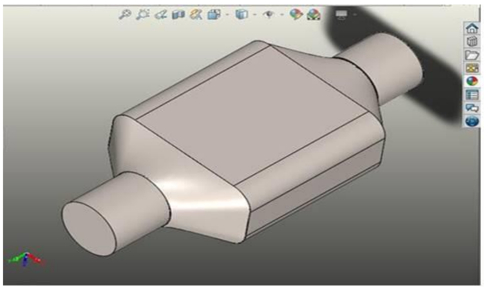

Fig. 1. Catalytic Converter in Solid Works

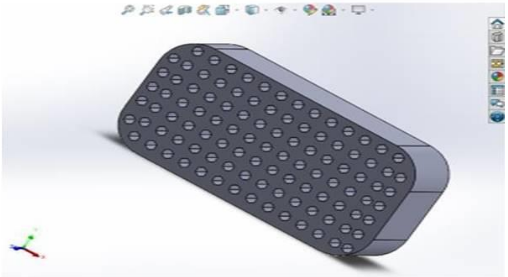

Fig.2 Modified Honeycomb Structure

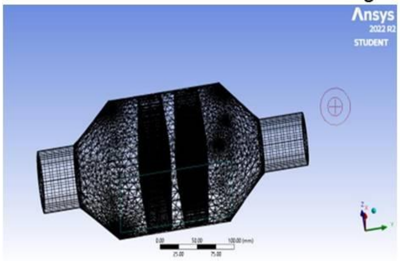

Fig. 3 Wireframe model in ANSYS

3.3 Meshing

Fig. 4 to conduct simulations, only the internal wetted surfaces were extracted from the CAD modelandmeshedintheANSYSWorkbench.ThismeshingwascrucialforperformingCFD(Computation alFluidDynamics)simulations.Variousassumptionsweremadeforthesimulations, including the assumption of steady flow,uniform fluid entering the domain throughtheinlet, and isotropicmaterialproperties.(7)

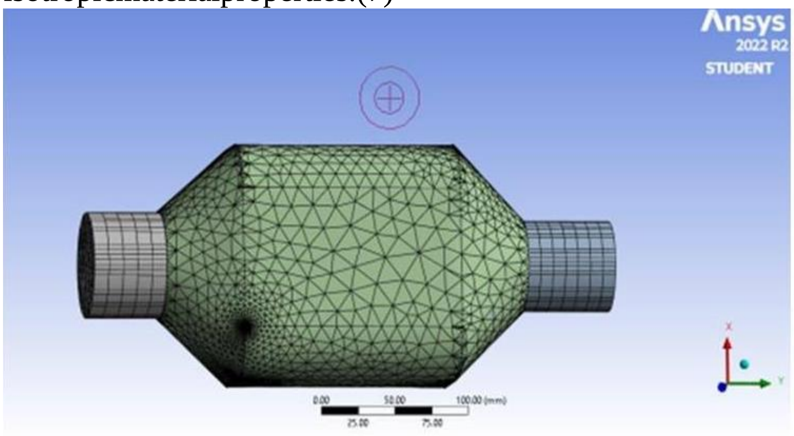

Fig.4 Meshing of the Catalytic Converter

3.4 AnalysisofCatalyticConverter

The models designed in SOLIDWORKS were imported into ANSYS for CFD analysis. Theanalysisinvolvedmeasuringvelocitydistribution,dynamicpressuredistribution,andturbulentinte nsityfordifferent models from Fig.5

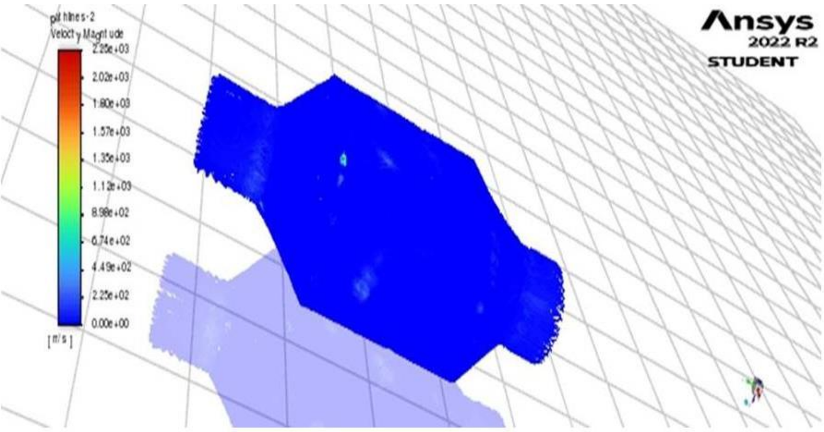

Fig.5 Total velocity

3.5 Conditions

3.5.1 FlowCondition

Table1FlowConditionforCatalytic Converter	
OuterCaseMaterial	STAINLESSSTEEL416
InletCondition	25m/s
OutletCondition	NoBackPressure
OutsideOperatingTemperature	300K
CADSoftware	SOLIDWORK
MeshandAnalysis	ANSYS
Solver	FLUENT

3.5.2 BoundaryCondition

Table2:CellZoneConditions		
Location	**Material**	**Value**
Fluid	CO andAir mixture	Density = 0.7535 kg/m^{3}Viscosity=3.0926 *10^{-05}kg/m-s

3.5.3 MaterialSpecification

Table3MaterialSpecification	
PhysicalProperties/Substance	ferrous-sulfate-heptahydrate
Formula	$FeSO_4.7H_2O$
Density(kg/m^3)	1898
SpecificHeatCp(J/kg-K)	1418.96
ThermalConductivity(W/m-K)	Kinetictheory
Viscosity(Kg/m-S)	Kinetictheory
MolecularWeightkg/kg-mol	278.02
EnthalpyJ/kg-mol	-988260800

EntropyJ/kg-mol-K	409100
TemperatureReference(K)	298

3.6 AnalysisDiagram

Fig. 6 Velocitydistributionacrossthecatalyticconverterwasanalyzed. Fig.7 Different speed conditions were studied to understand howvelocity affects fluid flowwithinthe converter.Fig.8 Thepressuredistributionwithinthecatalyticconverterwasinvestigated.Thisanalysisrevealedhowpressurelevels changedatdifferent speeds.(8)Turbulent intensity, representing wind velocity fluctuations, was assessed across the catalytic converter. Turbulence levels were compared at different sections. The experimental work conducted in this research aimed to evaluate the performance of the catalytic converter designand its modifications. Both CAD simulations and actual tests were used to provide insight intohow design modifications affected the catalytic converter's fluid flow, pressure distribution, andturbulencelevels.

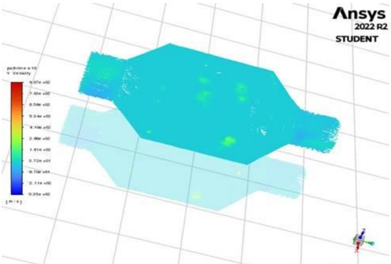

Fig.6 X-Velocity

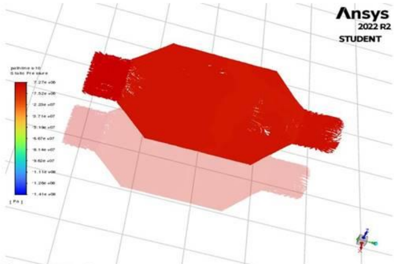

Fig. 7 Static Pressure

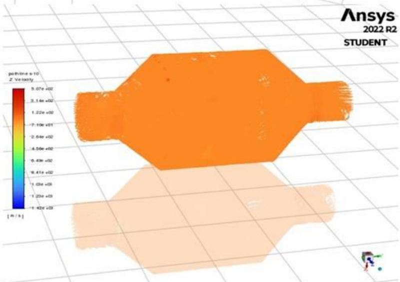

Fig.8 Z-Velocity

3.7 Test Engine Setup

A multi-cylinder, four-stroke, CRDI diesel engine placed on an engine bed was used for theexperimentalwork.(2)
Theloadwasmeasuredusingaloadcell,andaneddycurrentdynamometerofthewater-cooledtypewasconnectedtotheenginetoprovidepreciseloading. Various parameters, including cylinder pressure, heat release rate (HRR), and crankangle pulses, were monitored and recorded using a data acquisition system (DAS). A non-contact optical sensor placed close to the flywheel was used to keep the engine running at aconstant speed of 1000 rpm. A high-precision flow meter was installed to calculate fuelflowrates at specific time intervals. K-type thermocouples placed at various positions within thecylinder chamber were used to measure exhaust gas temperatures (EGT). Additionally, anAVL Di Gas 444 exhaust gas analyzer was used to assess CO, HC, and NOx emissions. Theexperimental setup was monitored and controlled using Lab VIEW software installed on acomputer.

Fig 9 : Test Engine Setup

4. Results and Discussion

4.1 DesignandAnalysisofCatalytic Converter

4.1.1 CFDAnalysisandSimulationResults

The design modifications of the catalytic converter aimed to enhance its performance inreducingharmfulemissions.Thesemodificationsincludedchangestothehoneycombstructure, diameter of holes, thickness of the honeycomb, and the addition of conical sectionsattheinletandoutlet.Thetraditionalcircularshapewasalsoalteredtoanoblongorovalshapetoim proveefficiency.

Toevaluatetheimpactofthesedesignchanges,ComputationalFluidDynamics(CFD)simulations were conducted using ANSYS Workbench. The internal wetted surfaces of theCADmodel weremeshed forCFDanalysis.

Fig 10 : Modified Honeycomb Structure

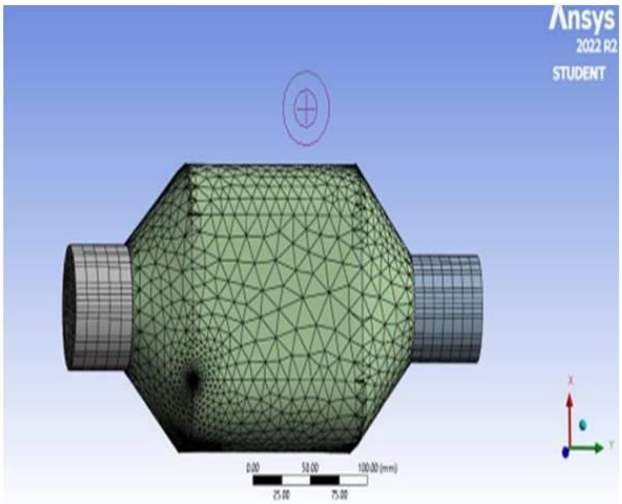

Fig 11: Meshing of the Catalytic Converter

TheCFDanalysisinvolvedmeasuringvelocitydistribution,dynamicpressuredistribution,andturbulen t intensity for different models. The results indicated improved velocity distributionand pressure distribution for the modified design when compared to the conventional model.Thesimulationsshowedthattheproposeddesignexhibitedmoreuniformflow,lowerturbulence, and less back pressure for exhaust gases. These findings suggest that the designmodifications have the potential to enhance the catalytic converter's performance in reducingemissions.

4.2 EmissionControlwith ReducingAgents

Furthermore,alongsidethedesignanalysis,theresearchdelvedintotheapplicationofdifferent reducing agents for the purpose of NOx emission reduction. The study specificallyinvestigatedSelectiveCatalyticReduction(SCR)technology,whichutilizesvariousreducing agents such as Ad Blue solution, Formic acid, and Glucose. Notably, Formic acidemergedasahighlyeffectiveoptionformitigatingNOxemissions,surpassingtheperformance of the traditional Ad Blue solution. Under full load conditions, Formic acidachievedaremarkablereductionofupto69.47%inNOxemissionsincomparisontoconventional catalytic converters. This study underscores the potential viability of Formicacidas a reducingagentin the context of NOx reduction in diesel engines.(9)

4.3 EmissionControlandAnalysis

4.3.1 CarbonDioxide(CO_2)Emissions

Fig. 12 indicates the Carbon dioxide (CO_2) is an unavoidable byproduct of the combustion process and is notchemicallyreactivelikeotherpollutantssuchascarbonmonoxide(CO)orhydrocarbons(HC).Hence ,catalyticconvertersdonotdirectlyreduceCO_2emissions.However,catalyticconverters indirectly contribute to reducing CO_2 emissions by mitigating other pollutants thatcontribute to climate change.For instance,catalytic converters areessential in loweringemissions of volatile organic compounds (VOCs) and NOx.

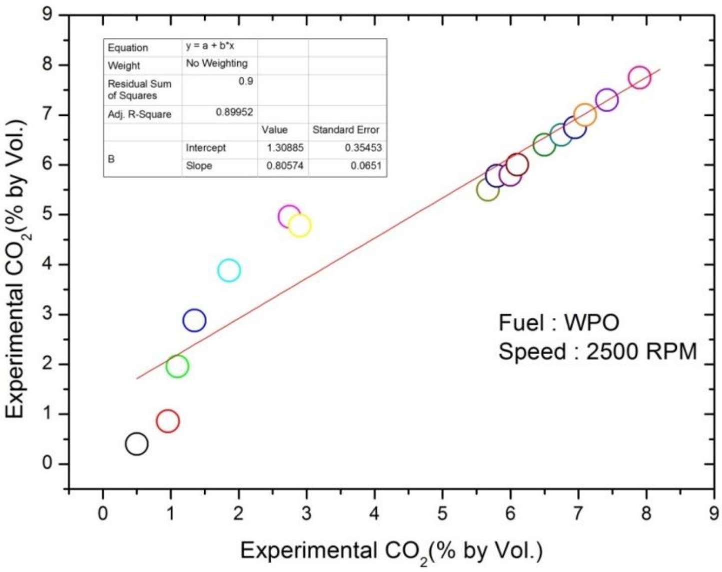

Figure: 12 Comparison of MRLP prediction of CO_2 with measured data for the 20 data points

4.3.2 Nitrogen Oxides (NOx)Emissions

Nitrogen oxide (NOx) emissions from a catalytic converter are influenced by the speed of thevehicle. Generally, higher speeds correspond to higher NOx emissions. (11) At lower speeds, NOxemissionsfromthecatalyticconverteraretypicallylower.Thisisprimarilybecausetheengineoperatesatreducedintensityduringlow-speeddriving,resultinginreducedexhaustproduction. Furthermore, catalytic converters are most efficient within a temperature range of400°C to 600°C, which is reached more rapidly at lower speeds. Conversely, as the vehicle'sspeed increases,

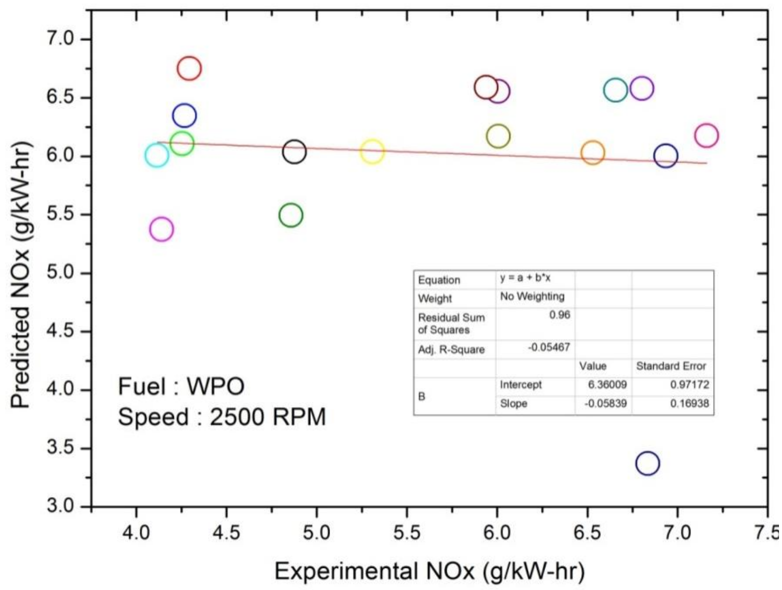

Figure: 13 Comparison of MRLP prediction of NO_X with measured data for the 20 data points

4.3.3 Hydrocarbon(HC)Emissions

The levels of hydrocarbon (HC) emissions from a vehicle's catalytic converter are influencedby various factors, including the vehicle's speed. Vehicle speed can impact the catalyticconverter'sefficiencyinconvertingharmfulexhaustgasesintoless harmfulcompounds.

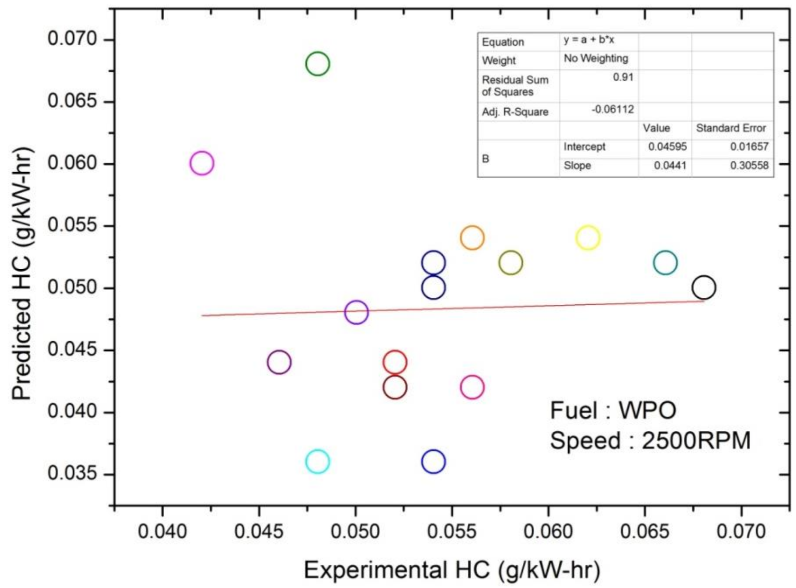

Figure: 14 Comparison of MRLP prediction of HG with measured data for the 20 data points

4.3.4 CarbonMonoxide(CO)Emissions

Fig 15 displays a comparison between experimental and predicted CO values. Duetothecatalyticconverter'sperformancebeingdependentonthetemperatureoftheexhaustgases,vehicle speed has an impact on carbonmonoxide (CO)emissionsfromtheconverter.Atlower speeds, the catalytic converter may not reach its optimal operating temperature, leadingto higher CO emissions. However, at higher speeds, the converter can achieve its optimal temperature more rapidly, resulting in lower CO emissions.(13)

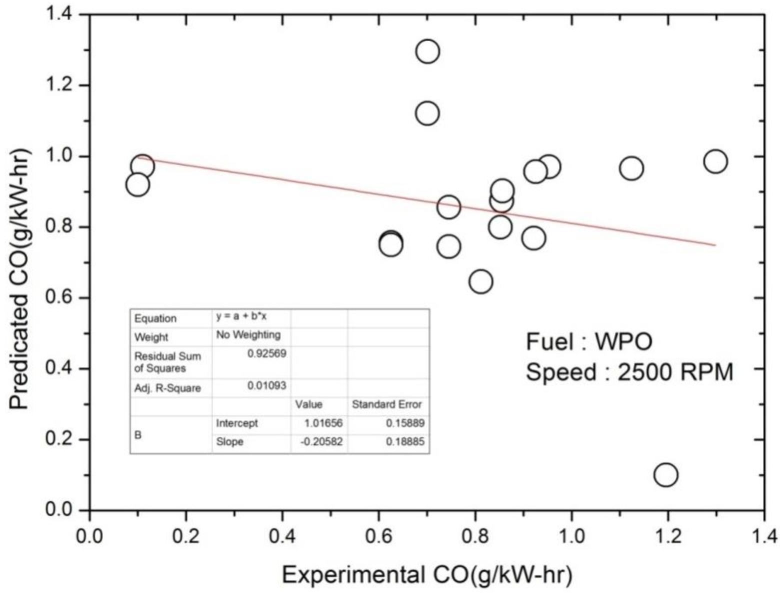

Figure: 15 Comparison of MRLP prediction of CO with measured data for the 20 data points

5. Conclusion

In this study, we conducted a comprehensive analysis of fluid flow within both the currentconventional catalytic converter design and a proposed innovative design. The investigationincluded an assessment of velocity, dynamic pressure, and turbulent intensity contours toevaluate the performance of these designs. The following summarizes our key findings and contributions: We embarked on a thorough examination of fluid flow dynamics in conventional and proposed catalytic converter designs. Our study involved the use of cutting-edge softwaretools, including SOLIDWORKS for creating the new catalytic converter filter design andANSYS FLUENT for conducting Computational Fluid Dynamics (CFD) tests. We exploredthe potential for enhancing the performance of catalytic converters through innovative designmodifications.

The analysis of fluid flow dynamics revealedthattheproposeddesignexhibitsnotableadvantages over the conventional design. The velocity distribution in the proposed design ismore uniform, contributing to improved performance. The proposed design displays reducedturbulence as the fluid enters the catalytic converter, minimizing disruptions in flow. Back pressure in the proposed designissignificantlylowerandmoreuniformlydistributedcomparedto the current model, resulting in improved exhaust system efficiency.The proposed design show cases substantial improvements over the conventional model,offeringenhanceduniformity,reduced turbulence,and optimized exhaust systemoperation.

References

1. Sudirman RizkiAriyanto, Suprayitno , Retno Wulandari ‘Design of Metallic Catalytic Converter using Pareto Optimization to Improve Engine Performance and Exhaust Emissions’ Automotive Experiences Vol. 6 No. 1 (2023) pp. 200-215
2. Suheni , Rudy Sunoko , Amin Setyo Leksono , Slamet Wahyudi ‘Optimization Design of Reducting Co & HC Gas through Alloy Converter Catalyst Prototype Model’ International Journal Of Multidisciplinary Research And Analysis Volume 06 Issue 01 January 2023
3. Ali Mokhtar; AndinusaRahmandhika; Suwignyo; Fredy WijayantoThe utilization of catalytic converter in reducing motorized vehicles emissions with copper and brass wire combined catalyst in the spiderwebs-shapeAIP Conf. Proc. 2453, 020002 (2022)
4. A. S. Sajitha; N. Bharath; G. Leo Megavel; B. Gowtham Performance enhancement and reduction of exhaust emissions in catalytic converter using the metallic oxide catalysts AIP Conf. Proc. 2387, 060001 (2021) November 01 2021
5. Herman Weltens, Harald Bressler, Frank Terres, Hubert Neumaier, Detlev

RammoserOptimisation of Catalytic Converter Gas Flow Distribution by CFD Prediction," SAE Technical Paper 930780, 1993,

6. Gwang Ho Jeong 1 , Seok Kim 1,2 and Young Tae Cho 1,2 Numerical Study of the Thermal and Fluid Behavior of Three-Dimensional Microstructures for Efficient Catalytic Converter Energies 2022, 15, 4200
7. Agostino Gambarotta, Viola Papetti and Panayotis Dimopoulos Eggenschwiler 'Analysis of the Effects of Catalytic Converter on Automotive Engines Performance Through Real-Time Simulation Models' Frontiers in Mechanical Engineering | www.frontiersin.org 2 August 2019 | Volume 5 | Article 48
8. Jigar Vaghela and Avdhoot Jejurkar 'CFD Analysis of Catalytic Converter for Mitigation of Emission International Journal of Science Technology & Engineering | Volume 4 | Issue 10 | April 2018
9. Mihir Joshi, Femina Patel, Sanjay Patel & Niraj Shah' Hydraulic Design of Diffuser of Catalytic Converter ''Smart Technologies for Energy, Environment and Sustainable Development 03 July 2019 pp 739–748
10. 10. Hesham A. Ibrahim1 , Sherif Abdou2 , and Wael H. Ahmed1Understanding Flow through Catalytic Converters Proceedings of the 4 th International Conference of Fluid Flow, Heat and Mass Transfer (FFHMT'17) Toronto, Canada – August 21 – 23, 2017 Paper No. 135
11. 11. R. E. Hayes, A. Fadic, J. Mmbaga, and A. Najafi, "CFD modelling of the automotive catalytic converter," Catal. Today, vol. 188, no. 1, pp. 94-105, 2012.
12. A Velmurugan, TV Rajamurugan, C Rajaganapathy, S Murugapoopathi, Kassian TT Amesho, Enhancing performance, reducing emissions, and optimizing combustion in compression ignition engines through hydrogen, nitrogen, and EGR addition: An experimental study, International Journal of Hydrogen Energy, https://doi.org/10.1016/j.ijhydene.2023.09.115 (2023)
13. A Abdul munaf, A Velmurugan, M Loganathan, M Bakkiyaraj and P Premkumar Studies on CRDI diesel engine performance and emissions using waste plastic oil and fly ash catalyst Engineering Research Express, Volume 6, DOI: 10.1088/2631-8695/ad2cce (2024)
14. Anupam mukharji, Kunal Roy, Konika Mondal Catalytic converter in automobile exhaust emission- general for research vol.2 (2016)
15. A Abdul Munaf, P Premkumar, A Velmurugan, Premdasu Nalluri, SK Rajesh Kanna, J Nishanth Jude Roy, & G Suresh Catalytic Degradation of Used Plastics oil as Liquid Fuel for IC Engines, Journal of Physics: Conference Series, 2021, 2054 (1) 012072. DOI: 10.1088/1742-6596/2054/1/012072
16. Velmurugan A, Loganathan M, James Gunasekran E. Experimental investigations on combustion, performance and emission characteristics of thermal cracked cashew nut shell liquid (TC-CNSL)-diesel blends in a diesel engine. Fuel, 2014, 132: 236 –245
17. S.K.Sharma, P.Goyal, S.Maheshwari, A.Chandra "A Technical Review Of Automobile Catalytic Converter: Current Status And Perspectives"- STOCEI-A Sustainable Approach (2013)