# Comparative investigation on potential application of hybrid nanofluids for Brushless Direct Current (BLDC) motor cooling system

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**Abstract.** In this study, the potential usage of hybrid nanofluids for brushless direct current (BLDC) motor cooling was compared. Due to their efficiency, durability, and small size, brushless direct current (BLDC) motors are a type of electric motor that are frequently employed in electric vehicles (EVs). In order to maintain appropriate operating temperatures and ensure long-term durability, cooling systems must be taken into account throughout the design of brushless direct current (BLDC) motors. Because excessive heat can shorten a motor's lifespan and affect its performance, effective cooling is crucial. Systems for cooling liquids need more parts and upkeep than those for cooling air. taken into account to get the maximum cooling effectiveness. The effectiveness and dependability of the liquid cooling system are greatly influenced by the system's correct design and implementation, including hose routing, sealing, and coolant choices. There are several approaches to improve a BLDC motor's hybrid nanofluid/nanofluid cooling system. In order to achieve the highest cooling efficiency, fluid flow velocity, nanoparticle concentration, and cooling system design should all be carefully taken into account.

## 1 INTRODUCTION

Transportation is essential to daily life however the rising cost of fuel poses a serious challenge along with pollution as another key issue [1]. Electric vehicles (EVs) can be a good replacement for the fossil-fuel vehicles using an electric motor providing the propulsion system [2-4]. To drive the wheels and move the car forward, the motor transforms electrical energy from the battery into mechanical energy. EVs use a variety of electric motor types, including such as brushless DC (BLDC) motors, induction motors (IM), synchronous reluctance motors (SynRM), and switched reluctance motors (SRM) [5]. A brushless direct current (BLDC) motor is a type of electric motor commonly used in electric vehicles (EVs) due to its effectiveness, dependability, and small size. BLDC motors do not need brushes or commutators for electrical connection or switching, in contrast to conventional brushed DC motors [6]. Instead, they use a control system to rely on electronic commutation.

Due to its small size and low maintenance requirements while maintaining high efficiency and controllability, brushless DC is one of the most well-liked and commonly used motors for various systems [7]. Effective cooling is essential because excessive heat can reduce a motor's lifespan and performance. There are a few typical cooling techniques for BLDC motors such as passive cooling, forced air cooling, liquid cooling, phase change cooling, and hybrid cooling. To obtain the best thermal management, a combination of cooling techniques could be used in some circumstances. For instance, a BLDC motor may make use of both forced air cooling with an integrated fan and passive cooling with heat sinks. Hybrid cooling systems offer improved capacity for dissipating heat.

Increased heat transfer rates between two surfaces or inside a fluid are referred to as heat transfer enhancement. including finned surfaces, extended surfaces, turbulence promoters, heat transfer enhancement insert devices, fluid additives, phase change materials, forced convection techniques, advanced heat exchanger designs, heat transfer coatings, and microscale heat transfer techniques. This study aims to carry out a comparative investigation of the cooling system on BLDC motors particularly the possibility of hybrid nanofluids usage as a potential coolant. BLDC motor used in this work is BLDC motor (HPM5000L) Liquid Cooling - 72V 5 kW as shown in Fig. 1 and the data specification listed in Table 1.

**Fig. 1.** Prototype of BLDC motor

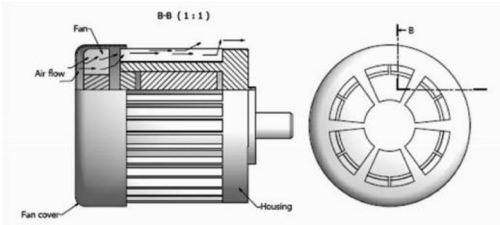


**Fig. 2**. Projection image of BLDC motor

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**Table 1** SPECIFICATION OF BLDC MOTOR

| Parameter | Specification |
|---|---|
| Voltage | 72 V |
| Power | 5 kW |
| Efficiency | 88% |
| Speed | 2000-6000 rpm |
| Casing | AluSmartum |
| Length (height) | 126 mm |
| Diameter | 206 mm |
| Shaft | customizable |

# 2 COOLING SYSTEM USING HYBRID NANOFLUIDS

## 2.1 Hybrid Nanofluids

Hybrid nanofluids is a new class of heat transfer fluids (HTFs) dispersed by nanocomposite particles below 100 nm into the base fluid [8]. Due to a synergistic impact, hybrid nanofluids might have better thermal network and rheological properties [9]. Hybrid nanofluids have gained significant attention for their potential applications in cooling systems [10]. Their unique properties can improve heat transfer efficiency and enhance the cooling performance of various systems. Here are some key aspects of hybrid nanofluids for cooling applications, such as enhanced thermal conductivity, improved heat dissipation, stability and sedimentation control, adjusted fluid properties as well as energy efficiency and sustainability [11-13]. Challenges such as cost-effectiveness, long-term stability, and scalability need to be addressed before widespread adoption in industrial cooling systems particularly electric vehicles applications [14]. Nevertheless, hybrid nanofluids show great potential in improving cooling performance and energy efficiency in various applications
[15].

Hybrid nanofluids based on a combination of aluminum oxide ($Al_2O_3$) and titanium dioxide ($TiO_2$) nanoparticles dispersed in water have been investigated for their cooling applications. Effect of $TiO_2$-$Al_2O_3$ nanoparticle mixing ratio on water-based hybrid nanofluid's thermal conductivity, rheological, and dynamic viscosity characteristics has been investigated experimentally by the previous researcher [16]. The heat transfer from a heated surface is examined by combining two passive enhancement techniques of using a minichannel and utilizing nanofluid [17]. In this work, an experimental investigation into the thermal performance of an aluminum minichannel heat sink with rectangular crosssections was conducted. The minichannel has a hydraulic diameter of 2 mm. As coolants, 0.5% volume fractions of distilled water, $TiO_2$-water nanofluid, $Al_2O_3$-water nanofluid, and hybrid $Al_2O_3$/$TiO_2$-water nanofluid were utilized. Murtadha et al. [18] studied hybrid nanofluids to cool the solar panels in order to achieve the optimum PV performance, including a rise in efficiency, longevity, and power production. In order to ascertain its effects and compare them to those of earlier studies that employed both $Al_2O_3$ and $TiO_2$ at the same concentrations, this study used a 2 wt% hybrid $Al_2O_3$/$TiO_2$ nanofluid coolant.

$TiO_2$ nanoparticle with maximum diameter of 100 nm was purchased from Merck America Chemical Vendor in Indonesia. Fig.3 shows the transmission electron microscopy (TEM) photograph of $TiO_2$ particles.

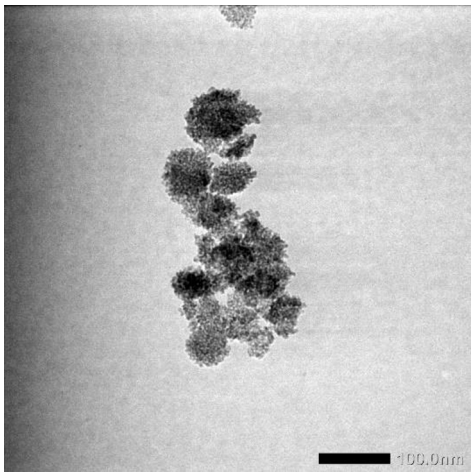


**Fig. 3**. TEM image of $TiO_2$

## 2.2 Cooling System for BLDC Motor

A Brushless DC (BLDC) motor is a type of electric motor commonly used in various applications, including electric vehicles (EVs) [19]. It offers several advantages over traditional brushed DC motors, such as higher efficiency, improved reliability, and better power-to-weight ratio [20]. Due to their efficiency, power density, and regenerative braking capabilities, BLDC motors have become a popular choice for electric vehicle propulsion. They play a crucial role in enabling electric vehicles to deliver efficient and reliable performance while minimizing environmental impact.

Cooling systems are essential for maintaining the optimal operating temperature of a BLDC motor, as excessive heat can negatively impact motor performance and lifespan. There are some common cooling methods used for BLDC motors such as air cooling, liquid cooling, direct cooling, oil cooling, and Phase Change Materials (PCMs). Liquid cooling systems involve circulating a coolant, such as water or a mixture of water and glycol also nanofluids/hybrid nanofluids through channels or jackets in the motor. The coolant absorbs heat from the motor and carries it away to an external heat exchanger, where the heat is dissipated. Liquid cooling offers higher heat transfer capabilities compared to air cooling and is particularly beneficial for high-power applications where more efficient heat dissipation is required.

The effectiveness of a 5000 W BLDC motor with a variable air flow rate has been examined by the previous researcher [18]. By using inlet flow rates of 0, 30, and 50 L/min during a 20-minute load test, the temperature rise and efficiency of the BLDC motor are examined. At 0 L/min, the temperature rise is very substantial, and

81.9%, 82%, and 82.7% are determined as the efficiencies. This study serves as a foundational investigation on the ideal air flow rate for the internal motor.

The BLDC motor underwent CFD research in order to investigate the temperature issue. The findings show that the highest temperatures are found at the end windings because there is a very slow rate of heat transmission through the insulation of the air gap and winding, both of which have very poor thermal conductivity [21].

## 3 COMPARATIVE THERMAL ASSESMENT

For a lot of electrically driven industrial drive systems particularly EVs applications, brushless DC electric motors have taken over as the primary motor type. They can generate all or nearly all of the rated torque and have the important benefit of precise variable-speed control under a variety of load scenarios. Despite the fact that variable-speed motors have been around for a while, prior technologies typically couldn't deliver nearly the whole rated torque at speeds that were modest compared to the motor's maximum speed. Instead, as the speed was decreased, output torque and other indicators of useable production frequently fell sharply. A motor with a higher output had to be employed when a variable-speed motor was required for an application that needed significant torque at a low speed.

Equipment designers are now able to specify smaller motor capacities than would otherwise be necessary when using conventional technologies since variable-speed DC brushless motors are now readily available and have good output over a wide speed range. However, these applications also pose unique problems for heat removal. All of the heat generated must be dissipated from a smaller surface area because the motors are physically smaller. Additionally, more motors can be accommodated within a given volume of an equipment enclosure, which raises the danger of overheating. Additionally, when using motors with reduced capacities, they must run at a lower percentage of their full load output or maximum duty cycle. In order to prevent an excessive temperature rise that could harm the motor or other equipment in which it is mounted, waste heat must be evacuated effectively.

### 3.1 Air Cooling

Due to their ease of use, affordability, and simplicity, air cooling systems are frequently used to cool BLDC motors. When heat causes air to naturally rise and circulate, natural convection, also known as passive cooling, takes place. Natural convection can be facilitated by proper motor enclosure design, including the positioning of vents or fins, which allows hot air to depart and cooler air to enter, aiding in heat dissipation. In the other hand, forced convection actively creates airflow across the motor's surface using a fan or blower. The motor alone or an additional power source can operate the fan. By accelerating the airflow, forced convection increases heat transfer while enhancing cooling effectiveness.

To further improve heat dissipation, a heat sink could be used along with air cooling. Heat sinks offer more surface area to transfer heat from the motor to the surrounding air. They are often built of thermally conductive materials like aluminum or copper. The heat sink can be placed independently or integrated into the motor's housing.

Air cooling systems include benefits such ease of use, dependability, and low maintenance requirements. The ambient temperature, airflow rate, and the appropriate design of the motor housing and cooling components, however, all affect how successful they are. To maintain the BLDC motor's best cooling performance, it's crucial to make sure there is enough airflow, eliminate obstructions, and routinely inspect and clean the cooling system.

### 3.2 Liquid Cooling

By using a coolant to move heat away from the motor, liquid cooling systems efficiently and effectively cool BLDC motors. To dissipate heat, a liquid coolant, such as water or a solution of water and glycol, is pumped via channels or jackets in the engine. To increase the cooling efficiency, coolants with high thermal conductivity and efficient heat transfer qualities are chosen. The coolant is moved around the cooling system using a pump. The pump generates the required flow and pressure to guarantee that the coolant reaches all crucial motor components, such as the windings and other heat-generating elements.

To release the heat that the coolant absorbed, a heat exchanger is used. The heat exchanger uses air or another cooling media to normally transfer heat from the coolant to the environment. Depending on the particular application and cooling needs, the heat exchanger may be an air-cooled radiator, a liquid-to-liquid heat exchanger, or a liquid-to-air heat exchanger. The coolant is transported between the motor, pump, and heat exchanger by means of hoses, pipes, and connectors in the cooling circuit. The circuit is made to minimize pressure drops and guarantee proper coolant flow, which promotes effective heat transfer and cooling.

The cooling system is monitored and controlled by a control system. To offer real-time temperature information, it might have temperature sensors positioned in key areas of the motor. In order to keep the motor operating within the specified temperature range, the control system modifies the pump speed or cooling flow rate based on the temperature measurements. A reservoir to store and maintain an adequate coolant level may be part of the liquid cooling system. A filtration system is also included to ensure the cleanliness of the coolant and avoid clogging or damage to the cooling components by removing impurities and pollutants from the coolant.

Liquid cooling systems offer several advantages for cooling BLDC motors, such as enhanced heat dissipation, uniform cooling, noise reduction, greater design flexibility, and higher cooling capacity. In contrast to air cooling systems, liquid cooling systems

need more parts and upkeep. The effectiveness and dependability of the liquid cooling system depend heavily on the right design and implementation of the system, including hose routing, sealing, and coolant selection. To ensure optimum cooling performance and avoid any problems that can impair the motor's operation, routine monitoring and maintenance is required, such as coolant level checks, filter changes, and system inspections.

### 3.3 Nanofluids/hybrid nano fluids cooling

The potential use of nanofluids/hybrid nanofluids as cooling fluids for a variety of applications, including BLDC motor cooling systems, has attracted attention. Nanoparticle suspensions in a base fluid, usually water or oil, are known as nanofluids. Nanofluids provide improved thermal conductivity and heat transfer qualities when employed in cooling systems, which can increase the cooling effectiveness of BLDC.

Aluminum oxide ($Al_2O_3$) and titanium dioxide ($TiO_2$) nanoparticles or their nanocomposites are frequently employed in nanofluids/hybrid nanofluids for cooling applications. These nanoparticles can improve the base fluid's capacity for heat transmission because of their high thermal conductivities. Nanoparticles are dispersed into the base fluid using methods like ultrasonication or stirring to create nanofluids. In order to ensure that the nanoparticles are evenly distributed throughout the fluid, it is crucial to produce a stable suspension. It could be necessary to alter the surface or add stabilizing chemicals to stop particle agglomeration and sedimentation over time.

The thermal conductivity of the nanofluid is increased by the addition of nanoparticles to the base fluid. Improved heat transmission from the motor to the fluid results from this, enabling more effective cooling. Nanofluids' improved thermal conductivity can reduce hotspots and the motor's overall temperature, enhancing the motor's performance and durability. Because nanoparticles are present, the flow properties of nanofluids may be different from those of the base fluid. Nanofluids' higher viscosity and different flow characteristics can have an impact on the cooling system's fluid flow and pressure drop. These aspects must be taken into account while designing and sizing the pumps, pipes, and heat exchangers that make up the cooling system.

It is critical to guarantee compatibility with the motor and other system parts when employing nanofluids in cooling systems. The materials utilized in the cooling system shouldn't corrode or be adversely affected by the nanoparticles. Potential compatibility problems can be reduced with the aid of compatibility tests and wise material selection. There are several ways to improve the efficiency of a BLDC motor's nanofluid cooling system. To get the highest cooling efficiency, factors such fluid flow rate, nanoparticle concentration, and cooling system design should be properly taken into account. The system parameters can be improved with the use of experimental research and computational fluid dynamics (CFD) simulations.

BLDC motor heat dissipation and cooling efficiency may be improved via nanofluid cooling systems. To completely comprehend the long-term stability, dependability, and overall effectiveness of nanofluids in real-world cooling applications, additional study and development are still needed. When adopting nanofluid-based cooling solutions, it is crucial to take into account the unique needs and limitations of the BLDC motor and cooling system.

## 4 FUTURE CHALLENGE

Outlining potential future challenges of the hybrid nanofluids usage for Brushless Direct Current (BLDC) motor cooling system can be described as follows: (a) ensuring stable and well-dispersed hybrid nanofluids over extended periods, as nanoparticles tend to agglomerate and settle, (b) determining the most effective concentration of hybrid nanofluids that provides improved cooling performance without causing detrimental effects like clogging or excessive viscosity, (c) gaining a deep understanding of the underlying heat transfer mechanisms responsible for the observed improvements in cooling efficiency, and (d) assessing the long-term stability and reliability of the hybrid nanofluids under real-world operating conditions, including potential degradation or erosion of cooling system components

## 5 CONCLUSION

This work investigated comparatively on potential application of hybrid nanofluids for brushless direct current (BLDC) motor cooling system. Liquid cooling systems require more maintenance than air cooling systems. The proper design and implementation of the system, including hose routing, sealing, and coolant selection, have a significant impact on the effectiveness and dependability of the liquid cooling system. The nanofluids/hybrid nanofluids cooling system of a BLDC motor can be enhanced in a number of ways. fluid flow velocity, nanoparticle concentration, and cooling system design should all be appropriately considered in order to get the best cooling efficiency. The suggestions of this present work is an investigation on the cooling performance of various hybrid nanofluids in BLDC motor cooling systems and compare their thermal efficiency.

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