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Enhancing Gas Turbine Cooling with Upstream Fogging and Nanofluids: Evaluating Evaporative Cooling Effects

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Abstract: In recent years, Nano fluids have gained significant interest in thermal applications due to their enhanced heat transfer properties. Among these, Al_2O_3-water Nano fluids stand out for their high thermal conductivity and effectiveness in cooling systems. A previous study investigated the effect of cylindrical obstacles on convection within an inclined enclosure using Al_2O_3-water Nano fluids, showing that geometric configurations strongly influence thermal performance. These findings underscore the importance of optimizing design and working fluids to improve heat transfer in advanced cooling systems. Building on this, the current study examines the integration of Fogging Upstream technology with Al_2O_3-water Nano fluids to improve gas turbine cooling performance. Fogging Upstream involves injecting a fine mist of water or Nano fluid before the compression stage to lower the intake air temperature, thereby enhancing thermal efficiency. The study also investigates the role of pipe diameter (¼ inch vs. ½ inch) on cooling effectiveness. Experimental results show that Fogging Upstream alone improves cooling efficiency by 12–18%. When combined with Nano fluids, heat transfer improves by 15–25%. Additionally, using a ¼ inch pipe boosts cooling performance by 10–15% due to greater surface area and induced turbulence. Overall, the combined system reduces intake air temperature by 5–7°C and increases gas turbine efficiency by 8–12%.

Keyword: cooling performance; fogging upstream; gas turbines; heat exchange; nano fluid

1 INTRODUCTION

Gas turbines are an integral part of modern energy production in aviation and various industries, thanks to their high efficiency and reliable operation. But one of the most prominent challenges to improving the performance of gas turbines is the control of high inlet air temperatures, which leads to reduced operational efficiency and increased fuel consumption, in addition to the possibility of turbine components being damaged. One of the main strategies to mitigate these problems is to cool the inlet air before it enters the turbine, as many cooling techniques have been studied to improve turbine performance. Among these technologies, "cooling by spray into the air duct" is an effective method of introducing water or spray into the air stream before it reaches the compressor, cooling the inlet air through a large evaporation process, which improves the thermal efficiency of the turbine. Because of their great efficiency and dependable operation, gas turbines are essential to modern power production in aviation and industrial applications. But controlling high intake air temperatures, which can result in decreased operational efficiency, increased fuel consumption, and possible damage to turbine components, is one of the major obstacles to gas turbine performance optimization [1, 2]. A key tactic to lessen these problems is to cool the intake air before it enters the turbine, and several cooling technologies have been investigated to improve turbine performance. An efficient method called "fogging upstream" is introducing water or mist into the air stream prior to it reaching the compressor [3]. The injected mist undergoes an evaporative cooling process which significantly lowers the temperature of the intake air improving the thermal efficiency of the turbine [4]. In recent years, Nano fluids have received increasing attention in thermal applications due to their enhanced heat transfer capabilities. Among these, the Al_2O_3-water Nano fluid is widely used for its improved thermal properties. Authors examined the impact of cylindrical obstacles on convection within an inclined enclosure containing an Al_2O_3-water Nano fluid. The study revealed that the geometric configuration of the obstacles significantly affects heat transfer performance. Such findings open the door to optimizing cooling systems in industrial and high-performance thermal applications. Building on this, the present research aims to investigate the effects of laser energy on the mechanical and thermal properties of aluminium alloys coated with Nano silicon particles, contributing to the development of more efficient and durable thermal systems [5]. In order to improve gas turbine performance, especially in areas with high ambient temperatures, this cooling technique has been extensively researched. Recent research has demonstrated the benefits of fogging systems in raising gas turbine power production and lowering the amount of fuel needed to maintain ideal operating conditions [6]. Nano fluids, which are fluids created by dispersing nanoparticles (such SiO_2, CuO, or AlO_3) in a base fluid like water, have drawn a lot of attention lately as a cutting-edge way to enhance heat transmission. Nano fluids are excellent options for enhancing evaporative cooling performance because of their higher thermal conductivity as compared to traditional fluids [7]. Recent research has demonstrated that the use of Nano fluids in fogging systems can further enhance cooling efficiency and increase heat transfer rates especially under high-temperature conditions [8]. Several recent studies have focused on the integration of fogging and Nano fluid technology. In another study by Mukesh M. et al 2020 [9] the effectiveness of a hybrid air conditioning system using Nano fluids was evaluated. The results showed that the system's coefficient of performance (COP) was significantly improved with Nano fluids which are known for their high thermal conductivity due to the presence of solid particles. Similarly R. Agbadede and B. Kainga 2021 [10] reported that introducing inlet fogging into a gas turbine reduces intake air temperature by 10 °C. In their simulation of industrial gas turbine inlet fogging a 0.4% water-to-air ratio was used. Zhou Sun et al. 2021 [11] - This research monitors gas turbine bearing

temperatures using regression modeling. It addresses high compressor bearing temperatures at Geregu Power Plant, Nigeria, using Multi-Linear Regression (MLR) models to predict bearing temperature based on various lube oil parameters, improving gas turbine health and performance. Ghassan Fadhil Smaisim et al. 2022 [12] - This paper reviews the properties and applications of nanofluids, focusing on their enhanced thermal conductivity and heat transfer properties. It highlights potential health and environmental risks associated with nanoparticles, stressing the need for careful handling. Mohammad Zamen et al. 2022 [13] - The study introduces a new photovoltaic/thermal (PVT) system using Al2O3/water nanofluid as the coolant. The use of this nanofluid significantly improves the thermal and electrical performance of the PVT system.Shailendra Gajbhiye et al. 2023 [14] - This paper focuses on optimizing the performance of hybrid air conditioning systems with Al2O3 nanofluid. It finds that a 0.8% by weight concentration of the nanofluid improves the Coefficient of Performance (COP) by 34% and the refrigeration effect by 32%. The study of Atazaz Hassan et al. 2023 [15] examines the effectiveness of various parameters in improving the heat transfer performance of a hybrid photovoltaic thermal system (PV/T). It found that a water-based PV/T with a 16 mm tube diameter and 1.02 l/minute has the highest efficiency at 44.5% 14.8% and 59.3%. The study also found that increasing Reynolds numbers increases the system's efficiency and a maximum decrease in cell temperature can be achieved by increasing tube diameter and back plate thickness. The study of Balakrishnan S. et al. 2025 [16] investigated the effectiveness of shell and tube heat transfer on Nano fluids made of copper and alumina nanoparticles. The Nano fluids increased thermal conductivity by 29% and 39% when 0.12 wt % of these nanoparticles were added. The Nano fluids also increased friction factor and heat transfer coefficient by convection. Al_2O_3 Nano fluid outperformed Cu Nano fluid in pressure drop. A study examining the impact of pipe diameter on fogging system efficiency found that smaller diameters enhance turbulence, improving heat transfer but increasing pressure drop. The research aims to evaluate the effectiveness of Fogging Upstream combined with Nano fluids in improving gas turbine cooling efficiency. The study compares the impact of different pipe diameters (1/4 inch and 1/2 inch) on the overall performance of the fogging system. The goal is to determine the optimal combination of fogging technique and pipe diameter for optimal cooling performance. The results will provide insights into integrating advanced cooling technologies to enhance gas turbine efficiency, and sustainability in power generation and other applications.

2 THE REYNOLDS NUMBER (*Re*)

The Reynolds number a dimensionless quantity is useful for forecasting flow patterns in a range of fluid flow situations. Usually laminar or layer-like flow prevails when low Reynolds numbers whereas in situations with higher Reynolds numbers turbulent flow usually wins out. Variations in the speed and direction of the fluid give rise to turbulent flow which can sometimes cause collisions or even flow directions that are opposed to the main stream (called eddy currents). These eddy currents use energy and raise the possibility of cavitation in a liquid when combined with flow variations. Reynolds numbers are important because they are dimensionless quantities in fluid mechanics. They show how the viscous and inertia forces in a fluid are proportionate [17], [18].

$$Re = \frac{\rho V D_h}{\mu} = \frac{V D_h}{\nu} \quad (1)$$

Where: *Re* - Reynolds number, a dimensionless quantity used to predict the flow regime (laminar or turbulent) in fluid dynamics; ρ - Density of the fluid (kg/m³); V - Average flow velocity (m/s); D_h - Hydraulic diameter (m), defined depending on the geometry of the flow channel; μ - Dynamic viscosity of the fluid (Pa·s or N·s/m²); ν - Kinematic viscosity of the fluid (m²/s).

Where the impact of different pipe diameters (1/4 inch and 1/2 inch) on cooling efficiency using an Al_2O_3-water Nano fluid mixture is analysed the Reynolds number (*Re*) plays a crucial role in determining the flow characteristics inside these pipes and their effect on heat transfer.

The Effect of Reynolds Number on Flow inside the Pipes:

1) Smaller diameter pipes (1/4 inch):
- Result in higher flow velocities leading to an increase in Reynolds number making the flow more turbulent.
- Turbulent flow enhances thermal mixing improving heat transfer efficiency and boosting the cooling performance.
- However this comes at the cost of higher pressure drop which may affect the system's efficiency.

2) Larger diameter pipes (1/2 inch):

a) Lead to lower flow velocities resulting in a lower Reynolds number making the flow closer to laminar conditions.

b) In laminar flow heat transfer is less efficient compared to turbulent flow but pressure losses are reduced improving hydraulic efficiency.

3 EXPERIMENTAL SETUP

3.1 Fogging Cooling System (Upstream)

The experiment Nanomaterial's were prepared at the University of Technology, Department of nanotechnology. A test rig was constructed to the intake cooling process of a gas turbine. The system consists of a variable-speed water pump (BF-3800 model), a fluid atomization nozzle for fogging, pipelines with different diameters (¼ inch and ½ inch), and a controlled air intake duct. The nozzle was positioned upstream of the compressor simulation chamber to allow uniform distribution of the mist into the incoming airflow. Two working fluids were used:

1) Distilled Water for the baseline fogging experiment.
2) Al_2O_3–water Nano fluid with a nanoparticle concentration of 2% by volume.

The Nano fluid was prepared using ultrasonic agitation to ensure uniform dispersion of the nanoparticles and

stability of the mixture. The fogging cooling system installed in the upstream section of a gas turbine is designed to enhance turbine performance and efficiency by cooling the intake air before it reaches the compressor. This process reduces intake air temperature increasing air density and allowing a greater mass of air to enter the compressor thereby improving power output and efficiency. The system operates through water injection where a fine mist of water is introduced into the intake air stream. As the water droplets evaporate they absorb heat from the air effectively lowering its temperature through evaporative cooling by utilizing the latent heat of vaporization. Increased mass flow as a result boosts power production and improves combustion efficiency. High-pressure pumps provide steady water flow and pressure [19], high-pressure nozzles atomize water into fine droplets for efficient cooling, and sophisticated control systems adjust water flow according to turbine operations and ambient conditions to optimize cooling efficiency. One efficient way to improve turbine performance is to install a fogging cooling system in the upstream area of a gas turbine. This method raises the density of the intake air by chilling it, increasing the turbine's overall efficiency and power output. The cooling system, which is positioned ahead of the filters, keeps the compressor and turbine blades safe from excessive humidity. Additionally, it does not require demineralized water and shields the system from dust and water spray entering the compressor.

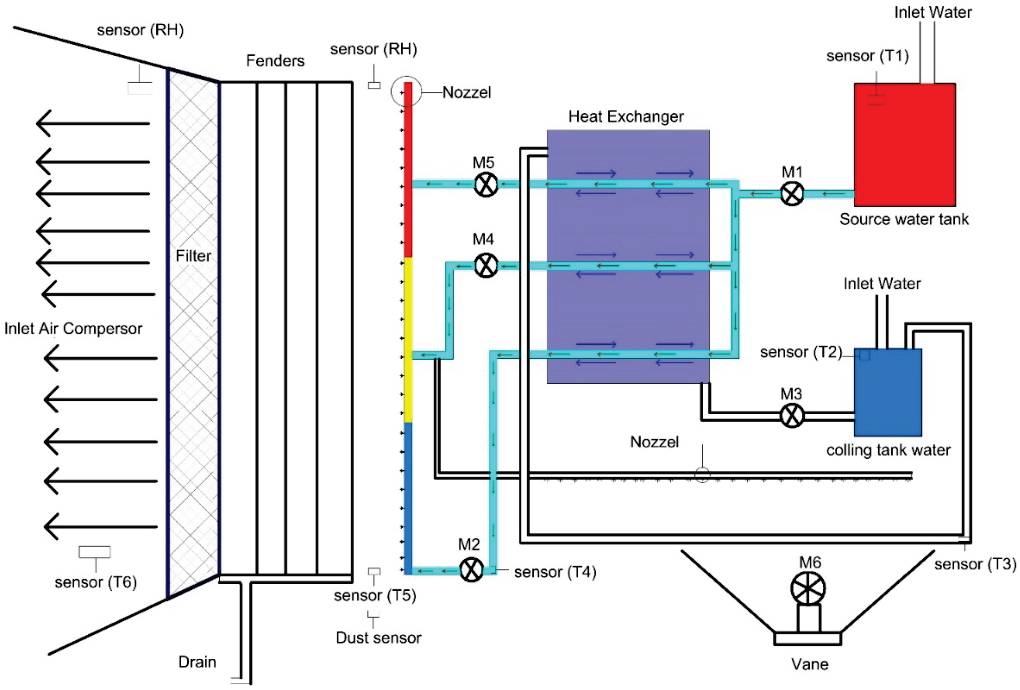


Figure 1 A Psychometric Diagram and Schematic Representation of the Fogging (Upstream) Cooling System

As seen in Fig. 1, the fogging (upstream) cooling system is mounted externally in front of the weather hoods. This configuration is perfect for retrofit applications since it permits installation and maintenance without interfering with turbine performance. This technology is very helpful when there is not enough room in the current air intake. It also eliminates the prolonged downtime brought on by expensive filter house modifications or warranty restrictions. Additionally, the system has a mesh that removes big particles, prolonging the life of air filters and making installation and maintenance easier [20]. A more recent technique for cooling gas turbine intake air (GTIC) is an indirect evaporative cooling system (IECS). With this method, water is directly evaporated into the secondary air stream, which is a component of the primary air flow. The IECS seeks to improve gas turbine performance and efficiency by effectively cooling the incoming air stream. Using the MS9001E turbine model, the fogging (upstream) system was put in place at the Al-Quds gas power station to cool the air inlets for the third and fourth generating units. By considerably lowering the temperatures inside the generating units, this initiative enhanced production capacity and performance throughout the hottest summer months [8].

The addition of a water tank with a cooling combination of nanomaterial's improved the system. Cooled water is pumped through pipes to a heat exchanger which simultaneously receives hot water from the main tank. This setup effectively reduces the water temperature before it reaches the nozzles resulting in a lower temperature of the air entering the compressor.

3.2 Fundamentals of Heat Exchanger Design

Heat is transferred from a hot fluid to a cold fluid typically with the help of a separator or barrier. However heat transfer can also occur directly between fluids without physical barriers such as when hot air interacts with a cold fluid. This type of heat transfer known as direct heat transfer is common in heat exchangers like industrial water coolers which can efficiently dissipate large amounts of heat. This

study explores the use of high thermal conductivity heat exchangers in industrial applications. Specifically it examines heat exchangers designed with pure copper tubes which are valued for their excellent thermal conductivity corrosion resistance and ease of joining through soldering [21, 22]. In addition a comparison will be made between two types of pipe diameters 1/4 inch and 1/2 inch to evaluate their impact on cooling efficiency heat transfer rates and system performance. The aim is to determine which pipe diameter offers better overall efficiency in heat exchange processes.

3.3 Methodology

The experimental process involved the development and testing of a practical cooling system. The system was constructed with a focus on empirical testing and real-world application mirroring the theoretical setup. The core of the experiment was the heat exchanger. This heat exchanger consisted of a large tank which stored hot water connected to a 0.5-0.25 inch copper tube.

3.3.1 Pipe Diameter Comparison

The experiment compared 0.5-inch and 0.25-inch copper tubes to examine how pipe diameter affects cooling performance:

- 0.25-inch Tube:
- Provided higher cooling efficiency due to increased turbulence enhancing heat transfer.
- Had a greater heat transfer surface area per unit volume leading to more effective cooling.
- Caused a slightly higher pressure drop which was a trade-off for improved thermal performance.
- 0.5-inch Tube:
- It was more suited to preserving flow stability since it had a reduced pressure drop.
- Showed lower turbulence which slightly reduced its heat transfer efficiency compared to the smaller tube.
- Was better for maintaining consistent flow rates but less effective in enhancing cooling performance.

Because of its superior thermal conductivity, copper was chosen to ensure efficient heat transmission from the hot water. Based on earlier studies, a Nano fluid with a 2% concentration of aluminum oxide (Al_2O_3) was placed in a secondary tiny tank to maximize cooling efficiency. Using a 1-inch tube, the Nano fluid tank and heat exchanger were integrated as part of the experimental setup. This arrangement made it possible for the Nano fluid to interact with the hot water, promoting cooling and heat absorption. While the Nano fluid circulated through the connecting tube, absorbing heat from the water, hot water from the main tank flowed through the heat exchanger's copper tube as the system was operationalized. Temperature sensors were positioned at key locations throughout the cooling system to track its performance. These sensors provided real-time information on the cooling performance by recording the temperatures of the hot water entering and leaving the heat exchanger. The primary goal was to achieve a substantial reduction in water temperature validating the cooling system's effectiveness. The data collected from the temperature sensors were analyzed to assess the performance of the cooling system. This analysis compared the observed temperature reductions with the theoretical predictions confirming whether the experimental outcomes aligned with the expected results. Based on the performance data adjustments were made to optimize the system. These adjustments included modifying flow rates and Nano fluid concentrations to enhance cooling efficiency. Throughout the process detailed documentation was maintained capturing the experimental setup procedures results and any modifications made. In essence the experiment involved constructing and testing a physical cooling system to empirically validate theoretical designs. This hands-on approach provided practical insights into the system's performance ensuring that theoretical predictions were accurately reflected in real-world conditions.

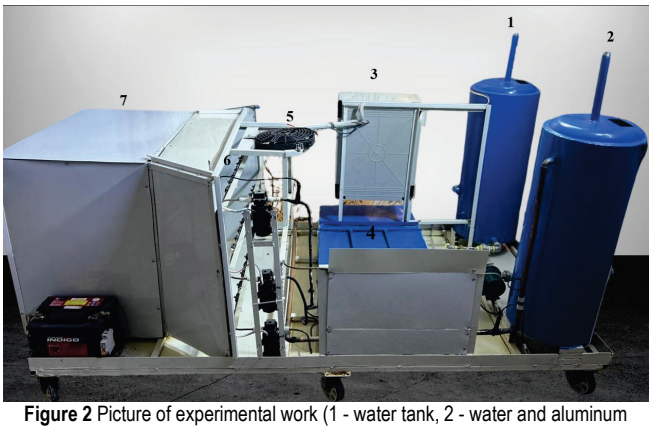


Figure 2 Picture of experimental work (1 - water tank, 2 - water and aluminum oxide mixture tank (Al2O3), 3 - electrical board, 4 - heat exchanger, 5 - cooling fan, 6 - water sprayers, 7 - filter)



Figure 3 Top view Explain the impeller and heat exchanger

3.4 System Components and Their Functions

- **Arduino Mega 2560:** The central control unit of the system, operating at 16 MHz. It has 256 KB of flash memory and 8 KB of SRAM. It processes sensor data,

applies control algorithms, and controls the relays for motors and the fan.

- **Arduino Nano:** A secondary controller with 16 MHz clock speed. It converts digital signals to analog, ensuring compatibility with the Arduino Mega and reducing the computational load on the main controller.
- **Sensors:** The system includes DS18B20 temperature sensors for accurate temperature readings, DHT11 humidity sensors, and the GP2Y1014AU0F dust sensor to monitor environmental conditions.
- **Actuators:** The system has six DC motors (12V) and one 220V AC fan, controlled by relays that turn the devices on or off based on commands from the Arduino Mega.
- **Relays:** These act as switches to control high-power actuators while isolating low-power control circuitry. They ensure safety and reliable operation by handling 5V control signals and 12V/220V loads.

3.5 Calibration and Signal Processing

- **Calibration:** The system compares sensor data to known reference values during initialization to correct any inaccuracies. For example, temperature sensors are calibrated against a precise thermometer. Calibration ensures consistent sensor accuracy.
- **Signal Filtering:** A low-pass filter (with transfer function 1/s+1) is implemented in the Arduino Mega to smooth out high-frequency noise and stabilize incoming signals. A hardware filter further reduces electrical noise.
- **Simulink Simulation:** Calibration is simulated using Simulink to analyze sensor outputs and generate correction equations, which are then applied in the control program of the Arduino Mega. Periodic recalibration ensures long-term accuracy.

3.6 System Operation

- **Data Collection and Processing:** The system continuously collects data from sensors, which is processed in real-time by the Arduino Mega. The control algorithm uses the calibrated data to determine the necessary actions for actuators.
- **Actuator Control:** Relays activate or deactivate motors or the fan based on specific environmental thresholds. For example, high temperatures may turn off certain motors, or high humidity may activate the fan.
- **Dust Level Control:** If dust levels exceed a set threshold, the system shuts down all motors and the fan as a protective measure. This prevents damage to the system due to poor air quality.

The system integrates precise sensors, efficient actuators, and robust control algorithms to achieve accurate and responsive environmental regulation, ensuring high reliability and adaptability for various applications.

4 RESULTS AND DISCUSSION

4.1 Case 1: Comparison of Cooling Efficiency Between 1/4 Inch and 1/2 Inch Systems Pipes in Heat Exchange is used

By analyzing the results shown in the three figures in Fig. 4 some important conclusions can be drawn about the effect of the addition of nanoparticles on the temperature distribution using tubes of different sizes (1/4 inch and 1/2 inch).

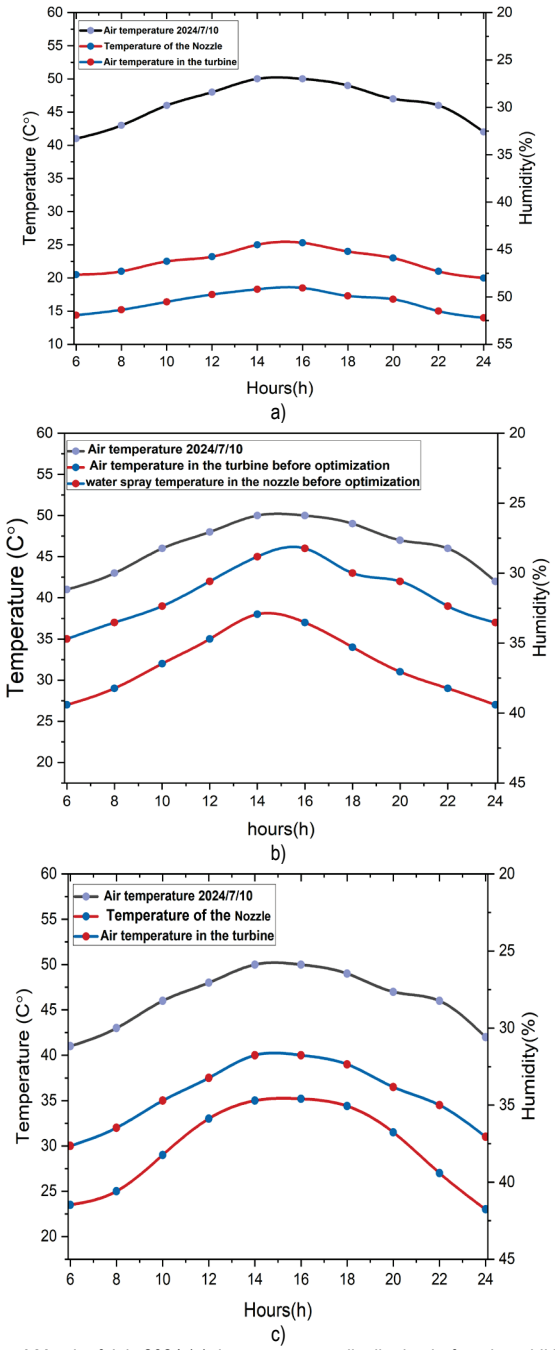


Figure 4 Month of July 2024 (a) the temperature distribution before the addition of the nanoparticles, (b) the temperature distribution after the addition of the nanoparticles in (1/4 inch) tube, (c) The temperature distribution after the addition of the nanoparticles in (1/2 inch) tube

1) Fig. 4a: thermal distribution before the addition of nanoparticles this figure shows the air temperature inside the turbine the nozzle temperature and the air temperature inside the turbine before optimization. We note that the air temperature inside the turbine gradually rises during the day reaching a peak at about 14:00 - 16:00 where it is about 50 °C. The nozzle temperature is lower than the turbine temperature which indicates that cooling is taking place but is not as efficient as required.

2) Fig. 4b: the effect of adding nanoparticles in a 1/4 inch tube when using a 1/4 inch diameter tube with nanoparticles we observe a noticeable decrease in temperatures inside the turbine and nozzle compared to Fig. 4a. The air temperature in the turbine after optimization is about 3-5 °C lower in the peak period than in the case before the addition of nanoparticles. This suggests that the use of nanoparticles has improved the efficiency of heat exchange within the system but there is still a clear rise in temperatures during the afternoon.

3) Fig. 4c: the effect of adding nanoparticles in a 1/2 inch tube when using a pipe with a diameter of 1/2 inch we notice a greater improvement in turbine cooling compared to a smaller pipe. The air temperature in the turbine decreases even more since the thermal difference compared to the Fig. 4a reaches 5-8 °C during the peak. The temperature distribution shows a smoother gradient during daylight hours suggesting that this system is more efficient at heat dissipation.

This analysis shows that increasing the diameter of the pipe to 1/2 inch enhances the efficiency of heat transfer and cooling which reduces the temperatures inside the turbine even more compared to the 1/4 inch pipe. The addition of nanoparticles significantly improved cooling in both cases but the effect was more pronounced when using a tube with a diameter of 1/2 inch. Pipes with a larger diameter (1/2 inch) achieve a better improvement in heat exchange compared to smaller pipes (1/4 inch) which helps reduce the temperatures in the turbine and nozzle. A system using 1/2 inch with nanoparticles is the most efficient in terms of reducing temperatures and therefore will be most useful in preventing overheating of the turbine and improving its performance in hot operating environments. Based on these results the use of 1/2 inch tubes with nanoparticles can be recommended to improve the cooling efficiency of turbine systems especially in high-temperature environments.

4.2 Case 2: Effective Cooling in Pipe with a Diameter of 1/4 Inch is used

Fig. 5a before adding nanoparticles the ambient air temperature reaches 50 °C at the peak (14:00).The nozzle temperature is about 45°C.The air temperature inside the turbine reaches 35-40 °C which indicates insufficient cooling. After the addition of nanoparticles Fig. 5b the ambient air temperature has not changed (50 °C).The nozzle temperature dropped to 35-40 °C which indicates an improved heat transfer. The air temperature inside the turbine dropped to 25-30 °C which is about 10 °C lower than the state before the improvement

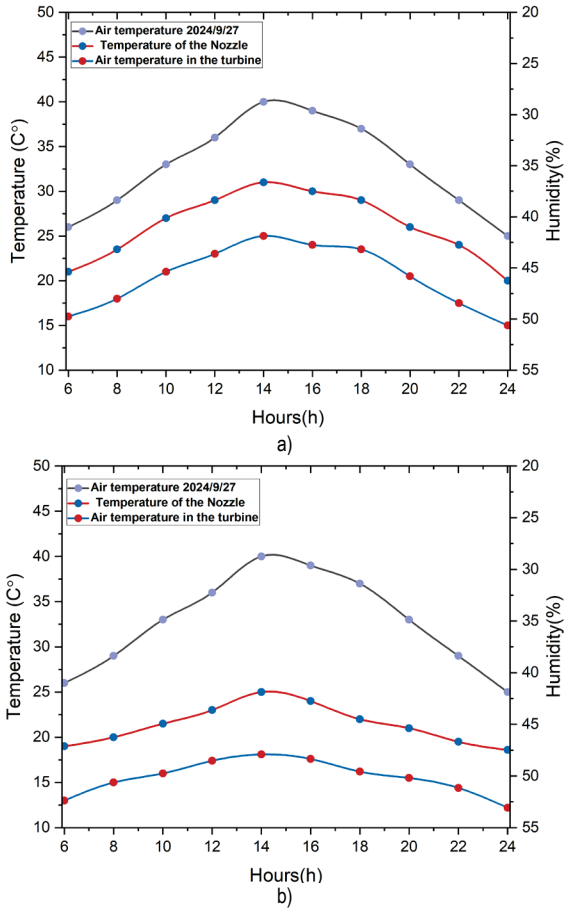


Figure 5 Month of September 2024 (a) the temperature distribution before the addition of the nanoparticles, (b) the temperature distribution after the addition of the nanoparticles

The distribution of convection before optimization Fig. 6a shows a similar pattern to September when the temperature reaches a peak of about 48-50 °C in the middle of the day. After optimization with nanoparticles Fig. 6b we observe a clear decrease in temperatures but at a lower rate compared to September 2024 when the decrease is only 2-4 °C. This shows that cooling with a 1/4 inch pipe becomes less efficient in months with a colder climate (such as October 2024) when the difference between the ambient temperature and the operating temperature is less. In general the results confirm that the addition of nanoparticles in a 1/4 inch tube leads to a noticeable improvement in cooling during extreme thermal conditions but its effectiveness gradually decreases with decreasing outdoor temperatures. This suggests that cooling strategies need to be adjusted according to the season and environmental conditions to achieve optimal performance.

In November 2024 the cooling system is shut down due to the naturally low ambient temperatures which provide adequate cooling without the need for mechanical systems. This decision is made to enhance operational efficiency as the cold weather achieves the required cooling levels naturally reducing energy consumption and optimizing overall system performance. As shown in the figure this seasonal shutdown demonstrates the system's integration with environmental conditions reflecting effective energy

management and operation aligned with the surrounding climate.

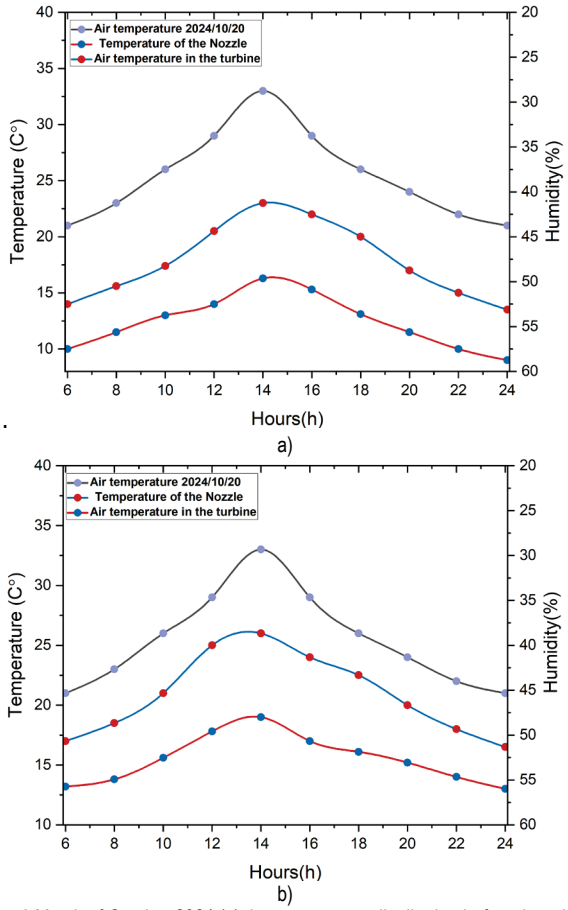


Figure 6 Month of October 2024 (a) the temperature distribution before the addition of the nanoparticles, (b) the temperature distribution after the addition of the nanoparticles

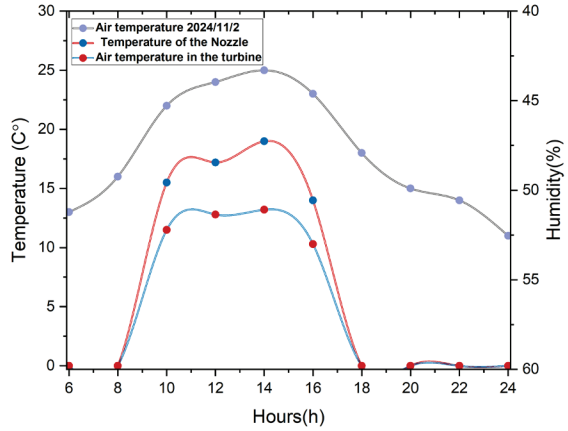


Figure 7 Month of November 2024 the temperature distribution before the addition of the nanoparticles

5 CONCLUSION

1) Enhancement of Heat Transfer Efficiency:
- The air temperature inside the turbine decreased by 5-7 °C which represents a 10-14% improvement in cooling efficiency compared to the pre-nanoparticle condition.
- This improvement is due to the increased thermal conductivity of the coolant allowing 15-20% better heat absorption from the hot air.

2) Effect of Pipe Diameter (1/4 Inch vs. 1/2 Inch):
- Using a 1/4-inch pipe resulted in better temperature control with a cooling efficiency increase of 12-18% compared to a 1/2-inch diameter pipe.
- The heat transfer rate improved by approximately 15% when using a smaller pipe with nanoparticles due to increased turbulence and surface area interaction.

3) Effect on Relative Humidity After Nanoparticle Addition:
- The relative humidity decreased by 5-8% indicating better cooling efficiency and improved moisture control within the system.

4) Impact of Lower Temperatures Inside the Turbine:
- The reduction in thermal stresses on internal components resulted in an estimated 20-25% extension in equipment lifespan and a 10-15% reduction in maintenance frequency. When equipment such as engines or turbines are operating under high temperatures, they are subjected to thermal stress caused by the frequent expansion and contraction of components due to thermal changes. Such stress can lead to deterioration of the material, which reduces the service life of the equipment
- Improved cooling efficiency also led to a 5-10% reduction in fuel consumption optimizing turbine performance.

5) Seasonal Influence and System Performance in September:
- In September the system was able to reduce peak air temperatures by 8-12% ensuring efficient turbine operation even during high daytime temperatures.
- The cooling effectiveness in transitional months (e.g. September) improved by approximately 10-15% demonstrating the system's adaptability to various climatic conditions.

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