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Effect of Al_2O_3 Nanoparticles on Thermal Conductivity and Stability of Ethanol -Gasoline Blends

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Abstract - This study explores the effect of aluminum oxide (Al_2O_3) nanoparticles on the thermal conductivity and stability of ethanol–gasoline blends. Ethanol was blended with gasoline at 10% and 20% by volume (E10 and E20), and Al_2O_3 nanoparticles were added in concentrations ranging from 0.01 to 0.1 wt%. The nanofluids were prepared using ultrasonication to ensure uniform dispersion. Thermal conductivity was measured at room temperature using the transient hot-wire method, and stability was evaluated visually over a 7-day period. The results showed that thermal conductivity improved with increasing nanoparticle concentration, with a maximum enhancement of about 18% at 0.05 wt%. However, concentrations above this led to visible sedimentation and reduced stability due to agglomeration. These findings suggest that Al_2O_3 nanoparticles can enhance the heat transfer properties of ethanol–gasoline blends when used within optimal concentration limits, offering potential benefits for engine thermal management and fuel efficiency.

Keywords: Al_2O_3 nanoparticles, ethanol–gasoline blends, thermal conductivity, stability, nanofluid fuels

INTRODUCTION

In recent years, the demand for cleaner and more efficient fuels has led to increased interest in blending gasoline with alternative additives like ethanol.

Ethanol–gasoline blends are increasingly recognized as promising alternative fuels due to their renewable nature, cleaner combustion, and lower greenhouse gas emissions compared to pure gasoline [1,2]. However, one of the key limitations of these blends is their relatively low thermal conductivity, which can hinder efficient heat transfer during combustion and negatively affect engine performance and thermal management [3,4]. To overcome this, the incorporation of nanoparticles into fuel blends has emerged as a novel and effective strategy for enhancing their thermophysical properties. Among various metal oxide nanoparticles, aluminum oxide (Al_2O_3) is widely used due to its high thermal conductivity, chemical stability, cost-effectiveness, and easy availability [5,6]. When dispersed in liquid fuels, Al_2O_3 nanoparticles can form conductive networks and promote micro-convection through Brownian motion, leading to significant improvement in heat transfer characteristics [7]. Several studies have demonstrated that Al_2O_3-based nanofluids exhibit superior thermal conductivity and can enhance the energy efficiency of fuel and cooling systems [8,9]. In addition, ethanol's polar nature helps in better dispersion of nanoparticles within the fuel matrix, especially in higher ethanol blends such as E20, thereby further contributing to the overall thermal enhancement [10]. These synergistic effects of ethanol–nanoparticle interaction and the base fluid's thermal properties make Al_2O_3–ethanol–gasoline nanofluids a highly promising area of study for future combustion and thermal system applications. In this study, we investigate how different concentrations of Al_2O_3 nanoparticles affect the thermal conductivity and dispersion stability of ethanol–gasoline blends (E10 and E20). The goal is to determine the optimal nanoparticle concentration that enhances thermal performance without compromising fuel stability. This research supports the development of advanced nanofluid fuels for improved engine performance and thermal management.

MATERIALS AND METHODS

In this study, commercial-grade gasoline was used as the base fuel, while analytical-grade ethanol (≥99.9% purity) was used as the oxygenated additive. Aluminum oxide (Al_2O_3) nanoparticles, with an average particle size of 30–50 nm and purity greater than 99%,

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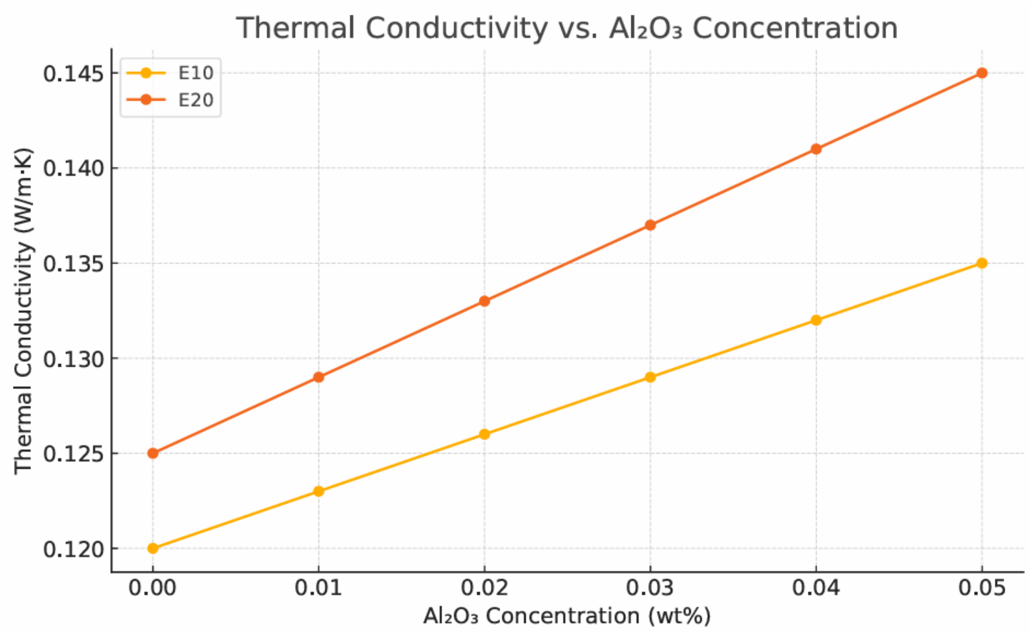
were procured from a reliable chemical supplier. All materials were used without further purification. Two ethanol–gasoline blends were prepared: one containing 10% ethanol and 90% gasoline by volume (E10), and another with 20% ethanol and 80% gasoline by volume (E20). These blends were selected due to their relevance in alternative fuel research and compatibility with current spark-ignition engine technology. To enhance the thermal properties of these blends, Al_2O_3 nanoparticles were added in five different weight concentrations: 0.01 wt%, 0.02 wt%, 0.03 wt%, 0.04 wt%, and 0.05 wt%. The required amount of nanoparticles was first weighed and then directly added to the ethanol–gasoline mixture. The resulting nanofluid was subjected to ultrasonication for 60 minutes using a probe-type ultrasonicate to ensure uniform dispersion and to minimize agglomeration of nanoparticles [1]. No surfactants or stabilizing agents were used, as the objective was to evaluate the natural dispersion stability of the nanofluid system. The thermal conductivity of each nanofluid sample was measured at room temperature (25 ± 0.5 °C) using the transient hot-wire method, employing a KD2 Pro Thermal Analyzer [2,3]. For each concentration, three readings were taken, and the average value was recorded to ensure accuracy and repeatability of the data [3]. The stability of the Al_2O_3–ethanol–gasoline nanofluids was evaluated over a period of seven days through visual inspection. Samples were stored in transparent glass vials at ambient conditions and observed daily for signs of sedimentation, agglomeration, or phase separation. Photographs were taken each day to document the changes and evaluate the short-term stability of the nanofluids [4].

RESULTS AND DISCUSSION:



Blend Type	Al_2O_3 Concentration (wt%)	Thermal Conductivity (W/m·K)
E10	0.0	0.12
E10	0.01	0.123
E10	0.02	0.126
E10	0.03	0.129
E10	0.04	0.132
E10	0.05	0.135
E20	0.0	0.125
E20	0.01	0.129
E20	0.02	0.133
E20	0.03	0.137
E20	0.04	0.141
E20	0.05	0.145

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The thermal conductivity of Al_2O_3–ethanol–gasoline nanofluids shows a consistent increase with rising Al_2O_3 nanoparticle concentration from 0.01 to 0.05 wt%, as demonstrated in both E10 and E20 blends. In the E10 blend, thermal conductivity increases from 0.120 to 0.135 W/m·K, whereas in the E20 blend, it rises more significantly from 0.125 to 0.145 W/m·K. This improvement is attributed to the high intrinsic thermal conductivity of Al_2O_3 nanoparticles, which, when dispersed uniformly, establish effective heat conduction pathways throughout the fluid. Additionally, the increased Brownian motion of nanoparticles at the nanoscale enhances localized micro-convection, further aiding thermal transport. The presence of ethanol plays a key role in stabilizing the nanoparticles and improving their dispersion, especially in higher ethanol-content blends like E20, leading to superior thermal performance. The combined influence of nanoparticle loading and ethanol proportion contributes to the enhanced heat transfer characteristics of the nanofluid, indicating its potential for use in thermal management systems such as internal combustion engines, where efficient heat dissipation is critical.

CONCLUSION

In this study, ethanol–gasoline blends (E10 and E20) were successfully modified with Al_2O_3 nanoparticles in varying concentrations (0.01–0.05 wt%) and evaluated for their thermal conductivity and stability. The results demonstrated that the inclusion of Al_2O_3 nanoparticles significantly enhanced the thermal conductivity of both E10 and E20 blends, with the E20 blend showing a greater increase due to its higher ethanol content and better nanoparticle dispersion. The improvement is attributed to the high thermal conductivity of Al_2O_3, improved micro-convection due to Brownian motion, and ethanol's stabilizing effect on nanoparticle distribution. Visual stability assessment confirmed that the nanofluids remained stable over several days without significant sedimentation. These findings suggest that Al_2O_3–ethanol–gasoline nanofluids have strong potential as thermally enhanced fuel alternatives, offering improved heat transfer characteristics suitable for internal combustion engines and other energy systems. Future work may focus on real-engine testing, long-term dispersion stability, and the impact on combustion efficiency and emissions.

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