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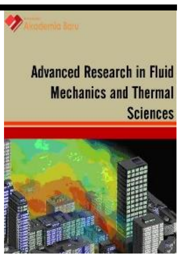

Influence of Nano Additives on the Thermo-physical Properties and Exhaust Emissions of Gasoline Fuel in SI Engine

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ABSTRACT

The reducing of exhaust emissions is an essential issue for environmental organizations in the world. In the current research, emissions of SI engines were reduced by using Alumina (AL_2O_3) and titanium dioxide (TiO_2) nanoparticles as additives to the high octane gasoline fuel used in the SI engine. 30 nm Alumina and titanium dioxide nanoparticles were mixed with high octane gasoline fuel at different concentrations. Different tests were carried out for the high-octane gasoline fuel before and after adding the nanoparticles, including thermal conductivity, viscosity, PH, density, morphology. Tests of the percentage of CO and O_2 emissions were also performed for the exhaust gases of the SI engine. Results show an increase in thermal conductivity from 0.14 to 0.15 and 0.154 (W/m.k) respectively of AL_2O_3 and TiO_2 nanofluid at 1% of volume concentration compared to the base fluid. Viscosity and density also showed an increase with increasing nanoparticle concentrations in the high-octane gasoline fuel. A decrease in the PH value of the high-octane gasoline fuel with an increase in nanoparticle concentrations was also observed. An improvement was noted in reducing carbon dioxide pollution emissions by alumina and titanium dioxide nanoparticles.

1. Introduction

In the last century, many researchers put much effort into reducing gas emissions form engines to reduce environmental pollution. One was of reducing gas emissions was by finding alternative bio sources for fuel engines or by improving the chemical and physical properties of fuel additives [1]. Two types of nanoparticles, Aluminum oxide (Al_2O_3) and titanium dioxide (TiO_2), with different volume from 1% - 5% and different base fluids, was added to fuel additives to prepare Nanofluids.

Bharti Yadav *et al.,* [2] used two correlations, one is theoretical, and another is experimental, and they showed Al_2O_3/Benzene Nanofluid is better than TiO_2/Benzene for transfer of heat in pipes.

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Several researchers used nanoparticles with fuels to raise the efficiency of fuel and to reduce the emissions of carbon monoxide by oxygen atoms contribution from their lattices to get complete combustion using 20 nm Aluminum oxide and 30 nm cobalt oxide nanoparticles. Enhancement in the thermal efficiency of brake, fuel consumption and temperature of exhaust gas was observed [3-4]. Besides, an improving in liquid kinematic viscosity, density, and thermal conductivity measurements of eleven diverse synthetic polyester-based with different temperatures was achieved using a different concentration of Aluminum oxide (Al_2O_3) and zinc oxide (ZnO) nanoparticles [5]. Aluminum oxide nanoparticles show improved properties such as high surface area stability, good dispersion as compared to other oxide nanoparticles and good Thermal and Physical Properties [6-7]. The influence of Alumina (Al_2O_3) and Cerium oxide (CeO_2) nanoparticles with biodiesel in engine diesel were also studied by Prabu *et al.,* [8]. The results show an increase in brake oil thermal efficiency after adding nanoparticles. Also, CO, HC, NOx and fume emissions were declined slightly. The adding of the alumina-water nanofluid was found to raise the efficiency of brake oil thermal properties to 5.5%, and reducing the consumption of fuel up to 3.94%, as compared to the base fluid. Besides, the addition of alumina-water nanofluid reduces exhaust emissions and noise by Miqdam *et al.,* [9]. Thermal properties of nanofluids for two different nanoparticles (copper oxide (CuO) and titanium dioxide (TiO_2)) with different percentages were measured for six different base fluids. The results show that CuO/gasoline nanofluid is performing better than TiO_2/gasoline for heat transfer in heat pipes by Abhijit *et al.,* [10]. Ruzi *et al.,* [11] was performed an experimental work to in order to investigate the exhaust emission in diesel engine. The results showed that Nitrogen Oxides and Particulate Matter for emulsion fuels reduced by 60% and 14.11% respectively compared to D2. In addition, they stated that CO2 and CO for emulsion fuels are increased compared to D2 by about 27.76% and 102.20% respectively. In the current research, Aluminum oxide (Al_2O_3) and titanium dioxide (TiO_2) were used to overcome different common issues due to its cost and high dispersion ability, which are lower than other materials.

It is evident from the above literatures that the effect of adding different nanoparticles on the exhausts of SI engine emissions is still minimal and has not been investigated sufficiently. Therefore, this research aims to reduce the emissions exhausts of SI engine, like CO and O_2, by studying the effect of adding two different nanoparticles (NPs) (Al_2O_3 (30nm) and TiO_2 (20-30nm), with different concentrations, on the thermal conductivity, viscosity, and pH of gasoline fuel under different volume concentrations.

2. Experimental Work

2.1 Materials and Methods

AL_2O_3 and TiO_2 nanoparticles were provided from US Research Nanomaterials, Inc. with a grain size of 30nm. High octane gasoline fuel (HOGF) used in SI engine was studied.

2.2 Preparation of Fuel Samples

Five Nano fuel samples of TiO_2 and AL_2O_3 in concentrations of 0.1, 0.3, 0.5, 0.7, and 1% were prepared using magnetic stirrer (JENWAY1000) for 30 min and ultrasonic mixer (MTI Corporation) for 15min. The physical properties of nanoparticles and gasoline in this research are shown in Table 1 and Table 2, respectively.

Table 1
The physical properties of nanoparticles

Nanoparticles	Type	Average particle diameter, nm	Purity, %	Density, kg/m^3
TiO_2	Anatas	20-30	99.99	3900
AL_2O_3	α	30	99.99	3700

Table 2
The physical properties of gasoline

Chemical Formula	Density, kg/m^3	Thermal Conductivity (W/m.k)	Odour
C_6H_6	879	0.140	Ormatic

In this study, two-step method is used to prepare the present nanofluids. Under this method, produced dry nanopowders are dispersed in base fluids at certain concentrations, (the weight fractions of nanoparticles in the base fluid are (0.1%, 0.3%, 0.5%, 0.7%, and 1%). The weighing of nanoparticles Is done by using an electronic balance with a high precision (TP-SERIES). Preparation of nanofluid Is carried out under vacuum condition using a vacuum device to avoid pollution and oxidation of metal. The stirring of nanoparticles in the base fluid Is achieved by a mechanical stirrer for a period of two days. Even after stirring, most of the particles remain agglomerated. To overcome this and to form a stable suspension, ultrasonic homogenizer of 1200W power was used for a duration of 10 to 30min.

Viscosity, thermal conductivity, and PH were measured using FUNGILAB SMART, DECAGON devices Inc, PHS-3CW Microprocessor pH/mv meter devices, respectively.

The thermal conductivity of nanofluid is measured by a KD2 Pro thermal property analyser (Decagon Devices, Inc., Pullman, WA, USA) as shown in Figure 1. It consists of a microcontroller of handheld and needles of the sensor. The sensor needle of KD2 consists of both elements of calefactory and a thermostat. The module of controller consists a battery, a 16-bit microcontroller/AD converter, and control circuitry of power. Each measure rotation depends of 60 s. Measurement of thermal conductivity requires that there is never vibration, blending of the fluid through or instantly before the measure and also the probe should be vertically inserted keen on the fluid to reduce errors as of free convection.

Fig. 1. Thermal conductivity device

The nanofluids viscosity is measured using Viscometer of Brookfield programmable (model: LVDV-II+, Brookfield Labs. of Engineering, Inc, Middleboro, MA, USA) which is connected to a PC as shown in Figure 2. The Viscometer leads a spindle engrossed in nanofluids. While the spindle is revolved, the friction of viscosity of the solution beside the spindle is intended through the calibrated spring deflection.

Fig. 2. Viscometer

The pH parameter was measured by using PHS-3CW Microprocessor pH/mv meter devices. The sample should be deep sufficient to cover the tip of the electrode, the probe's keen on the sample, remain for the meter to approach to equilibrium and the meter has reached equilibrium when the quantity becomes steady. Ensure the probe rinse with clean water before using it. And also dry it off with a clean tissue. Table 3 to Table 8 show the data of measurement of nanoparticles and gasoline.

Table 3
The values of thermal conductivity

Vol. Con. %	Al_2O_3	TiO_2
0.0000 (gasoline)	0.1400	0.1400
0.1000	0.1430	0.1415
0.3000	0.1460	0.1430
0.5000	0.1480	0.1450
0.7000	0.1500	0.1470
1.0000	0.1540	0.1500

Table 4
The values of viscosity

Vol. Con. %	Al_2O_3	TiO_2
0.0000	5.7000	5.7000
0.1000	5.9000	5.7800
0.3000	6.2000	6.0000
0.5000	6.6000	6.3000
0.7000	6.9000	6.6200
1.0000	7.4000	7.0000
0.0000	5.7000	5.7000

Table 5
The values of density

Vol. Con. %	Al_2O_3	TiO_2
0.0000	876.0000	876.0000
0.1000	877.0000	879.5000
0.3000	879.0000	883.0000
0.5000	881.0000	885.7000
0.7000	883.5000	888.2000
1.0000	886.0000	891.0000

Table 6
The values of pH

Vol. Con. %	Al_2O_3	TiO_2
0.0000	5.0000	5.0000
0.1000	4.9000	4.7000
0.3000	4.8000	4.5000
0.5000	4.6000	4.2000
0.7000	4.3500	4.0000
1.0000	4.1000	3.8000

Table 7
The values of CO_2

Vol. Con. %	Al_2O_3	TiO_2
0.0000	44.0000	44.0000
0.1000	37.0000	28.0000
0.3000	30.0000	26.0000
0.5000	26.0000	22.0000
0.7000	21.0000	18.0000
1.0000	17.0000	14.0000

Table 8
The values of O_2

Vol. Con. %	Al_2O_3	TiO_2
0.0000	0.4000	0.4000
0.1000	0.3500	0.3300
0.3000	0.3100	0.2900
0.5000	0.2600	0.2400
0.7000	0.2100	0.1900
1.0000	0.1800	0.1500

The high octane gasoline fuel was mixed separately with alumina and titanium oxide nanoparticles in different concentrations and fed into an internal combustion SI engine. The emission ratios for carbon monoxide (in ppm) and oxygen percentage gases are measured by using GAS Detector fixed in the outlet of the SI engine exhaust as shown in Figure 3 and Figure 4.

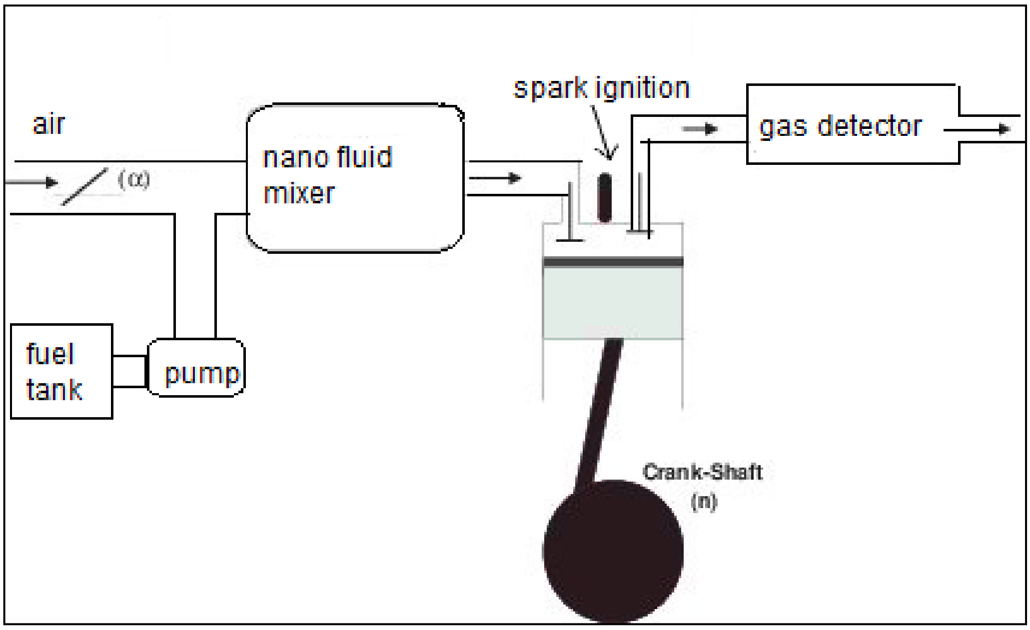
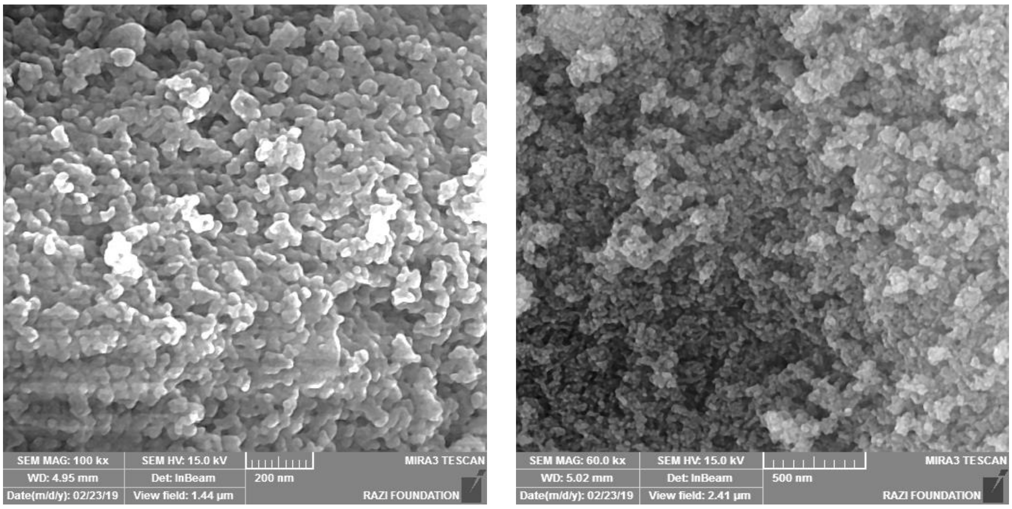


Fig. 3. Schematic of the system of gas detector connected with two-stroke SI engine

Fig. 4. Portable gas sensor

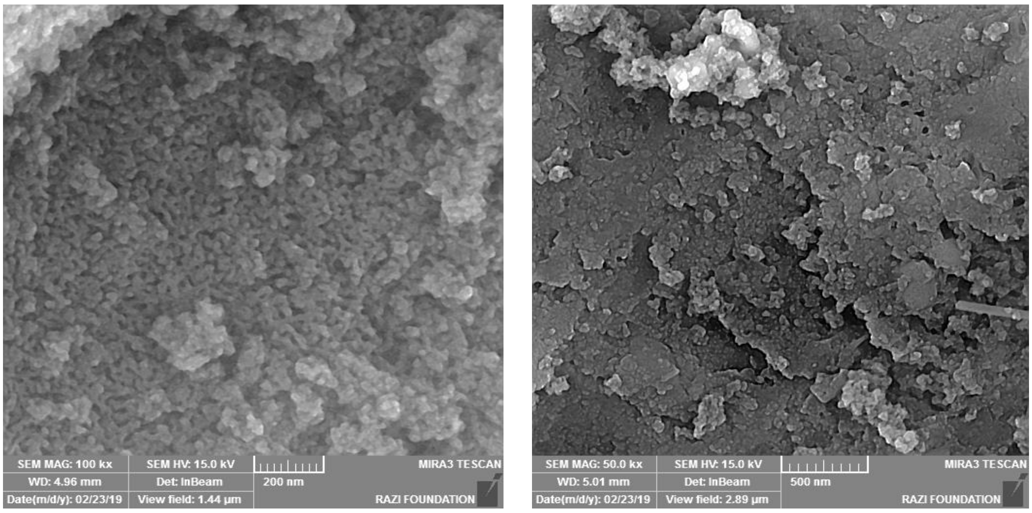
3. Results and Discussion

Figure 5 and Figure 6 show the scanning electron microscope (SEM) images of the TiO_2 and Al_2O_3 NPs mixed with gasoline, respectively. The SEM images show that the particles have regularly spread and it has a spherical of sizes form 200 and 500 nm. As the smaller nanoparticles were transformed into larger particles, aggregated happened.



(a) (b)

Fig. 5. SEM Morphology of TiO_2 nanoparticles



(a) (b)

Fig. 6. SEM Morphology of Al_2O_3 nanoparticles

Figure 7 reveals an increase in the thermal conductivity of gasoline with the addition of Al_2O_3 and TiO_2 nanoparticles. The improvement of the effective thermal conductivity of nanofluid was found to be 10% and 7% at a volume concentration of 1% Al_2O_3 and TiO_2 in the nanofluid, respectively. These results are in agreement with the research of Bharti *et al.,* [2].

The thermal conductivity of Al_2O_3 nanofluid was also noted to be higher than that of TiO_2 nanofluid because Al_2O_3 nanoparticles have high thermal conductivity than that of the TiO_2. The enhancement of the thermal conductivity due to the Brownian motion of particles and formation interface cover nearby the particle of nano considered, for example, a thermal bridge between nanoparticle and gasoline [12].

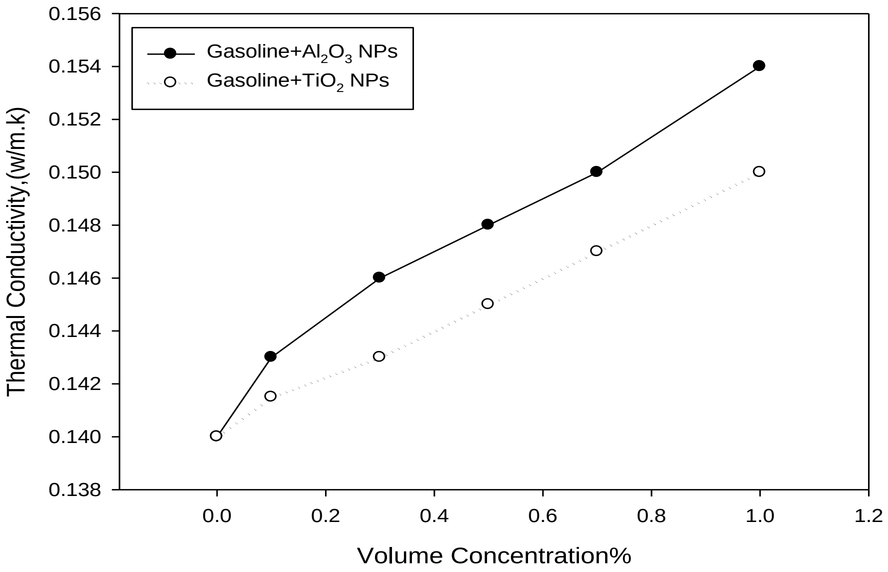


Fig. 7. Thermal conductivity of nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

Figure 8 shows the viscosity of Al_2O_3 and TiO_2 nanoparticles dispersed in gasoline. An increase in viscosity value with an increase in particle volume concentrations was observed due to the existence of nanoparticles sized have a highly connected surface area [13]. These results show an improvement of about 30% and 23% at Al_2O_3 and TiO_2 volume concentration of 1%.

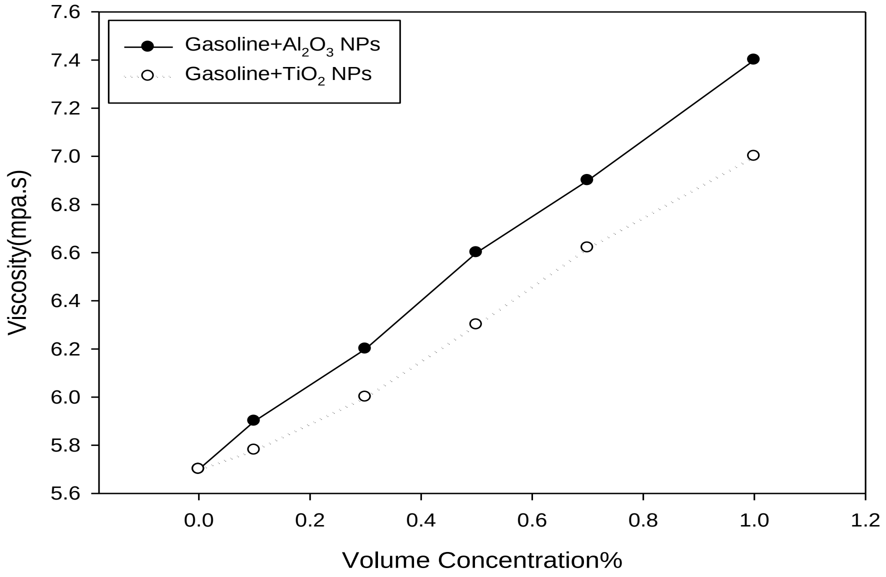


Fig. 8. The viscosity of nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

Figure 9 shows the variant of density in Al_2O_3, and TiO_2 nanoparticles with gasoline nanofluid at variant concentrations of a nanoparticle in the fluid. The density increases with increasing nanoparticles concentration. The density of Al_2O_3 (3.7 g/cm^3) is lesser than the TiO_2 density (3.9 g/cm^3).

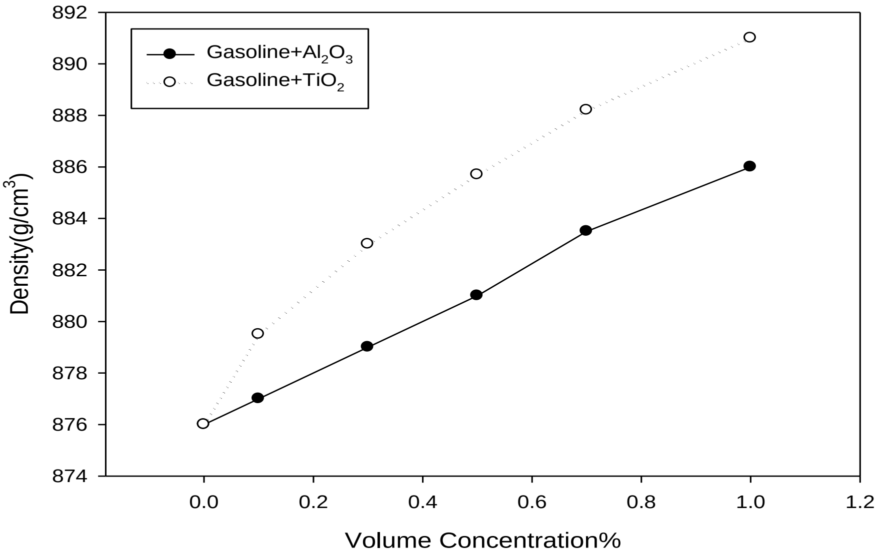


Fig. 9. The density of nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

Figure 10 shows the values of pH for Al_2O_3/gasoline and TiO_2/gasoline nanofluids correspondingly. The pH values of Al_2O_3/gasoline and TiO_2/ gasoline decreased from (5) to (4.1 and 3.8) of Al_2O_3 and TiO_2 respectively through the increase in volume concentration from (0 to 1%) of the nanoparticle. These results are in agreement with the research of Abdulwahab *et al.,* [14].

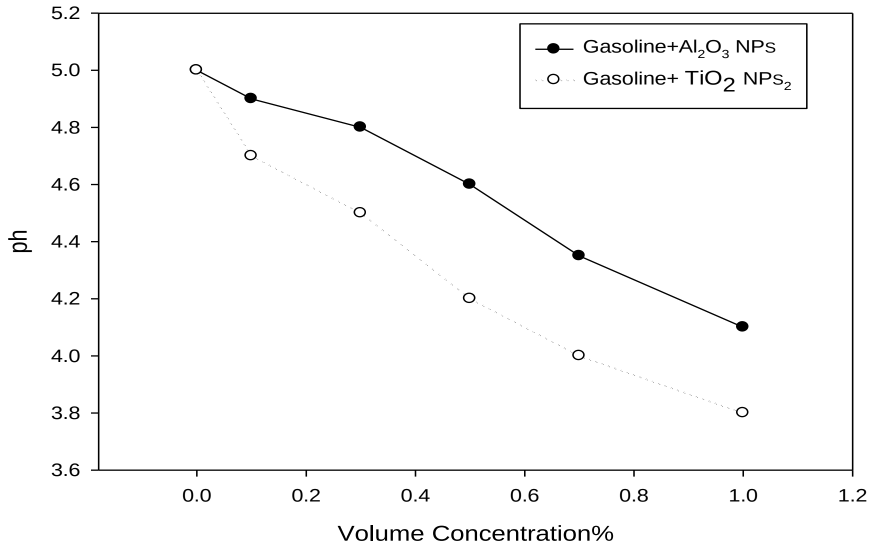


Fig. 10. pH of nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

Figure 11 and Figure 12 show the differences in the emission rate of CO and O_2 gases as a function of different volume concentrations of Al_2O_3 and TiO_2 nanoparticles. The CO emission drops with the addition of Al_2O_3 and TiO_2 nanoparticles to the gasoline fuel. When fuels blended with the nanoparticle, it leads to shortening the period of the ignition, and higher carbon burning activation leads to perfect burning. The CO emission was decreased by a rate of 61% and 68% at 1% nanoparticles concentration compared to the gasoline fuel base fluid because of the existence of a molecule of oxygen inherent in converting CO to CO_2. These results are in agreement with Ashrafur Rahman *et al.,* [15].

All organic compounds, when burned, give carbon dioxide and water vapor mainly in aromatic compounds. Carbon and carbon monoxide are also formed as by-products due to the increase in the carbon content of compounds as shown in Eq. (1), Walker *et al.,* [16].

$$C_6H_6 + 3O_2 \rightarrow CO_2 + 3H_2O + 4C \; + \; CO \tag{1}$$

Eq. (2) and Eq. (3) show the process of engine combustion after added of Al_2O_3 and TiO_2 nanoparticles to the gasoline fuel.

$$C_6H_6 + 2Al_2O_3 \rightarrow CO_2 + 3H_2O + 4C + CO + 4Al \tag{2}$$

$$C_6H_6 + 3TiO_2 \rightarrow \mathrm{CO_2} + 3H_2O + 4C + CO + 3Ti \tag{3}$$

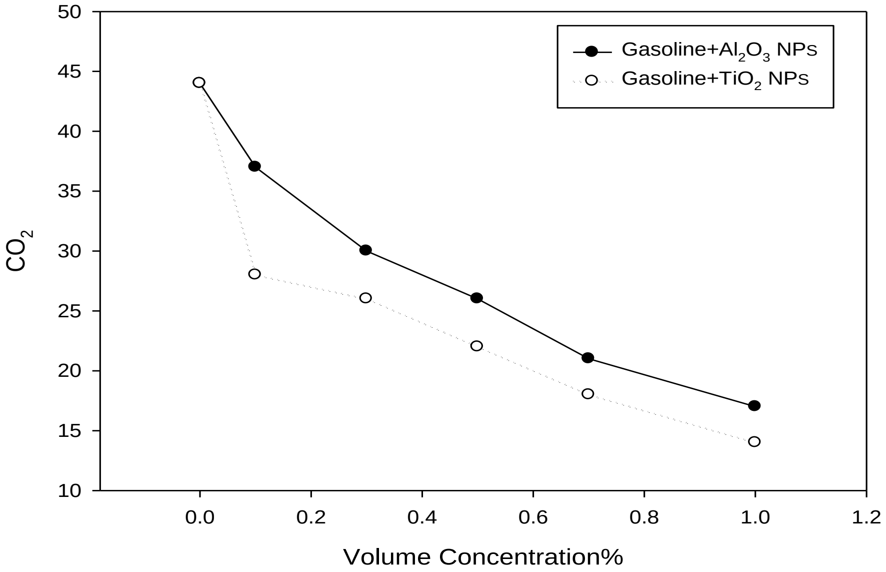


Fig. 11. Carbon monoxide emission against nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

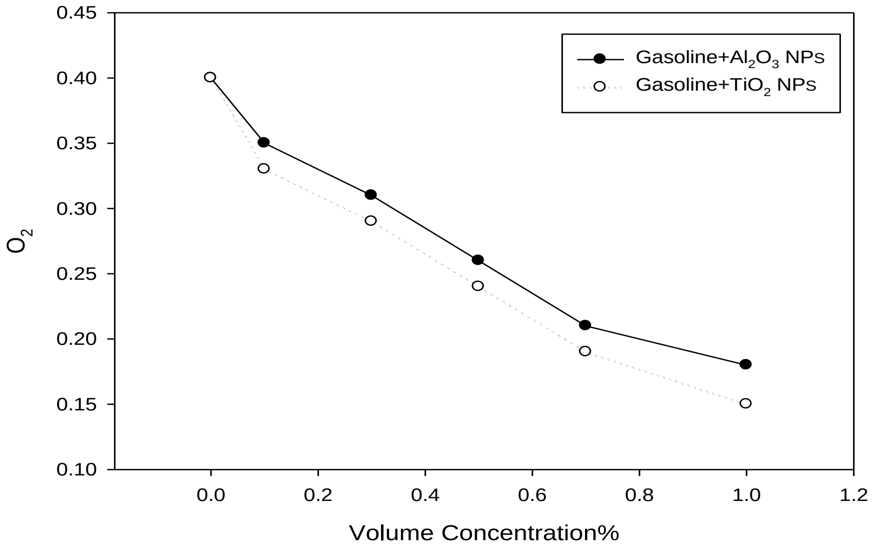


Fig. 12. Oxygen emission against nanoparticles/gasoline nanofluids at different concentration of Al_2O_3 and TiO_2 nanoparticle

4. Conclusions

The thermophysical properties such as thermal conductivity, viscosity, and density of Al_2O_3 and TiO_2– Gasoline nanofluid enhancement were compared with base fluid. The thermal conductivity had been enhanced by about 10% and 7% at 1% volume concentration for Al_2O_3 and TiO_2 nanoparticles respectively. Also, there is an enhancement in viscosity about 30% and 23% at 1% of volume concentration. The emission of CO drops with the use of Al_2O_3, and TiO_2 nanoparticles showed an enhancement in the performance gasoline engine. A reduction rate in emitted CO was 61%, and 68% at 1% volume concentration for Al_2O_3, and TiO_2 nanofluid respectively was observed. The obtained results displayed that increment of Al_2O_3 and TiO_2 nanoparticles concentrations would grow and increased it perform effectively.

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