Pura Aerem: Computational Analysis and Prototype Optimization of a Novel Multi-stage Extension Designed To Reduce PM10, CO2, CO Exiting TWC-OC Catalytic Converters

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Ambient air pollution presents a 7 million annual mortality rate and devastating environmental impacts, with gas-powered vehicles among the leading contributors. The current technology used within gas-powered vehicles is the TWC-OC catalytic converter, converting gasses such as CO, HC, and NOX into CO2 and trace pollutants. The goal of this study is to enhance TWC-OC catalytic converter filtration efficiency through a multi-stage extension, Pura Aerem (PA), which utilizes diffusion-interception capture methods to reduce PM10 levels, photoelectrochemical oxidation (PECO) technology for carbon monoxide destruction, and C60 Buckminsterfullerene Multi-Walled Buckypaper (MWBP) screening used for CO2 encapsulation. Mat3ra Molecular Dynamic (MDS) simulations were conducted to optimize carbon nanotechnology. An artificial intelligence (AI) image segmentation analysis of scanning-electron microscope (SEM) images was used to analyze layer parameters for input into Computational Fluid Dynamic (CFD) simulations via GeoDict and Solidworks, simulating laminar exhaust flow, validating filtration efficiency and optimizing flow rate. Components were 3D printed according to specifications for modularity. Levels of PM10, CO2, and CO were sampled from four environments with a wide range of vehicles. Pura Aerem reduces Fine PM and Coarse PM by 99.275% and 99.587% (respectively), CO2 by over 92.844%, and CO by 100%. Chi-square tests indicated that there was a significant FPM and CPM reduction ($p < 0.01$). Individual stages also showed high filtration efficiency. Thorough sensitivity analysis conducted to determine PA’s long-term effects on worldwide PM and gas emission levels within ambient atmosphere. PA is a promising emission solution for applications within internal combustion engines.