

Study on the Basic Properties of Graphene Nano Coolant

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Abstract

This study prepared graphene nano-coolants (GrNCs) by adding graphene (Gr) and gum arabic (GA) to a base coolant at different ratios. Six tests evaluated grinding performance, viscosity, thermal conductivity, sedimentation, specific heat, and heat-exchange performance. The results identified a different optimal Gr:GA ratio for each property. The 0%:1% ratio performed best in the grinding test, reducing friction and wear and improving cooling-system efficiency. The 0.075%:1% ratio had the lowest viscosity, which improved fluidity and reduced wear. The 0.05%:1% ratio provided the highest thermal conductivity, enhancing heat dissipation and reliability. The 0.025%:1% ratio produced the least sedimentation, maintained high thermal conductivity and stability, and achieved the best cooling performance with the lowest energy loss in the heat-exchange test. Accordingly, future vehicle tests should evaluate the 0.05%:1%, 0.075%:1%, and 0.025%:1% formulations for thermal conductivity, viscosity, and heat-exchange performance, respectively.

Keywords: graphene nanometers, coolant, sedimentation, grinding, viscosity, heat conduction, heat exchange.

1. Introduction

Since the Industrial Revolution, atmospheric CO₂ concentrations have increased from 280 ppm to 418 ppm [1]. This rise in CO₂ is driven mainly by fossil-fuel combustion, industrial livestock production, and deforestation. The resulting increase contributes to global warming. Because CO₂ is colorless, tasteless, odorless, not directly harmful to humans at typical ambient concentrations, and absorbs heat from solar radiation. The environmental impact of CO₂ is often overlooked.

In recent years, Taiwan's Environmental Protection Administration has actively promoted the retirement of older vehicles. In 2011, more than 9,000 large diesel vehicles were retired; these vehicles accounted for approximately 46% of the air pollution produced by all diesel vehicles. Since 1999, 1.685 million older motorcycles have been retired, reducing the number of such vehicles by about 35% and motorcycle-related air

pollution by approximately 14% [2].

These initiatives underscore the importance of reducing carbon emissions and air pollution. Because Taiwan is densely populated and has limited land area, motorcycle use is widespread. According to Ministry of Transportation and Communications statistics for February 2023, Taiwan had 22,880,071 motorcycles—equivalent to 98 motorcycles per 100 people [3]. Their waste heat and emissions of CO₂ and other greenhouse gases are substantial.

Recent studies indicate that nanofluids (NFs) can improve heat dissipation in heat-transfer applications. Ambreen et al. [4] examined the thermal conductivity, flow behavior, and simulated performance of NFs made from different materials and particle sizes. They found that smaller nanoparticles generally improved heat-dissipation performance in heat-exchange devices.

Based on these findings, this study evaluates whether using NFs in electric-motorcycle coolants can improve thermal efficiency.

1.1 Research background and motivation

As environmental awareness grows, governments are tightening emissions and fuel-consumption standards to reduce the health effects of exhaust and dependence on finite petroleum resources. Many countries have also announced plans to end sales of fuel-powered and hybrid vehicles: the Netherlands and Norway by 2025; the United Kingdom, Sweden, and India by 2030; and Taiwan by 2040 [5].

Advances in battery and motor technology, together with stricter regulations, are accelerating the shift toward electric vehicles. However, motors and batteries generate substantial heat and must be kept within safe operating temperatures. Conventional solutions—such as larger cooling pipes, radiators, and coolant tanks—can meet this need but require additional space and cost.

Because thermal management is critical in every electric vehicle, cooling systems are often enlarged to maintain suitable operating temperatures. Nanofluids (NFs), which have high thermal conductivity, offer a less disruptive alternative. Replacing conventional coolant with NFs may enhance heat removal from motors and batteries without modifying the radiator, coolant tank, or other hardware. This approach could improve both vehicle performance and cost efficiency.

This study uses graphene (Gr) because of its high thermal conductivity and heat-dissipation capability. Gr is added to the original coolant to produce graphene nano-coolant (GrNC), which is then evaluated for its ability to improve the cooling performance and temperature control of electric motorcycles.

1.2 Research purposes

This study has the following objectives:

- (1) Prepare graphene nanofluids (GrNFs).
- (2) Prepare graphene nano-coolant (GrNC).
- (3) Compare the basic test results for the GrNC formulations and identify the optimal concentration.
- (4) Test the optimal GrNC concentration on a heat-exchange simulation platform and analyze its heat-dissipation performance.
- (5) Apply the optimal GrNC concentration to an electric motorcycle and compare the cooling system's heat-dissipation performance.
- (6) Analyze the findings to assess the feasibility of using GrNC in electric motorcycles and identify priorities for further evaluation.

1.3 Research methods and framework

This study uses three sequential methods: literature review, sample preparation, and experimental evaluation. First, the literature is reviewed to determine appropriate GrNC weight ratios. The prepared formulations are then compared through sedimentation, specific-heat, viscosity, and grinding tests to identify the optimal GrNC concentration. Finally, the selected GrNC is evaluated on a heat-exchange simulation platform and in a vehicle test, and the results are compared with published findings to assess its feasibility. Figure 1 presents the research architecture.

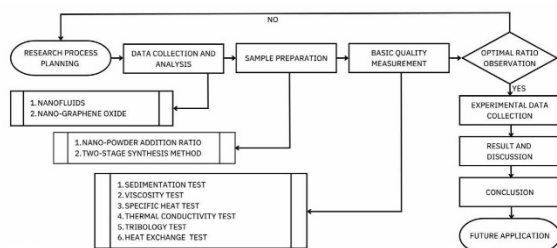


Figure 1 Research Architecture

2. Literature review

According to many studies and literature, the performance of heat conduction and heat dissipation of nanofluids is better than that of general fluids. This study mainly uses nano Gr and cooling water for preparation and testing, and the separate descriptions of nano Gr and cooling liquid as follows:

2.1 Nanofluids (nanofluids, NFs)

Adding nanoparticles to a working fluid alters thermophysical properties such as viscosity and thermal conductivity. Studies of metal-oxide and carbon-based

nanofluids (NFs) generally show that thermal conductivity increases with nanoparticle concentration, thereby improving overall heat-transfer performance [6–8]. Accordingly, nanofluids have demonstrated considerable potential as cooling media in heat-exchange applications.

2.2 Graphene (Gr)

In October 2002, Dr. Zhang Bozeng published the world's first graphene patent, describing its composition, manufacturing process, and application technologies [9]. Graphene's exceptional electronic, thermal, optical, and mechanical properties have since prompted extensive engineering research. Compared with other nanoparticles, graphene offers the following advantages [10–12]:

- (1) It is the thinnest known nanomaterial while also exhibiting exceptional strength.
- (2) It has excellent optical transparency.
- (3) It has high thermal conductivity.
- (4) It has extremely low electrical resistivity.
- (5) Its high surface-area-to-volume ratio enhances heat-transfer performance.
- (6) It is relatively easy to synthesize and offers greater stability.

2.3 Coolant

Coolant prevents a system from overheating by transferring generated heat to another medium for use or dissipation. An ideal coolant has a high heat capacity and low viscosity, is non-toxic and non-corrosive, remains chemically stable, and is cost-effective. Some applications also require electrical insulation.

3. Experimental design

The experimental design involves preparing the required equipment and applying appropriate methods to compare the properties of five GrNC formulations and identify the optimal ratio.

3.1 Research equipment

(1) Ultrasonic Viscometer

The detection rod is inserted into the test liquid, ensuring that the liquid level is above the marked position on the rod. The heater is used to measure viscosity at each specified temperature, as shown in Figure 2.



Figure 2 Ultrasonic viscometer

(2) Ultrasonic oscillator

The ultrasonic oscillator is filled with an appropriate amount of water, then the sample is placed inside. Ultrasonic vibrations break the material into smaller particles, promoting more uniform dispersion in the liquid. The operating time and heating temperature can also be adjusted, as shown in Figure 3.



Figure 3 Ultrasonic oscillator

(3) Thermal conductivity meter

The probe is inserted into the test liquid, and its other end is connected to the thermal conductivity meter. The heater is used to bring the liquid to the specified temperature. Its thermal conductivity is measured afterwards, as shown in Figure 4.



Figure 4 Thermal conductivity meter

(4) Heat exchange simulation platform

The heat exchange simulation platform simulates the cooling system of a car, 7.5 liters of GrNC is added to the water tank, and the GrNC is circulated in the pipeline through the water pump. There are two detection instruments in front of the machine, which record the temperature at different positions every second, including the temperature of the water inlet and outlet of the water tank and the temperature of the heater. Finally, a fan is used to simulate the wind impact effect of the vehicle while driving, as shown in Figure 5.

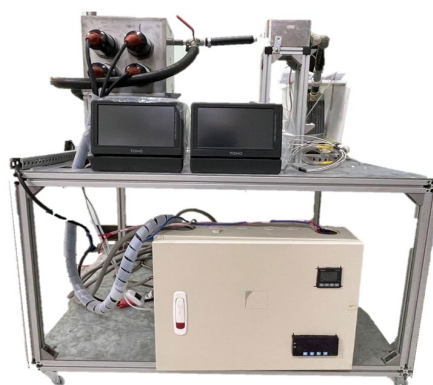


Figure 5 Heat exchange simulation platform

(5) Grinding machine

The test liquid (1-2 ml) is applied evenly to a dedicated grinding test piece. The test piece is subsequently placed in the grinding machine, as shown in Figure 6. The machine's rotating shaft holds a base with three small steel balls that rub against the test piece. The resulting wear is inspected after setting the specified rotational speed, applied pressure, and number of revolutions.



Figure 6 Grinding machine

(6) Heater

Used together with an ultrasonic viscometer and a thermal conductivity meter, the main function is to heat the liquid to be tested to a specified temperature, as shown in Figure 7.



Figure 7 Heater

(7) Electromagnetic stirrer

A capsule-shaped magnetic stir bar is placed in the liquid container; the container is then set on the electromagnetic stirrer. The controls are adjusted to regulate stirring speed and temperature. Before testing, the stirrer is used to disperse any added materials uniformly and prevent them from settling at the bottom, as shown in Figure 8.



Figure 8 Electromagnetic stirrer

(8) Electronic weighing scale

Used to measure the required substances for preparing liquid mixtures at specified proportions. Side and top covers minimize measurement errors. The scale also measures the grinding test piece before and after testing to determine weight loss, as shown in Figure 9. Before each measurement, the scale is reset to zero.

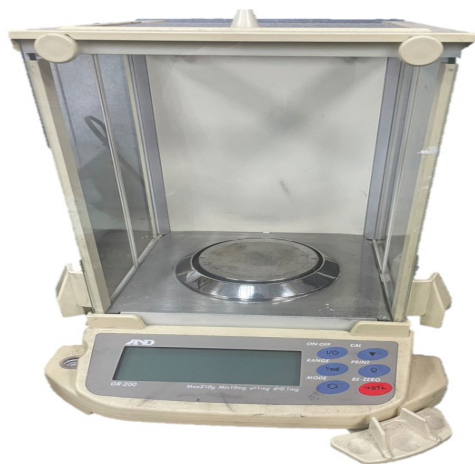


Figure 9 Electronic weighing scale

(9) Electronic thermometer

Electronic thermometers use sensing elements, such as thermistors and thermally conductive materials, to measure temperature, as shown in Figure 10. They typically respond quickly, cover a wide temperature range, and provide an easy-to-read digital display. In the viscosity and thermal-conductivity tests, the thermometer measures the heating-platform temperature.



Figure 10 Electronic thermometer

3.2 Experimental method

Five Gr:GA formulations were prepared at ratios of 0%:1%, 0.025%:1%, 0.05%:1%, 0.075%:1%, and 0.1%:1%. The graphene nanomaterial and gum arabic dispersant were incorporated into the base coolant and homogenized using an ultrasonic oscillator and an electromagnetic heating stirrer. Each formulation was subjected to the basic property tests described below. The results were then evaluated comprehensively to identify the best-performing GrNC formulation and quantify its improvement relative to the base coolant.

For the sedimentation test, the five GrNC formulations were stored under static conditions, and sedimentation was visually assessed after 1, 7, 14, and 28 days.

For the grinding test, each GrNC formulation was evaluated using a grinding machine under an applied load of 150 N, a rotational speed of 600 rpm, and 5,000 revolutions. Three replicate tests were performed for each formulation. The mass of each test piece was measured before and after grinding, and the mean mass loss and wear-loss ratio were calculated to compare the wear performance of the five formulations.

Viscosity was measured using an ultrasonic viscometer equipped with a heater and thermometer. Each sample was heated on the heating platform from 30 °C to 90 °C, and measurements were obtained at 10 °C intervals. At each temperature, 10 measurements were recorded. The results were compiled and plotted to compare temperature-dependent viscosity among the five GrNC formulations.

For the thermal-conductivity test, an appropriate volume of each sample was placed in the test vessel and heated to the required temperature. A feedback probe on the heater monitored the sample temperature, and the thermal-conductivity sensor was immersed in the liquid. Measurements were conducted from 30 °C to 90 °C at 10 °C intervals, with 10 readings recorded at each temperature. The compiled results were plotted to

compare changes in thermal conductivity among the five GrNC formulations as temperature increased.

Heat-exchange performance was evaluated using a simulation platform representing an automotive cooling system. A water pump circulated each GrNC formulation through the pipeline while a heater raised the fluid temperature to either 60 °C or 80 °C. After the target temperature was reached, the system was held for 30 min before the heater was switched off. A fan directed airflow across the radiator to simulate the cooling effect of a moving vehicle. Each experiment lasted 200 min, during which temperature changes were recorded on an SD card. The data were subsequently processed in Excel and plotted to compare the cooling performance of the five GrNC formulations.

4. Results and Discussion

Five graphene nano-coolant (GrNC) formulations were prepared by adding graphene nanoparticles (Gr) and gum arabic (GA) to the base coolant at Gr:GA ratios of 0%:1%, 0.025%:1%, 0.05%:1%, 0.075%:1%, and 0.1%:1%. Six fundamental experiments were subsequently conducted to evaluate the properties of each formulation and identify the best-performing ratio. The results of these experiments are presented in the following sections.

4.1 Settlement test

No visible sedimentation was observed after 1 day. By day 7, however, the nanomaterials had settled at the bottom of the containers, and by day 28, the deposited Gr had formed a compact sediment layer, as shown in Figures 11 and 12. Among the tested formulations, the 0.025%:1% Gr:GA ratio exhibited the least sedimentation and was therefore identified as the optimal formulation. Its lower sediment accumulation indicates improved long-term stability, a reduced risk of cooling-system blockage and performance degradation, and better retention of thermal-conductivity performance.

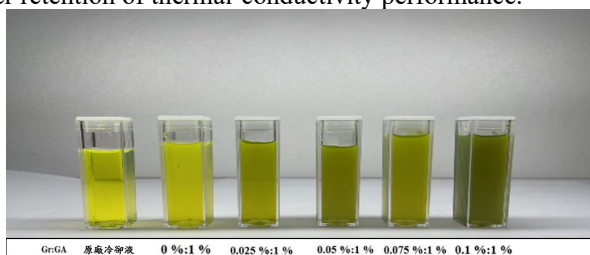


Figure 11 Settlement status on the first day of storage

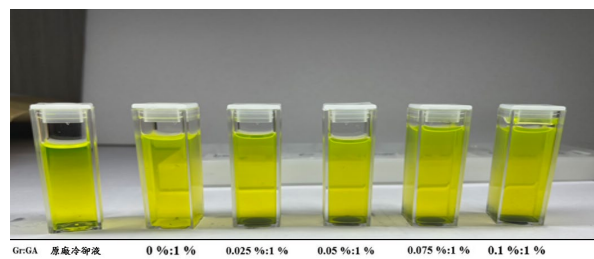


Figure 12 Settlement status on the 28th day of storage

4.2 Grinding test

Grinding tests were conducted using GrNC formulations with different Gr:GA ratios. Wear loss ranged from 0.001 to 0.014 g. The 0.05%:1% formulation produced the greatest wear loss (approximately 0.0136 g), whereas the 0%:1% formulation produced the lowest wear loss (approximately 0.0018 g). Thus, the 0%:1% Gr:GA ratio showed the best grinding performance. Its low wear loss indicates reduced friction and wear within the cooling system, which may extend service life, decrease energy and mechanical losses, and improve system efficiency and performance, as shown in Figure 13.

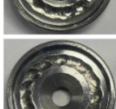
Gr:GA	Schematic Diagram	Wear Loss Weight (g)	Improvement Rate (%)
Pure Coolant		0.094	0
0 %:1 %		0.00183	98
0.025 %:1 %		0.00533	94.3
0.05 %:1 %		0.0136	85.5
0.075 %:1 %		0.0035	96.2
0.1 %:1 %		0.00277	97

Figure 13 Average wear loss weight and improvement rate

4.3 Viscosity test

Viscosity was evaluated over a temperature range of 30–90 °C to simulate the increase in coolant temperature

from cold-start conditions to normal vehicle operation. Among the five GrNC formulations, the 0.075%:1% Gr:GA formulation exhibited the lowest viscosity across most of the tested temperature range, including both low- and high-temperature conditions. It was therefore identified as the optimal formulation in the viscosity test. The lower viscosity indicates improved fluidity through the cooling circuit, which may reduce frictional and wear-related losses and enhance energy efficiency, as shown in Figure 14.

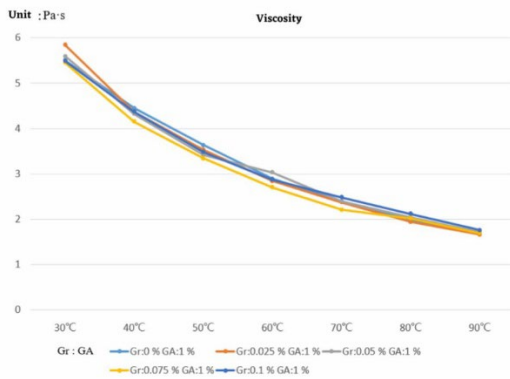


Figure 14 Viscosity of each ratio from 0 to 90 °C

4.4 Thermal conductivity test

Thermal conductivity was measured from 30 to 90 °C to compare the temperature-dependent performance of the GrNC formulations and simulate the transition from a cold start to normal engine operating conditions. The experimental results showed that the 0.05%:1% Gr:GA formulation exhibited the highest thermal conductivity at most test temperatures and was therefore identified as the optimal formulation. Its consistently high thermal conductivity indicates an enhanced capacity for rapid heat dissipation, which may reduce temperature gradients, thermal stress, and damage caused by thermal expansion while improving cooling performance and system reliability, as shown in Figure 15.

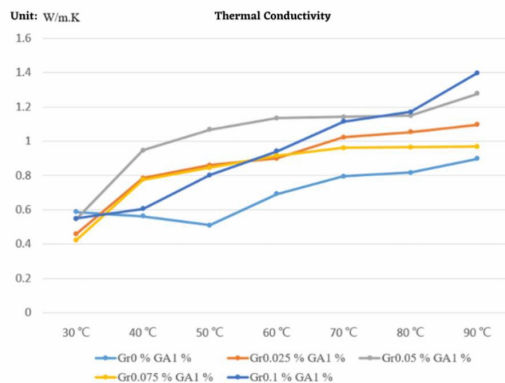


Figure 15 Thermal conductivity of each ratio from 0 to 90 °C

4.5 Specific heat test

Specific heat capacity represents the quantity of heat absorbed or released per unit mass of a substance for a unit change in temperature. According to Newton's law of cooling, the cooling rate is proportional to the temperature difference between an object and its surroundings. Thus, a coolant with a lower specific heat capacity can undergo a more rapid temperature decrease after transferring heat to the ambient air through the radiator. As shown in Figure 16, the 0.025%:1% Gr:GA formulation exhibited the lowest specific heat capacity over the 20–90 °C temperature range and consequently demonstrated the fastest cooling response.

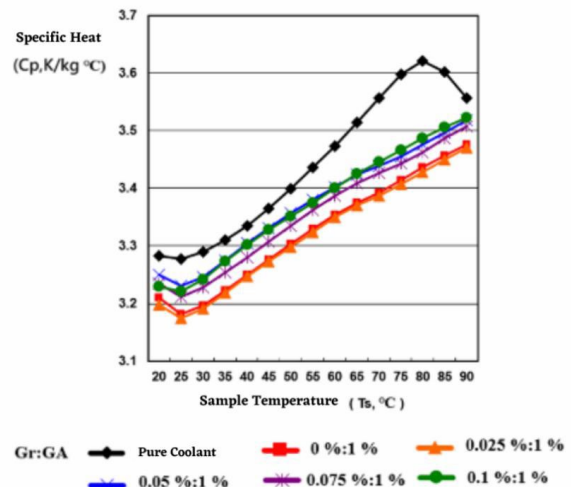


Figure 16 Changes of specific heat at various temperatures

4.6 Heat exchange simulation platform test

All GrNC formulations were evaluated using the heat-exchange simulation platform. A fan was positioned in front of the platform to reproduce the convective cooling generated by airflow during vehicle operation. Each formulation was heated to the specified temperature, after which its cooling response was monitored. As shown in Figures 17 and 18, the 0.025%:1% Gr:GA formulation exhibited the best cooling performance. Analysis of the heating and cooling slopes indicated that this formulation provided superior heat dissipation and thermal conductivity, greater reliability and stability, and the lowest energy loss. The results also indicated that the addition of GA as a dispersant reduced cooling effectiveness.

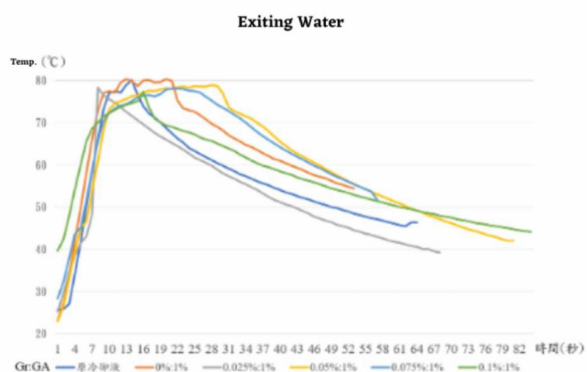


Figure 17 Water tank outlet temperature

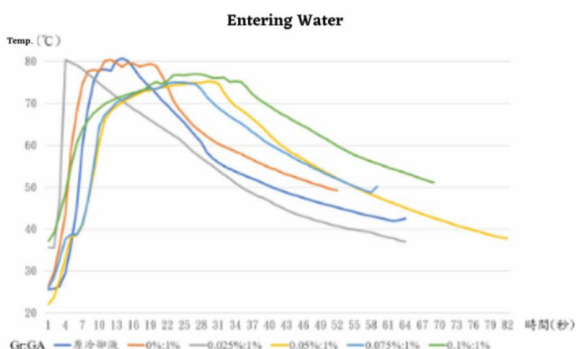


Figure 18 Water tank inlet temperature

5. Conclusion

This study evaluated graphene nano-coolant (GrNC) formulations prepared by incorporating graphene (Gr) and gum arabic (GA) into a base coolant at different ratios. Six properties were assessed: grinding performance, viscosity, thermal conductivity, sedimentation stability, specific heat capacity, and heat-exchange performance. The optimal Gr:GA ratios were 0%:1% for grinding performance, 0.075%:1% for viscosity, 0.05%:1% for thermal conductivity, and 0.025%:1% for sedimentation stability. Heat-exchange testing further showed that the 0.025%:1% formulation provided the best cooling performance. Overall, the 0.05%:1%, 0.075%:1%, and 0.025%:1% formulations demonstrated the strongest thermal-conductivity, viscosity, and heat-exchange performance, respectively. Future research should evaluate these three formulations under actual vehicle operating conditions to confirm their practical performance.

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