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CERIUM OXIDE AS AN ADDITIVE IN BIODIESEL/DIESEL FUELED INTERNAL COMBUSTION ENGINES: A CONCISE REVIEW

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ABSTRACT

Fuel and engine technologies have advanced dramatically because of ever-increasing pollution limits and need for fuel economy. Fuel additives have been used to improve engine efficiency for more than a century, but developments in direct injection gasoline engines have posed new challenges that must be solved. In today's world of economic competitiveness, the rapid depletion of fossil fuel supplies is driving a critical demand for increased internal combustion engine efficiency. Coatings have been discovered to have a substantial impact on engine efficiency in the automobile sector. The higher the operating temperature, the higher the system's efficiency. The findings of recent studies on cerium oxide as fuel additive and thermal barrier coating materials in internal combustion engines are discussed in this review article, including combustion characteristics, performance, and emissions.

Keywords: Diesel engines, Fuel additives. Engine performance, Emission characteristics

INTRODUCTION

Biofuels are the most widely used alternative fuel. [1]. Biofuels are the most well-known alternative fuels for replacing fossil fuels in internal combustion engines (biodiesel, bioethanol, biomethanol, etc.). Biofuels made from vegetable oil look to be a viable replacement for fossil fuels. They are more environmentally friendly, biodegradable, nontoxic, recyclable, and benzene-free, and their production is quite simple. [2,3].

Biofuels are created from all parts of plants, including wood, resin, leaves, and grass, using a steam distillation technology that has advantages like lower kinematic viscosity and higher calorific value, allowing for more fuel atomization and evaporation. Because of their greater efficiency, stability, durability, and cheap fuel cost, compression ignition engines were perfect for heavy-duty applications such as agriculture, industry, and transportation. [4-5]. The search for a viable alternative source of energy has been going on for a long time to find a viable solution to the issues of rapidly depleting natural oil reserves and environmental pollution caused by harmful gas emissions such as CO and NOx from the countless automobiles that run on petrol or diesel [6]. Because of better thermal barrier coatings, future gas turbines will be able to operate at higher gas temperatures (TBCs). As a result, considerable effort is being expended in the development of innovative materials that surpass the existing industry standard, yttria-stabilized zirconia (YSZ) [7]. In diesel engines, reduced heat rejection is most effective in turbocharged engines and least useful in regularly aspirated engines. To gain better performance over a wide variety of engine loads, it's critical to pair the engine with a turbocharger. [8].

RESEARCH FINDINGS ON EFFECT OF FUEL ADDITIVES ON ENGINE PERFORMANCE:

Table 1 shows the summary of cerium oxide as fuel additive used in diesel engines from the previously published research studies.

Table 1. Summary of Cerium oxide used as fuel additives with the source of fuel

Fuel	Fuel additive	Engine coating	Findings	References
LPO biodiesel	Surfactant	NA	The stability, performance, and emissions of lemon oil emulsions were investigated. Water was used to emulsify lemon oil in varied quantities. The performance and emissions of emulsions with varying water amounts were investigated.	[9]
Diesel	CeO_2 nanoparticle	NA	Although cerium oxide nanoparticles are used as a diesel fuel additive to reduce particulate matter emissions and increase fuel economy, their environmental fate is unclear. Cerium oxide was recovered and described from the exhaust stream	[10]

			of a diesel engine because of the combustion of diesel fuel containing the additive EnviroxTM, which employs suspended nanoscale cerium oxide to reduce particulate matter emissions and increase fuel efficiency.	
Lemongrass oil	CeO_2 nanoparticle	NA	The effects of crank angle on cylinder gas pressure and heat release rate (HRR) for neat diesel, neat LGO, LGO emulsion, and LGO nano emulsion fuels have been investigated.	[11]
Jatropha biodiesel	CeO_2 . Al_2O_3 nanoparticle	NA	Due to its potential advantage of high surface area to volume ratio, acting as a catalyst for better combustion, the effect of nanoparticle as an additive in Jatropha biodiesel has been experimentally investigated in a single cylinder DI diesel engine with the goal of diluting the level of pollutants in the exhaust and improving engine performance.	[12]
Castor oil	CeO_2 nanoparticle	NA	Experimental research looked at the performance and emission characteristics of a compression ignition engine that used cerium oxide nanoparticles as an additive in pure diesel and diesel-biodiesel-ethanol mixes.	[13]
Pure diesel	CeO_2	NA	When cerium oxide nanoparticles and water-based ferrofluid are introduced to diesel fuel, the link between compression ignition engine performance and emission characteristics is investigated.	[14]
Jatropha biodiesel	CeO_2	NA	In a single cylinder, four stroke DI diesel engine, an experiment is conducted to examine the performance and emission characteristics of nano particles such as Alumina (Al_2O_3) and Cerium oxide (CeO_2) as additions in Jatropha biodiesel.	[15]
Pungam oil biodiesel	CeO_2	NA	Biodiesel derived from Calophyllum Inophyllum oil was shown to be a feasible alternative to ultra-low sulfur diesel in the study.	[16]
Jatropha biodiesel	CeO_2	NA	To explore the possibilities of synthesized nanofuel, single-cylinder diesel engines were employed to conduct engine performance and emission tests, which demonstrated a 15 percent average reduction in NO emissions for B5 and B10 blends with 15 ppm of catalytic nanoparticle concentration.	[17]
Jatropha biodiesel	CeO_2	NA	The performance, combustion, and emission aspects of nanoparticles dispersed test fuels are investigated in a single cylinder constant speed DI diesel engine.	[18]
Lemon grass oil	CeO_2	NA	An experimental study of the combined impact of nanoemulsified LGO25 with DEE and EGR was performed on a single cylinder direct injection diesel engine.	[19]
Waste cooking oil	CeO_2	NA	Low-level cerium oxide-containing water in B5 has been researched for its impact on engine performance and emission characteristics.	[20]
Diesel	CeO_2	NA	In an experimental investigation, the performance, combustion, and emission characteristics of a diesel engine were assessed	[21]

			using cerium oxide (CeO2) nanoparticles as diesel fuel additives.	
Jatropha	CeO_2	NA	The effects of additive nanoparticles on fuel characteristics, engine performance, and emissions are explored, and the injection dosage of the additive is optimized. There are also performance comparisons of the fuel with and without the additive.	[22]
Pungam oil biodiesel	CeO_2	NA	Different types of additives, as well as different fuel qualities, are compared and discussed. Finally, in preparation for future research, the advantages and prospects of using nanofluid as an extra fuel are explained.	[23]
Ginger grass oil	CeO_2	NA	The experiment employed a 1500rpm, four-stroke, single-cylinder, water-cooled diesel engine. The effects of a Cerium Oxide nano-additive added to Ginger grass oil-Diesel blends on brake thermal efficiency, specific fuel consumption, and exhaust pollutants were studied.	[24]
Waste cooking oil	CeO_2	NA	The effect of iron-doped cerium oxide ($FeCeO_2$) nanoparticles as a fuel additive was investigated experimentally using waste cooking oil methyl ester in a four-stroke, single-cylinder, direct injection diesel engine..	[25]
Waste cooking oil	CeO_2	NA	An experimental trial was conducted at full engine load to evaluate the reduction in CO, NOx, and UBHC of synthetic biodiesel based on waste cooking oil at various concentrations of CeO_2 nanoparticles and Ce0.5Co0.5 nano-composite oxide.	[26]
Castor oil	CeO_2	NA	Experimentally, the performance, combustion, and emission characteristics of a variable compression ratio engine using Cerium Oxide Nanoparticles and Carbon Nanotubes as fuel-borne nanoparticles additives in Diesterol (diesel–biodiesel–ethanol) mixes are studied.	[27]
Waste cooking oil	CeO_2	NA	At different injection timings, the performance of a biodiesel engine employing waste cooking oil biodiesel mixed with cerium oxide (CeO2) nanoparticles as additives was examined.	[28]
Lemon grass oil	CeO_2	Coated with Zirconia	Lemongrass oil is used as a biofuel since it has a lower density and viscosity than diesel.	[29]
Diesel	CeO_2	Coated zirconia	This experimental inquiry looks at the performance and emission characteristics of a single cylinder diesel engine with yttria and ceria stabilized zirconia coating on the cylinder liner and piston head.	[30]
Citron oil biodiesel	CeO_2	Coated Zirconia	B15, B20, and B25 blends were tested for emissions and performance in a single cylinder compression ignition engine with and without TBC under the same conditions.	[31]

Lemon oil was emulsified with a water-water combination of 5% and 10%. Only stable emulsions with 5% water were tested for performance and emissions, and only stable emulsions with 10% water were examined for performance and emissions. When compared to pure lemon oil, the findings revealed that due to the micro-explosion phenomena of water, the brake thermal efficiency improved, and the brake specific fuel consumption increased. When the calorific value of the fuel was reduced due to the addition of water, NOx emissions dropped but HC and CO emissions increased. [9].

The use of more realistic material in future toxicity studies and modeling will be required since pure, laboratory-produced nanoscale cerium oxide is not an acceptable surrogate for cerium oxide emitted from fuel-borne catalyst applications. [10].

When compared to pure LGO, despite the minor increase in HC and CO emissions, the LGO emulsion fuel may reduce smoke and NOX emissions and improve Brake Thermal Efficiency (BTE) and Brake Specific Energy Consumption (BSEC). [11]. Ceria nanoparticles boost brake thermal efficiency for both test fuels due to their high surface area to volume ratio, allowing for better combustion through higher atomization, faster air-mixture mixing, and faster fuel evaporation. [12].

HC emissions are minimized because cerium oxide's activation energy burns off carbon deposits within the engine cylinder at wall temperature and prevents the development of non-polar compounds on the cylinder wall. [13,14]. The cerium nano particle mixed test fuels demonstrated a significant increase in brake thermal efficiency, approaching that of pure diesel, as well as a decrease in nitric oxide, carbon monoxide, unburned hydrocarbon, and smoke emissions. [15]. The mixing quality of biodiesel spray with air can be improved by improving the design of the fuel injection system. Cerium oxide nanoparticles (CON) can be used as a nanofuel additive catalyst to aid enhance combustion efficiency. [16]. In diesel-biodiesel blends, the addition of catalytic nanoparticles has no influence on the fuel characteristics. [17].

Nanoparticles in biodiesel minimize ignition delay and enhance combustion start-up, resulting in a lower heat release rate and cylinder pressure at full load. [18]. With DEE and EGR mode, the combustion duration and ignition delay increase for nano-emulsified LGO25 fuel but decrease for nano-emulsified LGO25 fuel. [19]. According to the findings, an aqueous nano-emulsion of cerium oxide improved overall combustion quality. Fuel utilization for brakes should be accurate. [20].

CeO_2 in diesel fuel plays an important role in the dehydrogenation process at high temperatures due to its high redox capability. When nano-CeO_2 is introduced to neat diesel, the cylinder pressure steadily rises in comparison to the reference neat diesel. [21]. The flash point and viscosity of biodiesel were found to increase when cerium oxide nanoparticles were added. Hydrocarbon and NOx emissions are greatly reduced when cerium oxide nanoparticles are used. [22]. A nanofluid is a dispersion mixture of nano-sized particles dispersed in a liquid medium. It improves heat transmission properties and promotes great energy efficiency in a wide variety of technological applications. [23]. The HC content of the blends increased as the amount of Ginger grass oil in the blends increased [24].

The reduction in NOx emissions was 15.7 percent, however there was no change in unburned hydrocarbon (HC) emissions. Carbon monoxide (CO) emissions were reduced by up to 24.6 percent for B30 and 15.4 percent for B30 using nano-additives. The B30 with 20% $FeCeO_2$ outperforms the B30 with 10% $FeCeO_2$ in terms of cylinder pressure and emissions. [25]. The data demonstrated that when biodiesel and its mixes were burned at full engine load, both CeO_2 and Ce0.5Co0.5 nanocomposite oxides exhibited significant decreases in CO, NOx, and UBHC [26].

Carbon Nanotubes operate as a catalyst to speed up the burning process, resulting in a shorter ignition time and a lower heat release rate, as well as a faster peak heat release rate.[27]. By extending fuel injection time and adding nanoparticles, engine combustion may be improved while emissions are lowered. This helps to conserve diesel fuel while also lowering pollutants in the environment [28]. The BTE and BSEC of lemongrass oil coupled with cerium oxides enhances the combustion characteristics due to the increased surface area. [29]. Engine with yittria and ceria stabilized zirconia coating with varying dosing levels of CeO_2 and diesel combination as a fuel mixture shows an increase in BTE [30]. The viscosity of raw biooil is significantly reduced when CMPO is blended with diesel. The performance and emission characteristics of the aforesaid composition with TBC covering are also improved [31].

CONCLUSION:

The review article presented an overview on cerium oxide as fuel additive and thermal barrier coating materials in internal combustion engines. The following improvements were observed with the addition of fuel additives:

- Brake and indicated power increase with loading conditions.
- Friction power increases from 0 to 25% and decreases with loading condition beyond 25%.
- Brake thermal efficiency increases with loading conditions. Indicated thermal and volumetric efficiencies decrease with loading conditions.
- Specific fuel consumption and exhaust gas temperature decreases and increases with loading conditions, respectively.
- NOx emissions increase at low and decrease at high loading conditions. CO emissions decrease at low and increase at high loading conditions.

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