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Retraction

Retracted: Copper Oxide Nanoparticles Incorporated in the Metal Mesh Used to Enhance the Heat Transfer Performance of the Catalytic Converter and to Reduce Emission

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

1. Discrepancies in scope
2. Discrepancies in the description of the research reported
3. Discrepancies between the availability of data and the research described
4. Inappropriate citations
5. Incoherent, meaningless and/or irrelevant content included in the article
6. Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] M. Prabhahar, S. Prakash, M. Saravana Kumar et al., "Copper Oxide Nanoparticles Incorporated in the Metal Mesh Used to Enhance the Heat Transfer Performance of the Catalytic Converter and to Reduce Emission," *Journal of Nanomaterials*, vol. 2022, Article ID 9169713, 9 pages, 2022.

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Research Article

Copper Oxide Nanoparticles Incorporated in the Metal Mesh Used to Enhance the Heat Transfer Performance of the Catalytic Converter and to Reduce Emission

M. Prabhahar,[1] S. Prakash,[1] M. Saravana Kumar,[1] S. Sendilvelan,[2] M. V. Sreerag,[1] B. S. Akhil Vishnu,[1] Asif Samad,[1] B. Jansi Rani,[3] Haiter Lenin Allasi,[4] Adisu Haile,[4] and Praveen Kumar Issac[5]

[1]*Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, Vinayaka Mission Research Foundation, Tamil Nadu 603 104, India*
[2]*Department of Mechanical Engineering, Dr. M.G.R. Educational and Research Institute, Chennai 600095, Tamil Nadu, India*
[3]*Nano Energy & Catalysts Research Lab, Department of Materials Science and Engineering, Engineering Research Institute, Ajou University, Suwon, Republic of Korea*
[4]*Department of Mechanical Engineering, Wollo University, Kombolcha Institute of Technology, Kombolcha, Ethiopia Post Box No. 208*
[5]*Department of Medical Biotechnology and Integrative Physiology, Institute of Biotechnology, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Thandalam, Chennai, 602 105 Tamil Nadu, India*

Correspondence should be addressed to M. Prabhahar; mprabhahar@gmail.com and Adisu Haile; adisu.haile@wu.edu.et

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Heating the catalysts chemically at a cold start is indeed an approach to achieving catalytic performance. The purpose of this effort is to reduce cold flow emissions to background levels during regular engine operation. To address this issue, a thermal model was created, and a temperature study of various configurations was performed utilizing the computational dynamics method. This was followed by a regression model to confirm the results of the experiment. The article discusses how using a computational fluid dynamic to simulate the transient temperature profile of a chemically heated catalytic converter (CHCC) in exhaust may aid in the development of a much more powerful and energy-efficient catalytic converter. In this research, nanoparticles have been used as a heat transfer enhancement agent to improve the thermal conductivity of the exhaust gases. This work has been proposed to calculate the flow behaviour and heat transfer of nanoparticles in the proposed catalytic converter. The nanomaterial composite, created by incorporating copper oxide nanoparticles (CuO_2) on the surfaces of metal mesh, is used in the catalytic converter. The analytical technique has previously demonstrated its use in better predicting and comprehending the dynamic behaviour of a tightly linked catalyst and its thermally light-off period. The converter was evaluated in this study together with the SI (spark ignition) engine, and the data collected has been verified using analysis of regression. It is seen that in the converter with nanocopper oxide configuration, 50% carbon monoxide (CO) conversion efficiency is possible when the temperature of the main converter reaches 250°C and the CO is initially 2.7% Vol, and after reaching light off, it is 1.95% Vol. The time it takes to reach 250°C is 48 seconds after a cold start. In the case of hydrocarbons (HC), 50% HC conversion is reached during the test period of 168 seconds after the cold start. The HC is 605 ppm initially, and after light off, it is 130 ppm. The time taken to reach the HC light-off temperature is 300°C, with nanocopper oxide reaching this temperature in 168 seconds.

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1. Introduction

The automotive sector is critical to emerging countries' economic stability and development. For a long period in our country, individual transport was seen as a privilege and a demand of the rich. However, as private transportation is now a fundamental and universal feature of contemporary life, India's automotive segment is all set to take off in a big way. The majority of the world's automobiles are establishing manufacturing facilities in India. Such rapid growth in the automotive sector brings numerous difficulties to light, one of which is vehicle emissions. It is not necessary to stress the significance of clean air in maintaining a decent and healthy lifestyle. As a result, emissions must be significantly reduced in order to preserve a relatively secure planet for future generations [1–7].

Global ecological degradation has prompted academics to concentrate on the construction of LEV (low emission vehicles) and ULEV (ultralow emission vehicles). Automobiles produce large amounts of HC (hydrocarbons), CO (carbon monoxide), and PM (particulate matter) [8–10]. Catalytic emission controls are universally acknowledged as one of the most economical methods of pollution reduction. A catalyst exhaust control system transforms the toxic components of the vehicle's emissions chemically into innocuous gases using a precious metal catalyst. This method is likely to lower carbon and hydrocarbon emissions by up to 80% and particulate matter by more than 50% [11].

The current generation of gasoline automobiles evaluated as shown in the FTP (Federal Test Procedure) generates between 70% and 80% of exhaust within the first 1 or 2 minutes after cold starting. It is mostly owing to the catalytic converter's lack of effectiveness until it hits light-off temperature. Thus, immediately raising the catalytic converter's temperature during the cold start of the vehicle is critical for lowering carbon and hydrocarbon emissions [12]. The problem of complying with ULEV and LEV standards has led to the development of a variety of novel converter ideas aimed at reducing cold-start emission levels. However, one novel notion is the pre-cold-start electrothermal catalyst method. The primary challenge in using the electrothermal catalyst technique is the significant electrical energy consumption and heat-up time [13]. Significant advancements have been achieved in the last several years to lower usage of power to the 2 and 3 kW range. To generate between two and three kW from 12-volt batteries, huge wire widths and a complex switching power system are required. Even a little power need of two kilowatts does have a noticeable effect on the life of the battery. Even more likely would be to heat the catalyst with energy from renewable sources, like electricity, heat, or the chemical energy in the exhaust [14].

Placing the hot catalyst nearer to the primary converter enhances the engine's backpressure. The primary converter and hot catalyst being located nearer the engine accelerated the thermal deterioration of the catalyst and backpressure. The reduced mass of the hot catalyst results in a lower electrical power requirement and a shorter heat-up time. The rate of temperature rise is proportional to the mass of the converter [15]. By maximizing the hot mass, it is possible to accelerate the rate of temperature rise, which results in an exothermic reaction [16]. When the exothermic reaction occurs, a large amount of chemical energy is generated, which functions as a heat source for the primary converter. As a result, the time necessary to activate the catalyst is slightly decreased. This energy depends on the temperature of the catalyst. You can utilize this energy by starting the catalytic activity as quickly as possible. One way to start the catalytic activity as quickly as possible is to produce a more rapid temperature rise in the converter. The exothermic reaction from the oxidation of HC and CO releases an abundance of chemical energy. This energy must be added rapidly and be sufficient to maintain an effective catalyst temperature for high conversion efficiency. The quantity of energy stored in the electrically heated catalyst (EHC) and light-off converter (LOC) is critical because it determines the operating temperature of these components. Recent EHC activities have focused efforts on electrical energy reductions. To achieve a high conversion rate at low electric power, the electric energy has to be used to heat small portions of the catalyst intensively and rapidly, thus inducing the catalytic reaction within a few seconds. The reactions not only reduce emissions but also add a significant amount of exothermic energy to the gas stream. The rate of temperature rise is proportional to the mass of the converter. By optimizing the heated mass, it is possible to greatly increase the rate of temperature rise. Thus, by heating only a small volume of catalyst, it is possible to reach the temperature where catalytic activity begins and releases the chemical energy of the exhaust very rapidly. Once the exothermic reaction begins, an abundance of chemical energy is released, which acts to heat the main converter (1.5% CO removal results in a 220 K Temperature rise). The chemically heated catalytic converter (CHCC) rapidly achieves high temperatures, and the heat created by exothermic oxidation

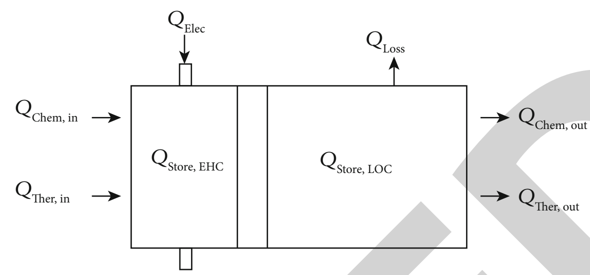

Figure 1: Energy balance diagram.

Table 1: Properties of nanoparticle copper oxide.

Item	Specifications
Name (chemical)	Copper oxide (CuO_2)
Molecular weight	79.545 g/mol
Color	Black
Density	6.4 g/cm^4
Thickness	30-50 nm
Purity	99.90%

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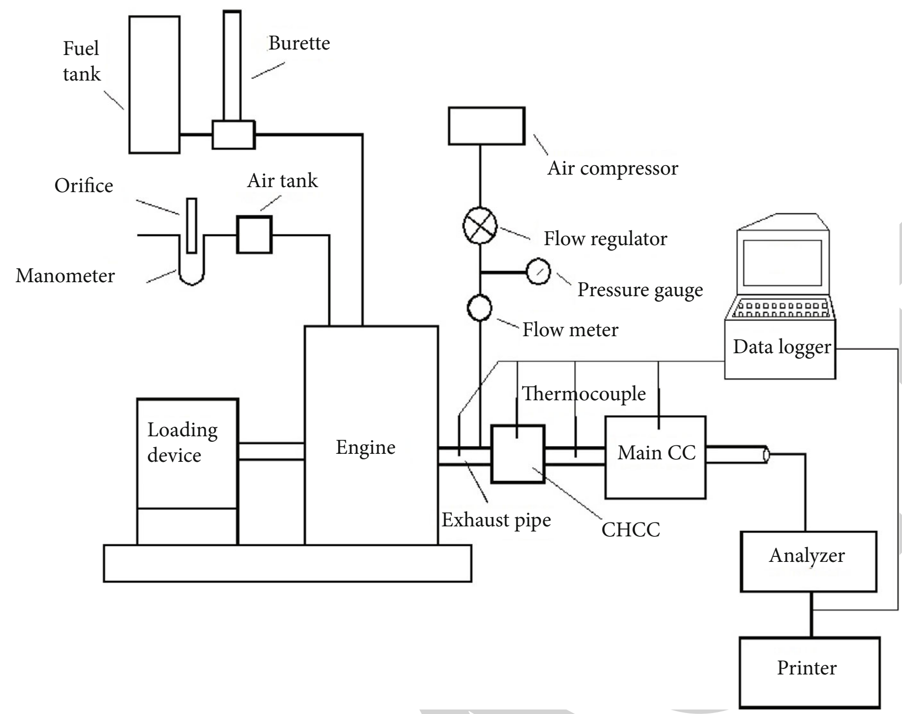

Figure 2: Experimental setup.

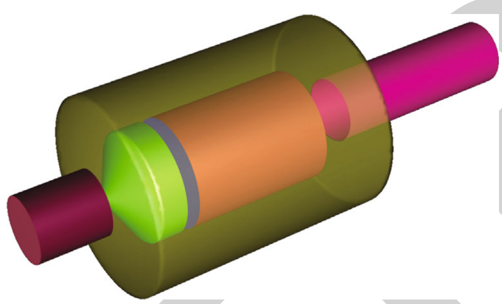

Figure 3: New proposed CHCC model.

is transferred by the exhaust gas to the primary converter, where it achieves a faster light off, resulting in reduced emissions at power levels in the range of 1.5 kW [17]. The walls of the metal mesh are incorporated with copper oxide nanocomposite to enhance the conduction rate. The goal of this work is to look at how well CHCC works using CFD analysis and regression analysis.

One technique to get the catalytic activity started as quickly as possible is to increase the converter's temperature. The rate of temperature rise is proportional to the mass of the converter. It is feasible to considerably accelerate the rate of temperature rise by optimizing the heated mass. Catalytic activity can be initiated, and exhaust chemical energy is released extremely quickly by heating a small volume catalyst to a high temperature. A large amount of chemical energy is released during the exothermic reaction, which in turn heats the primary converter. Figure 1 schematically depicts the system's energy balance. The catalytic converter produces chemical energy and thermal energy, as can be seen in the energy balance. In terms of energy equation (1), we can say

$$Q_{\text{Chem,out.}} + Q_{\text{Ther,out.}} = Q_{\text{Chem,in}} + Q_{\text{Ther,in}} + Q_{\text{Elec}} - Q_{\text{Store,EHC}} - Q_{\text{Store,LOC}} - Q_{\text{Loss}}, \quad (1)$$

where $Q_{\text{Chem,out}}$ is the chemical energy that comes out of the converter, $Q_{\text{Ther,out}}$ is the thermal energy that comes out of the converter, $Q_{\text{Chem,in}}$ is the chemical energy that enters the converter, $Q_{\text{Ther,in}}$ is the thermal energy that enters the converter, Q_{Elec} is the electrical energy supplied, $Q_{\text{Store,EHC}}$ is the energy stored in the EHC converter, $Q_{\text{Store,LOC}}$ is the energy stored in the LOC converter, and Q_{Loss} is the loss of energy that goes out of the converter.

These are the energy sources available to heat the converter. The electrically heated catalytic (EHC) converter is extremely effective in lowering cold-start CO and HC emissions. EHC preheating or postheating reduced emissions significantly. These systems typically require 600-700 A current and a high electrical output of more than 4 kW. A heavy-duty alternator, either a big-size battery or a separate battery for EHC, large diameter wires, and a heavy-duty semiconductor switch are required to supply this high power of 4 kW to a conventional EHC [18]. As a result of the added weight, the cost rises, and the fuel economy suffers. Recent EHC operations have focused on reducing the amount of electrical energy required. 1.5 kW of heating is possible with the available battery. The EHC and LOC are coated with CuO_2 nanoparticles at a size of 30–50 nm. The properties of nanoparticles are given in Table 1. The experimental setup is also shown in Figure 2.

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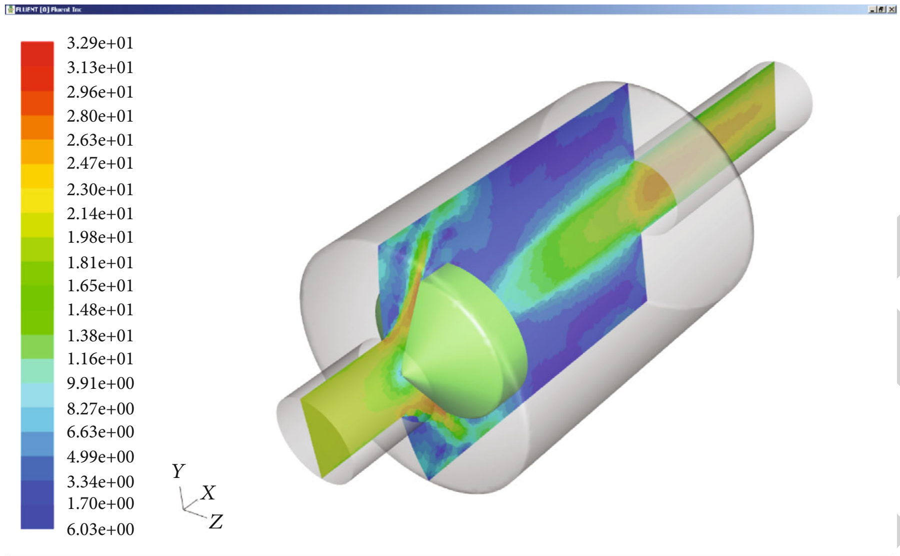

Figure 4: Velocity contours.

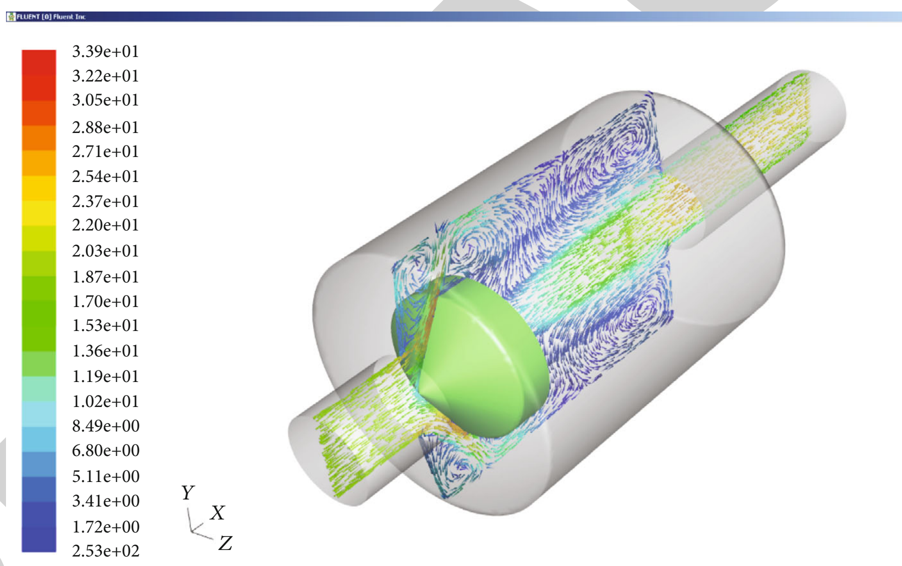

Figure 5: Velocity vector contours.

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2. Analysis of the New Proposed Model

This CFD analysis is aimed at determining the temperature at the outlet of the manifold for the varying inlet temperature that varies unsteadily. There is a heater kept in the path of the fluid which heats the fluid, which leads to a further increase in the temperature of the fluid at the outlet as shown in Figure 3.

The models detailed are indeed part of an initial study to investigate the significance of accounting for multidimensional impacts in designing vehicle catalytic converters [19]. Although simulating a single system of a catalytic converter is useful in analyzing core difficulties, it is far from suitable for comprehensive catalytic converter modeling and evaluation. For CFD (computational fluid dynamics) to create an influence on building designs within the automobile industry, it is of greatest significance to be capable of simulating the full catalytic converter, as compared to a traditional channel of the catalyst. CHCC is represented as a porous block.

The heater element (EHC) and LOC are assumed to be made of copper with a density of 8978 kg/m^3, Cp = 381 J/kg-k, and thermal conductivity of 387.6 W/m-k. The CFD domain is discretized into 1385443 triangles and 708987 tetrahedrons. The problem is assumed to be unsteady, compressible, and turbulent. Fluent is used to solve the problem. The K-ε (K-epsilon) standard model, which is a two-equation model in nature, is used to model turbulence. The energy equation is activated to see the conjugate heat

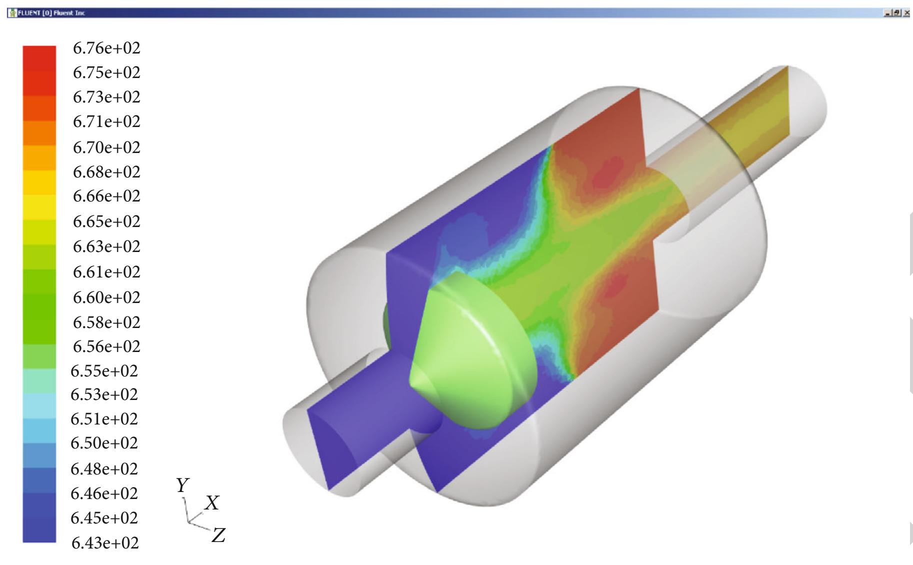

Figure 6: Temperature distribution 120 sec after engine start.

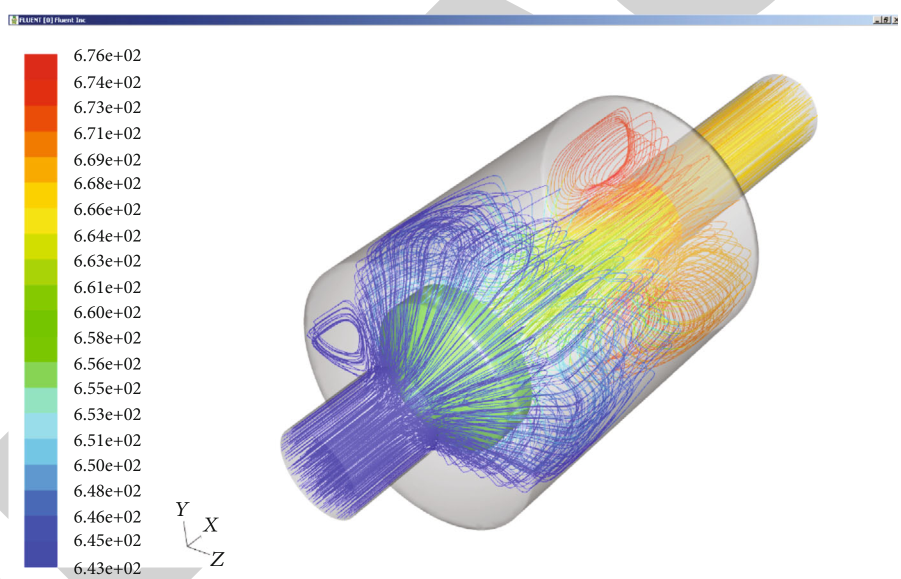

Figure 7: Temperature path lines 120 sec after engine start.

transfer, which solves heat transfer with convection. The unsteady profile is given at the inlet using a profile file option. The scheme of second-order discretization is used. The heater element (EHC) is set to 400°C [20]. It is discovered through pressure distribution. The backpressure developed due to this configuration is slightly higher between the outlet of the engine and the inlet of CHCC. Figures 4 and 5 show how the speed of CHCC changed at different times during the simulation.

It is found from the velocity contour that the velocity is higher at the inlet and outlet of CHCC. It is also found that the velocity is remarkably high near the conical surface and the centerline of the outlet exhaust pipe. It is found from velocity vector distribution that the conical portion helps to divert the exhaust effectively and creates better turbulence for maximum heat transfer from the heater element. A vortex is formed at all four corners of the CHCC, and the swirl motion is desirable for better mixing of the exhaust with any incoming secondary air. The introduction of secondary air helps the unburnt hydrocarbons react with the incoming air to oxidize into CO_2 and H_2O [21]. It is also found that the vortex created in front of the conical section is not desirable, which must be removed by modifying the outer case of the CHCC design. The velocity vector also indicates that the flow finally passes through the center portion of the LOC, which is also desirable to activate the LOC as quickly as possible so that more will be generated and carried to the main catalytic converter. The velocity contour depicts that the

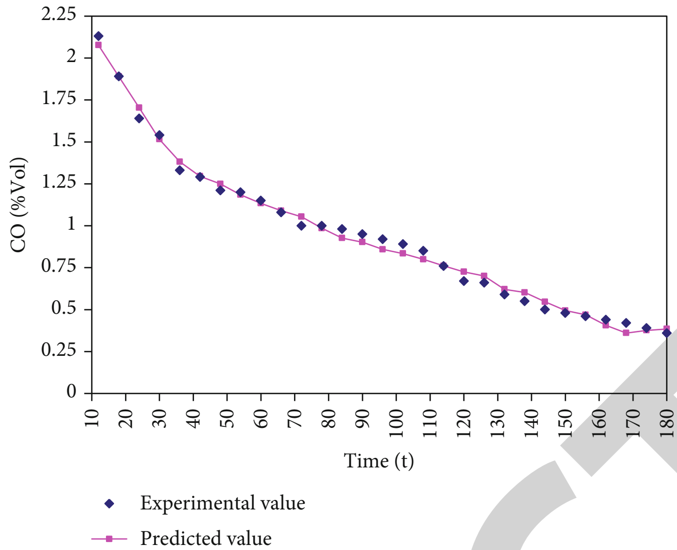

Figure 8: Variation in the rate of CO in % Vol. over time following a cold start.

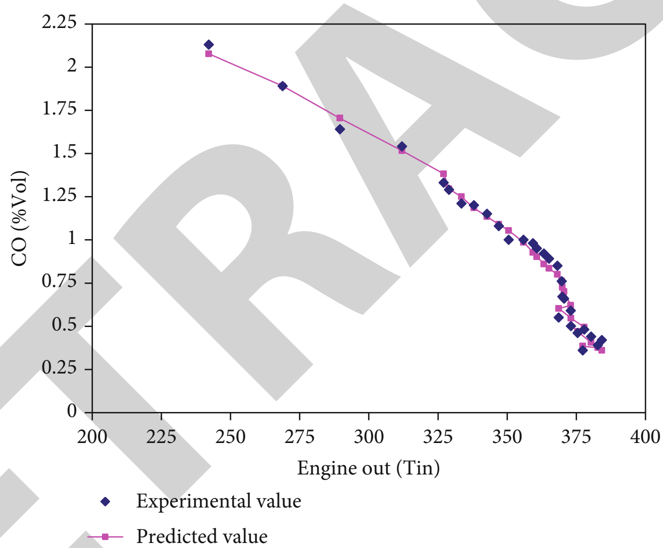

Figure 9: Variation in the rate of CO in % Vol. with engine exhaust temperature.

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exhaust gas needs some residence time to convert CO to CO_2. The model was proposed to give enough time and required temperature to attain.

Figure 6 indicates that the heat created due to the nanoparticles carried down to the main catalytic converter heats it more effectively than the previous configuration. Figure 7 depicts the temperature path lines, which show the way the heat is carried away to heat the main converter. Once the main converter is heated up to the light-off temperature, its efficiency is around 98% as per the previous work [22].

3. Theoretical Investigation: Multiple Regression Analysis

The benefit of this strategy would be that no prior predictions about the correlation's shape are required. The technique is validated based on preliminary results. Regression is a method for determining the shape of the finest correlation, including its constants, while genetic algorithms are one approach to accomplish this. Comparisons based on empirical results are frequently used to estimate the rate of heat generation in thermoelectric elements. Most of the time, this transition from empirical observations to correlations is done by first choosing a certain functional form of the relationship and then figuring out the constants [23].

The efficiency of CO conversion rate, CHCC is temperature-dependent on the emission well before CHCC, the temperature of both MC and the duration of the engine's cold start, all of which are managed as independent factors. The following data from a trial run of 1.5 kW heating and 90 lpm air supply is being used to correlate the condition required for CHCC.

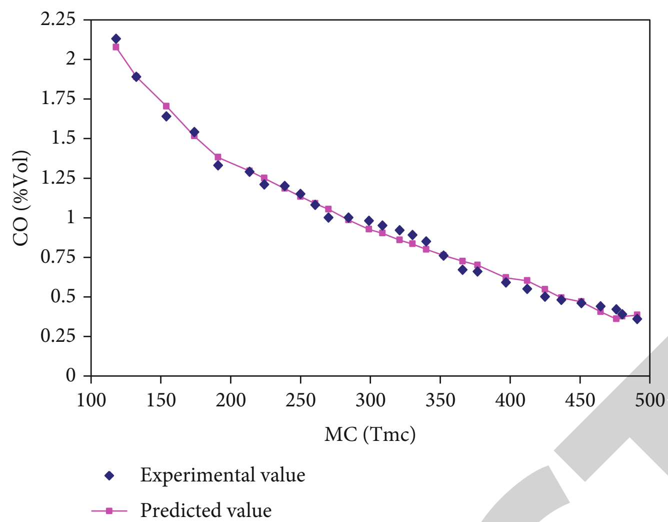

FIGURE 10: Variation in the rate of CO conversion as a function of MC temperature.

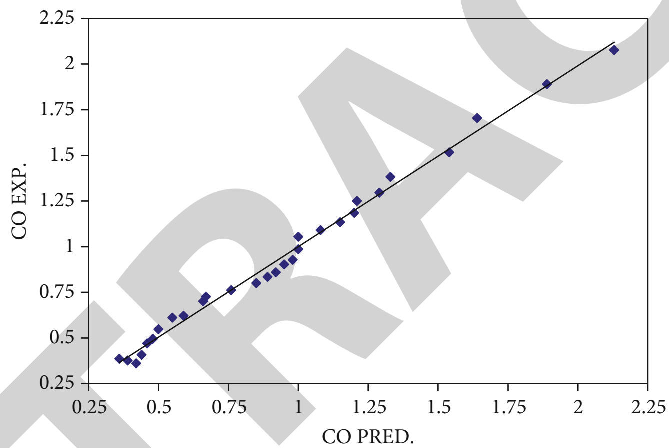

FIGURE 11: Differences in CO experimental and projected values.

TABLE 2: Time to reach light off for different configurations.

Catalytic converter configuration	Time taken to reach light-off temperature for CO reduction	Time taken to reach light-off temperature for HC reduction
145 cubic centimeter EHC catalytic converter without copper oxide nanoparticle coating	156 seconds after the engine started	180 seconds after the engine started
145 cubic centimeter EHC catalytic converter with copper oxide nanoparticle coating	48 seconds after the engine started	168 seconds after the engine started

With this method, the experimental data is used to test the procedure. Regression is a way to find the best-fitting correlation's shape and constants, and genetic programming gives you a way to do it. The heat rate in thermal components is estimated by using correlations that were found through experiments. This process of turning experimental data into correlations is done by first choosing a specific functional form of the correlation and then figuring out the constants for that form.

The CO conversion rate, which is a measure of how well the converter works, depends on the temperature of the exhaust before the converter, the temperature of the main converter (MC), and how long it has been since the engine was cold started. These factors are treated as independent variables, and data from a test run with 1.5 kW of heating is shown in

$$\mathrm{CO}(\%\mathrm{conversion}) = 51.87132 - 0.24151t - 0.0009\mathrm{Tin} + 0.173323\,\mathrm{Tmc}, \quad (2)$$

where t is the number of seconds since the engine was

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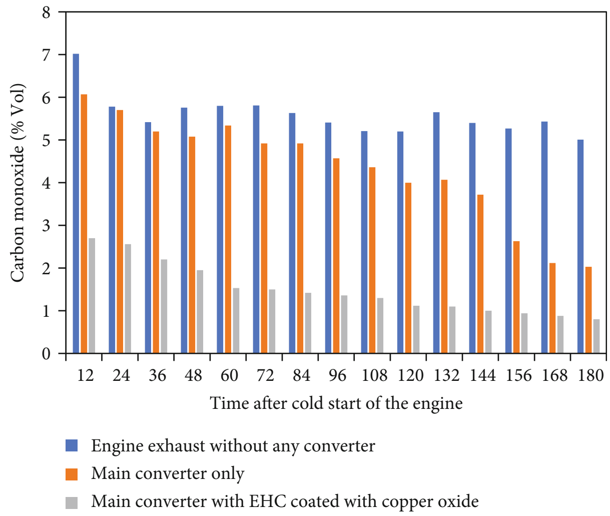

Figure 12: Variation between the CO with time after a cold start of the engine in seconds.

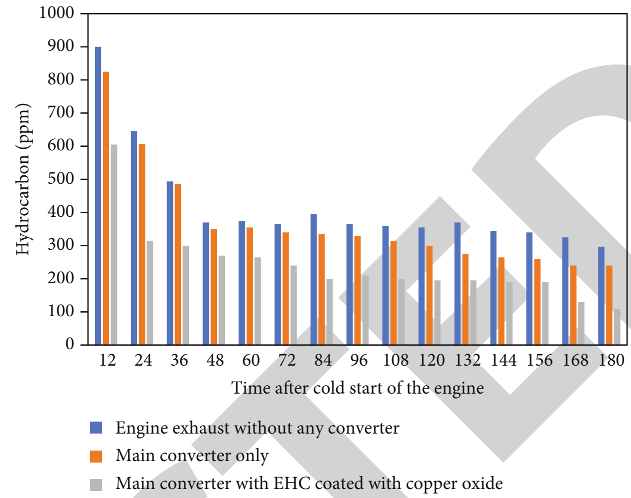

Figure 13: Variation between the HC with time after a cold start of the engine in seconds.

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turned on cold, Tin is the exhaust temperature before the converter in °C, and Tmc is the main converter's surface temperature in °C.

This equation is a useful engineering tool for figuring out how well the converter will work with the nanocopper oxide.

The above method is a useful engineering method for quantifying the CHCC's performance under specified conditions. Figures 8–10 illustrate the projected and empirical rate of conversion in CO vs. period in seconds after a cold start, engine exhaust temperatures before CHCC, and main catalytic converter temperature, respectively. By setting the third independent variable and the matching rate of conversion of CO, all two independent variables may be predicted [24]. As can be seen from the graphs, the projected values and experimental data are very congruent.

The projected and observed results of the rate of CO conversion are shown in Figure 11. According to a study of the sample data, the projected results are quite similar to the experimental standards [25]. As a result, the established model may be utilized confidently to assess the condition required. The time to reach light off for the catalytic converter coated with copper oxide nanoparticles is given in Table 2.

According to Table 2, the main catalytic converter reaches the light-off temperature at different times after the cold start for different configurations. The MC quickly approaches the CO and HC light-off temperatures. This could be because the heat made by the oxidation reactions raises the temperature of the exhaust gas, making the catalyst light off faster. According to Figure 12, the CO percent by volume is larger at the start of the engine in all situations and subsequently drops as the duration after the cold start increases. It is also seen that, except for engine exhaust and MC alone, the CO decrease in percent by volume is more than 50% before the CO light-off temperature is reached. This could be because of CO oxidation in the presence of air and a copper oxide nanocatalyst. According to Figure 13, the hydrocarbon concentration in ppm is higher at the start of the engine and subsequently drops over time for all configurations examined. The hydrocarbon content in ppm is lower for EHC and even lower for EHC with nanocopper oxide. This could be because there is enough oxygen in the exhaust, which raises the temperature at which the light goes out and makes the conversion process more efficient.

4. Conclusion

The new proposed model has analyzed the thermal conductivity and flow characteristics of copper oxide nanoparticles incorporated in the metal mesh used to enhance the heat transfer performance of the catalytic converter. The newly created model is very effective at receiving heat from EHC while passing through it. The velocity vector and magnitude show that the flow pattern creates turbulent and vortex space in the CHCC. The heat from the EHC is shown to be carried by the flow, which then accumulates it as required towards the conclusion of the CHCC. It is seen that the analyses give a better picture of the internal flow of the exhaust gas and heat transfer path. This program may be utilized for converter modelling and evaluation, although exothermic heat generation is far more essential than catalytic converter temperature analysis, even though exothermic heat generation is much more important than the temperature analysis in the catalytic converter. The regression analysis shows that the experimental value and predicted values are conformed in the validation.

Data Availability

The data used to support the findings of this study are included within the article

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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