JOURNAL LA MULTIAPP

VOL. 07, ISSUE 03 (566-580), 2026
DOI: 10.37899/journallamultiapp.v7i3.841

Thermal Effectiveness Analysis of Lube Oil Cooler Fan with Capacity of 40.332 Kg/S with Pressure of 5 Bar

Angga Bahri Pratama[1], Abdul Razak[1], Sahat[2], Nelson Manurung[2], Berta Br Ginting[3], Franklin Taruyun Hudeardo Sinaga[2], Zumhari[4]

[1]Program Studi Teknik Konversi Energi, Jurusan Teknik Mesin, Politeknik Negeri Medan, Jl. Almamater No.1, Padang Bulan, Kec. Medan Baru, Medan, Sumatera Utara 20155, Indonesia
[2]Program Studi Teknik Mesin, Jurusan Teknik Mesin, Politeknik Negeri Medan, Jl. Almamater No.1, Padang Bulan, Kec. Medan Baru, Medan, Sumatera Utara 20155, Indonesia
[3]Program Studi Teknologi Rekayasa Manufaktur, Jurusan Teknik Mesin, Politeknik Negeri Medan, Jl. Almamater No.1, Padang Bulan, Kec. Medan Baru, Medan, Sumatera Utara 20155, Indonesia
[4]Program Studi Teknik Elektronika, Jurusan Teknik Elektro, Politeknik Negeri Medan, Jl. Almamater No.1, Padang Bulan, Kec. Medan Baru, Medan, Sumatera Utara 20155, Indonesia

**Corresponding Author: Abdul Razak*
Email: abdulrazak@polmed.ac.id

Article Info

Article history:
Received 9 January 2026
Received in revised form 27 February 2026
Accepted 17 April 2026

Keywords:
Thermal Effectiveness
Lube Oil Cooler
Heat Exchanger
Gas Turbine
Cooling System

Abstract

The Lube Oil Cooler Fan is an essential component in the lubrication system of a gas turbine because it maintains lubricating oil temperature within a safe operating range. This study aims to analyze the thermal performance and effectiveness of the Lube Oil Cooler Fan on Gas Turbine GT 1.1 at PT XYZ. The study employed a descriptive quantitative approach using field observation data and heat transfer calculations. The analysis was conducted through the Log Mean Temperature Difference method and heat exchanger effectiveness approach by considering fluid temperature changes, mass flow rates, thermophysical properties, flow characteristics, convective heat transfer coefficients, overall heat transfer coefficient, heat transfer rate, and thermal effectiveness. The results show that the lubricating oil temperature decreased from 61°C to 49°C, while the cooling air temperature increased from 32°C to 53.5°C. The tube side heat transfer coefficient was 40.71 W/m²°C, the shell side heat transfer coefficient was 308 W/m²°C, and the overall heat transfer coefficient was 30.61 W/m²°C. The calculated heat transfer rate was 992.57 W or approximately 0.993 kW. The lubricating oil was identified as the minimum heat capacity fluid, with a heat capacity rate of 33.13 kW/°C. The thermal effectiveness of the Lube Oil Cooler Fan was 41.4%, indicating that the cooler was able to perform its cooling function, although its performance remained moderate. Routine monitoring, stable airflow control, and periodic cleaning are recommended to improve thermal performance.

Introduction

Gas turbine power plants play a significant role in the generation of electricity as they can convert heat energy of combustion gases into mechanical energy and then electrical energy in the generator (Julius et al., 2025; Kindra et al, 2025; Samie et al., 2025). In this power plant, air is drawn from the atmosphere and then compressed, mixed with fuel and then burned in the combustion chamber to generate high temperature and pressure gas. The gas is then expanded on the turbine blades and rotates the turbine shaft that is connected to the generator.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

The process is similar to the Brayton cycle, where compression, combustion, expansion and exhaust are all part of the energy conversion cycle (Maulana & Lesmana, 2021). Given that the gas turbine exhaust temperature can be higher than 500°C, the operation of this system is not only focused on energy conversion but also the thermal stability of each component to ensure it remains in the safe operation zone (Maulana & Lesmana, 2021; Andriani et al., 2025; Lv et al., 2025; Zhang et al., 2023).

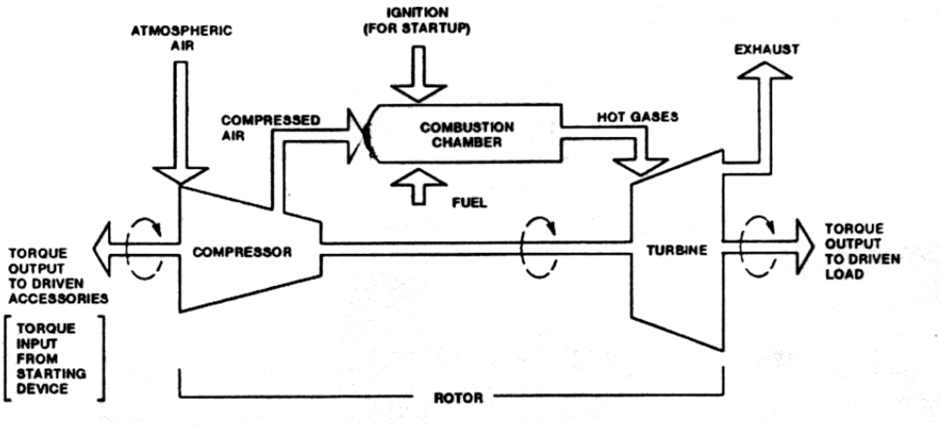

Figure 1. Working Diagram of PLTG

The performance of a gas turbine power plant does not depend solely on primary components like the compressor, combustion chamber, turbine and generator. It also relies on the efficiency of the auxiliaries that ensure the continuity and safety of the operation. Lubrication system is one of the most important ones in this respect since it prevents friction, wear and metal-to-metal contact of the rotating components and bearings. In a gas turbine, the shaft and bearing system runs at high speed and under a high heat load. Thus, the lubricating oil needs to have the proper viscosity and temperature stability. If the lubricating oil temperature rises to the point where it exceeds the permissible limit, the viscosity and protective film of lubricating oil may reduce and the risk of mechanical failure may increase. Therefore, temperature control of lubricating oil is an important aspect in ensuring the reliability of the turbine system (Rizal, 2017; Naidu et al., 2024; Osintsev et al., 2024).

In a recirculating system, the lubricating oil is circulating within the turbine and heat is transferred from the bearing and other components. Once heated, the oil cannot be directly re introduced into the system as higher temperature may decrease its lubricating and protective properties. The Lube Oil Cooler Fan is then used to cool the hot oil before it is returned to the lubricating system. During cooling, the lubricating oil is the hot fluid and the air provided by the fan is the cooling fluid. The heat is then transferred from the oil, through the tube wall, to the air via convection and conduction. The concept is straightforward, but the performance of this heat transfer process depends on a number of interrelated parameters, such as temperature difference between the fluids, mass flow rate, fluid properties, surface area, flow regime, fouling resistance, and the overall heat transfer coefficient (Pratrityo et al., 2025; Hatte et al., 2022; Ilyunin et al., 2024).

The efficiency of a Lube Oil Cooler Fan is linked to the underlying theory of heat transfer in heat exchangers. Hot lube oil circulates in the tube, while air flows across the outside of the tube, and heat is transferred from the hotter fluid to the cooler fluid. This process involves convection from the oil to the inner wall of the tube, conduction through the tube, and convection from the outer wall of the tube to the cooling air. The performance of the cooler in terms of heat removal is determined by the effectiveness of the thermal resistances being overcome during operation. Reductions in the air flow, cleanliness of the heat transfer surface, or the temperature difference between the air and oil might lead to a reduction in the heat removed from the oil. This decrease in heat removal may have an impact on the thermal performance of the lubrication system and, ultimately, may affect the reliability of the gas turbine unit (Egeten et al., 2014; Banihabib et al., 2024; Gao et al., 2026).

Some previous works have demonstrated that thermal analysis of oil coolers and heat exchangers can be carried out by using the Log Mean Temperature Difference, convective heat transfer coefficient, overall heat transfer coefficient, heat transfer rate, and thermal effectiveness. They enable researchers to determine whether there is temperature lowering, and how heat is transferred in a given operating condition. Earlier studies on oil coolers and heat exchanger systems have highlighted that fluid flow, flow arrangement, fouling and thermophysical properties are the main factors affecting the heat transfer characteristics of a system (Maulana & Lesmana, 2021; Siagian, 2016; Syarief & Mahesa, 2021). Research on cooling and lubrication systems for gas turbines also demonstrates that the cooling performance is vital to prevent the thermal degradation of the lubricating oil and maintain the reliability of the machinery (Wibowo & Dwiyantoro, 2014; Pratrityo et al., 2025). However, each cooler unit has its own operating condition, so it is important to assess its performance with real data instead of only using assumptions.

This requirement for an on-site assessment is critical in the case of the Lube Oil Cooler Fan on GT 1.1 at PT XYZ. While the role of the cooler is to cool the lube oil, the performance of the cooler depends on the operating conditions that have been recorded, such as the oil and air temperature at inlet and outlet, the mass flow rate of the oil and air, and the physical properties of the heat transfer surface. An evaluation of the cooler performance with respect to these parameters can give a more accurate measure of the cooler's heat transfer efficiency to the lubricating oil. It can also reveal whether the current cooling process is sufficient or needs to be improved by controlling the flow conditions, cleanliness of the heat transfer surface or heat transfer area. Such analysis in an industrial power generation system is helpful because even small reduction in cooling effectiveness may influence the long term reliability and maintenance requirements (Barmavatu et al., 2026; Yusmaini et al., 2026;

With this understanding, this research will examine the heat effectiveness of the Lube Oil Cooler Fan on Gas Turbine GT 1.1 at PT XYZ. This includes the temperature variations of the lubricating oil and cooling air, the thermophysical properties of the two fluids, the flow properties on the shell (air) and tube (oil) sides, the convective heat transfer coefficients, the overall heat transfer coefficient, the heat transfer rate, and the effectiveness of the cooling process. This research uses the Log Mean Temperature Difference and heat exchanger effectiveness methods to assess the heat transfer process from lubricating oil to air by the cooler. The findings will be used to determine the condition of the Lube Oil Cooler Fan and to assist in future efforts to enhance cooling performance of the gas turbine lubrication system.

Methods

Research Approach

This study employed a descriptive quantitative approach based on thermal performance analysis to evaluate the effectiveness of the Lube Oil Cooler Fan on GT 1.1 at PT XYZ. This approach was selected because the study focused on calculating heat transfer performance using operational data obtained from field observation. The analysis was conducted by applying heat transfer principles, particularly the Log Mean Temperature Difference method and heat exchanger effectiveness approach. The main parameters analyzed in this study included fluid inlet and outlet temperatures, mass flow rates, thermophysical properties, heat transfer coefficients, overall heat transfer coefficient, heat transfer rate, and thermal effectiveness.

Research Object

In this research, the Lube Oil Cooler Fan in the lubrication system of Gas Turbine GT 1.1 was used as a case study. The purpose of this particular component is to cool the lubricating oil before being recycled to the turbine lubrication system. During heat transfer, the lubricating oil is the hot fluid and the cooling fluid is the air provided by the fan. The heat of the lubricating oil is transferred to the cooling air by conduction and convection through the wall of the tube. Thus, the effectiveness of the Lube Oil Cooler Fan was assessed by analysing the fluid temperature variations and thermal parameters used to calculate the heat transfer process.

Data Collection

The information used in this study was acquired from literature study and field measurement. The literature study involved examining the relevant literature on Lube Oil Cooler Fan systems, heat exchangers, thermophysical properties of fluids and methods of heat transfer calculation. These sources provided information to justify the theory and calculation method used in this study.

Direct observation was conducted to gather data for the thermal calculation. The measured data were the air inlet and outlet temperatures, lubricating oil inlet and outlet temperatures, air mass flow rate, lubricating oil mass flow rate and cooler geometry. The temperature data included the temperature of the air inlet, air outlet, oil inlet and oil outlet. Using these data, the average temperatures, the fluid properties, temperature difference, heat transfer rate, and effectiveness were then calculated.

Data Analysis Procedure

The heat transfer analysis was done in a number of steps. First, the fan cross sectional area was determined from the fan length and width. This was used to represent the air flow area of the cooling system. Next, we calculated the average temperature of the fluid. The average temperature of the lubricating oil was determined from the inlet and outlet temperature of the oil and the average temperature of air was determined from the inlet and outlet temperature of air. The average temperature of each fluid was used to calculate the thermophysical properties of the fluid from the fluid property tables.

Once the properties of the fluids were calculated, the next step was to calculate the Log Mean Temperature Difference. The LMTD was then corrected for the cross flow configuration of the Lube Oil Cooler Fan. The correction factor was calculated based on the P and R parameters which were calculated from the hot and cold fluid temperatures. The corrected value of temperature difference was then used to calculate the heat transfer rate.

Determination of Fluid Properties

The average temperatures of the lubricating oil and air were used to determine their thermophysical properties. The average temperature for the lubricating oil was found from the oil temperatures at the inlet and outlet. The properties were specific heat, Prandtl number, thermal conductivity and density. For air, the average temperature was calculated using the inlet and outlet air temperatures, and then converted to the Kelvin scale to determine the properties from the air property table. The properties of air used in the calculation were specific heat, dynamic viscosity, Prandtl number, thermal conductivity, and density.

The properties of the fluid were determined because they influence the calculation of heat capacity rate, Reynolds number, Nusselt number and convective heat transfer coefficient. In this paper, the specific heat of oil was used for the hot fluid heat capacity rate while specific heat of air was used for the cold fluid heat capacity rate.

Calculation of Flow Characteristics

Reynolds number was used to determine the flow conditions on the tube side and shell side. For the tube side, the velocity of the lubricating oil flow was determined from the mass flow rate, density and flow area through the tubes. The Reynolds number was calculated to classify the oil. This classification was used to determine the appropriate correlation for the Nusselt number to calculate the tube side heat transfer coefficient.

On the shell side, the flow area for the air was determined considering the tube pitch, outside tube diameter and clearance. The air velocity was then used to calculate the shell side Reynolds number. The Reynolds number was used to determine the nature of the air flow. If the air flow was turbulent, the Nusselt number was determined using a correlation for turbulent flow. This ensured that the convective heat transfer coefficient was calculated using the correct flow regime.

Calculation of Convective Heat Transfer Coefficients

The tube side convective heat transfer coefficient was then determined by the Nusselt number, thermal conductivities of the lubricating oil, and characteristic diameter of the tube. The tube side coefficient in this case is the heat transfer coefficient between the lubricating oil and the tube.

The shell side coefficient of convective heat transfer was calculated from the Nusselt number, thermal conductivity of air, and characteristic diameter of the flow. The flow on the shell side was found to be turbulent and the Nusselt number correlation for turbulent flow was used. The shell side coefficient is indicative of the cooling air's capacity to accept heat from the tube. These two heat transfer coefficients were used as the key input parameters in determining the overall heat transfer coefficient.

Calculation of Overall Heat Transfer Coefficient

The overall heat transfer coefficient was determined with the thermal resistance of the tube side, shell side, tube, and fouling layer. The tube wall was considered as carbon steel with the thermal conductivity used. The fouling factors were considered so any contaminants or deposits on the heat transfer surface could be accounted for, which may affect the heat transfer efficiency of the cooler.

The air side fouling factor was based on the industrial air fouling factor used in the calculation and the oil side fouling factor was based on the fouling factor table for lubricating oil. Taking into account these resistances, the overall heat transfer coefficient gave a better picture of the heat transfer ability of the Lube Oil Cooler Fan.

Calculation of Heat Transfer Rate

The heat transfer rate was calculated with the overall heat transfer coefficient, heat transfer area, Log Mean Temperature Difference and correction factor. The equation used was the heat transfer equation for a corrected LMTD. This was to calculate the heat taken away from the lubricating oil by the cooling air during operation.

The rate of heat transfer calculated from this operation was then used as the actual heat transfer rate to assess the cooler effectiveness. It also provided a means for inferring whether the Lube Oil Cooler Fan was able to dissipate the heat from the lubricating oil at the observed operating condition.

Calculation of Thermal Effectiveness

The thermal effectiveness was calculated with a comparison between the actual heat transfer and the maximum heat transfer. In the calculation of effectiveness, the heat capacity rate of hot and cold fluids was calculated first. The heat capacity rate of air was determined based on the air mass flow rate and the specific heat of air, and the heat capacity rate of the lubricating oil was determined based on the mass flow rate of lubricating oil and the specific heat of the lubricating oil.

The smaller heat capacity rate was chosen as the minimum heat capacity rate. In this study, the heat capacity rate of lubricating oil was smaller than that of the air, so the lubricating oil was the minimum heat capacity fluid. This value was then used in the calculation of the maximum heat transfer and the heat transfer effectiveness of the Lube Oil Cooler Fan.

Scope of Analysis

This study only focused on the thermal performance assessment of the Lube Oil Cooler Fan using field observed data and theoretical heat transfer analyses. The study considered the change in fluid temperature, thermophysical properties, flow properties, heat transfer coefficient, overall heat transfer coefficient, heat transfer rate, and effectiveness. No numerical simulation, mechanical failure analysis, cost analysis and long term degradation were performed in this study. Consequently, this study should be considered as a thermal performance assessment based on the actual operating condition of Lube Oil Cooler Fan on GT 1.1.

Results and Discussion

Operating Conditions of the Lube Oil Cooler Fan

The field observation of the Lube Oil Cooler Fan on GT 1.1 at PT XYZ showed temperature changes in both the cooling air and the lubricating oil during the heat transfer process. Air acted as the cooling fluid and experienced an increase in temperature after absorbing heat from the lubricating oil. In contrast, the lubricating oil acted as the hot fluid and experienced a decrease in temperature after passing through the cooling system. These operating data became the main basis for calculating the thermal performance and effectiveness of the Lube Oil Cooler Fan.

Table 1. Operating Data of the Lube Oil Cooler Fan

Parameter	Symbol	Value	Unit
Air inlet temperature	Tci	32	°C
Air outlet temperature	Tco	53.5	°C
Oil inlet temperature	Thi	61	°C
Oil outlet temperature	Tho	49	°C
Air mass flow rate	$\dot{m}c$	40.332	kg/s
Oil mass flow rate	$\dot{m}h$	16.350	kg/s

As shown in Table 1, the lubricating oil temperature decreased from 61°C to 49°C after passing through the Lube Oil Cooler Fan. At the same time, the air temperature increased from 32°C to 53.5°C. This temperature change indicates that heat was transferred from the lubricating oil to the cooling air, confirming that the cooling system performed its function in reducing the oil temperature before the lubricant returned to the gas turbine lubrication system.

Fan Cross Sectional Area

The initial calculation was conducted by determining the fan cross sectional area based on the fan length and width. This value was used as one of the geometric parameters in the thermal analysis because it relates to the airflow area in the cooling process.

Table 2. Fan Cross Sectional Area

Parameter	Symbol	Value	Unit
Fan length	P	0.8	m
Fan width	l	0.2	m
Fan cross sectional area	AFan	0.16	m²

Based on Table 2, the fan cross sectional area was obtained as 0.16 m² from the multiplication of 0.8 m and 0.2 m. This area was used as an initial parameter in evaluating the airflow characteristics of the Lube Oil Cooler Fan.

Thermophysical Properties of Lubricating Oil

The thermophysical properties of the lubricating oil were determined based on the average temperature of the hot fluid. The average oil temperature was calculated from the inlet and outlet oil temperatures. Based on the oil inlet temperature of 61°C and the oil outlet temperature of 49°C, the average oil temperature was 55°C. This value was then used as the basis for interpolating the fluid properties.

Table 3. Thermophysical Properties of Lubricating Oil

Parameter	Symbol	Value	Unit
Oil inlet temperature	Thi	61	°C
Oil outlet temperature	Tho	49	°C
Average oil temperature	Th	55	°C
Specific heat of lubricating oil	Cp	2.026	kJ/kg°C
Prandtl number	Pr	1.505	Dimensionless
Thermal conductivity	k	0.141	W/m°C
Density	ρ	867.043	kg/m³

Table 3 presents the thermophysical properties of the lubricating oil used in the calculation. The specific heat value of 2.026 kJ/kg°C was used to calculate the heat capacity rate of the hot fluid. This value provides a more consistent basis for the calculation of thermal effectiveness than the previously inconsistent value.

Thermophysical Properties of Air

The thermophysical properties of air were determined based on the average temperature of the cooling fluid. The air inlet temperature was 32°C, while the outlet temperature was 53.5°C. Therefore, the average air temperature was 42.75°C. This temperature was converted into 315.75 K to match the air property table used in the calculation.

Table 4. Thermophysical Properties of Air

Parameter	Symbol	Value	Unit
Air inlet temperature	Tci	32	°C
Air outlet temperature	Tco	53.5	°C
Average air temperature	Tc	42.75	°C
Average air temperature	Tc	315.75	K
Specific heat of air	Cp	1.00673	kJ/kg°C
Dynamic viscosity	μ	1.91827×10^{-5}	kg/m.s
Prandtl number	Pr	0.7046	Dimensionless

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Thermal conductivity	k	0.02743	W/m°C
Density	ρ	5.517	kg/m³

Table 4 shows the thermophysical properties of air used in the shell side calculation. The specific heat of air was set at 1.00673 kJ/kg°C because this value was used in calculating the heat capacity rate of the cooling fluid. These properties were also used to determine the Reynolds number, Nusselt number, and convective heat transfer coefficient on the air side.

Log Mean Temperature Difference

The Log Mean Temperature Difference was used to determine the effective temperature difference between the lubricating oil and the cooling air. Since the Lube Oil Cooler Fan operates under a cross flow configuration, the LMTD value was used together with a correction factor in calculating the heat transfer rate.

Table 5. Log Mean Temperature Difference

Parameter	**Symbol**	**Value**	**Unit**
Oil inlet temperature	Thi	61	°C
Oil outlet temperature	Tho	49	°C
Air inlet temperature	Tci	32	°C
Air outlet temperature	Tco	53.5	°C
Log mean temperature difference	ΔTLMTD	11.60	°C

Based on Table 5, the ΔTLMTD value was 11.60°C. This value represents the effective temperature difference that drives heat transfer from the lubricating oil to the cooling air.

Tube Side Heat Transfer Analysis

The tube side analysis was conducted to determine the flow characteristics of the lubricating oil and the convective heat transfer coefficient on the tube side. The calculation included the tube flow area, flow velocity, Reynolds number, Nusselt number, and tube side convective heat transfer coefficient.

Table 6. Tube Side Heat Transfer Calculation

Parameter	**Symbol**	**Value**	**Unit or description**
Tube flow area	At	0.139274	m²
Tube side flow velocity	Vt	0.13539639	m/s
Tube side Reynolds number	Ret	13.9799523323	Laminar flow
Tube side Nusselt number	Nud	3.6673690116682	Dimensionless
Tube side heat transfer coefficient	hi	40.71	W/m²°C

Table 6 shows that the tube side Reynolds number was 13.9799523323, indicating laminar flow of the lubricating oil. The Nusselt number of 3.6673690116682 was then used to determine the tube side convective heat transfer coefficient. The calculated tube side heat transfer coefficient was 40.71 W/m²°C.

Shell Side Heat Transfer Analysis

The shell side analysis was conducted to determine the flow characteristics of air as the cooling fluid. The calculation included tube pitch, outside tube diameter, clearance, shell flow area, air velocity, Reynolds number, Nusselt number, and shell side convective heat transfer coefficient.

Table 7. Shell Side Heat Transfer Calculation

Parameter	**Symbol**	**Value**	**Unit or description**
Tube pitch	Pt	0.017275	m

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Outside tube diameter	Do	0.01382	m
Clearance	C	0.003455	m
Shell flow area	As	0.48	m²
Shell side flow velocity	Vs	70.02	m/s
Shell side Reynolds number	Res	68,600	Turbulent flow
Shell side Nusselt number	Nu	155.25	Dimensionless
Shell side heat transfer coefficient	ho	308	W/m²°C

Based on Table 7, the shell side air velocity was 70.02 m/s. The shell side Reynolds number was 68,600, indicating that the air flow was turbulent. Therefore, the Nusselt number was calculated using a turbulent flow correlation. The resulting Nusselt number was 155.25, and the shell side convective heat transfer coefficient was 308 W/m²°C. This value indicates that heat transfer on the air side was strengthened by the turbulent flow condition.

Overall Heat Transfer Coefficient

The overall heat transfer coefficient was calculated by considering the tube side heat transfer coefficient, shell side heat transfer coefficient, thermal conductivity of the tube material, and fouling factors. This calculation is important because the overall heat transfer process is influenced by the thermal resistance on the oil side, air side, tube wall, and heat transfer surface.

Table 8. Overall Heat Transfer Coefficient and Fouling Factor

Parameter	Symbol	Value	Unit
Tube side heat transfer coefficient	hi	40.71	W/m²°C
Shell side heat transfer coefficient	ho	308	W/m²°C
Thermal conductivity of carbon steel	k	43	W/m°C
Fouling factor for lubricating oil	Rdi	Based on the fouling factor table used	m²°C/W
Fouling factor for industrial air	Rdo	0.0004	m²°C/W
Overall heat transfer coefficient	U	30.61	W/m²°C

As shown in Table 8, the overall heat transfer coefficient was 30.61 W/m²°C. This value represents the total ability of the cooler to transfer heat from the lubricating oil to the cooling air after considering heat transfer resistance and fouling effects. Since the cooler was still in relatively good condition, the fouling resistance did not dominate the overall heat transfer process.

Correction Factor and Heat Transfer Rate

Because the Lube Oil Cooler Fan operates under a cross flow configuration, a correction factor was applied in the heat transfer rate calculation. The correction factor was determined using the P and R parameters derived from the inlet and outlet temperatures of the hot and cold fluids.

Table 9. Correction Factor and Heat Transfer Rate

Parameter	Symbol	Value	Unit
Correction parameter	P	0.413	Dimensionless
Correction parameter	R	1.791	Dimensionless
Correction factor	F	0.843	Dimensionless
Overall heat transfer coefficient	U	30.61	W/m²°C

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Heat transfer area	Ao	3.316782	m²
Log mean temperature difference	ΔTLMTD	11.60	°C
Heat transferred	Qpp	992.57	W
Heat transferred	Qpp	0.993	kW

Table 9 shows that the heat transferred by the Lube Oil Cooler Fan was 992.57 W or approximately 0.993 kW. This value was obtained by multiplying the overall heat transfer coefficient, heat transfer area, logarithmic mean temperature difference, and correction factor. The result indicates that the heat transfer process occurred during operation, although performance improvement is still possible through optimization of operating conditions and heat transfer surface area.

Thermal Effectiveness of the Lube Oil Cooler Fan

Thermal effectiveness was calculated by comparing the actual heat transfer to the maximum possible heat transfer. Before calculating the effectiveness, the heat capacity rates of the cooling fluid and hot fluid were determined based on the mass flow rate and specific heat of each fluid.

Table 10. Heat Capacity Rate and Thermal Effectiveness Calculation

Parameter	**Symbol**	**Value**	**Unit or description**
Air mass flow rate	$\dot{m}c$	40.332	kg/s
Specific heat of air	Cp air	1.00673	kJ/kg°C
Heat capacity rate of cold fluid	Cc	40.603	kW/°C
Oil mass flow rate	$\dot{m}h$	16.350	kg/s
Specific heat of lubricating oil	Cp oil	2.026	kJ/kg°C
Heat capacity rate of hot fluid	Ch	33.13	kW/°C
Minimum heat capacity fluid	Cmin	Lubricating oil	
Thermal effectiveness	ε	0.414	Dimensionless
Thermal effectiveness	ε	41.4	%

Based on Table 10, the heat capacity rate of the cold fluid was 40.603 kW/°C, while the heat capacity rate of the hot fluid was 33.13 kW/°C. Since Ch was lower than Cc, the lubricating oil was identified as the minimum heat capacity fluid. The thermal effectiveness of the Lube Oil Cooler Fan was 0.414 or 41.4%. This result indicates that the cooler was able to utilize part of the maximum possible heat transfer, although its thermal performance can still be improved through better operating control and heat transfer enhancement.

The 41.4% thermal effectiveness shows that, in the current operating condition, the Lube Oil Cooler Fan could carry out the cooling process, but its performance was moderate. The drop in temperature of the lubricating oil from 61°C to 49°C indicates that heat was removed from the system, whereas the rise of cooling air temperature from 32°C to 53.5°C indicates the flow of cooling air absorbed the heat. This outcome must not be viewed merely as a temperature drop because the performance of a cooler is also influenced by the heat capacity rate, flow, heat transfer area, fouling resistance, and overall heat transfer coefficient. Other recent studies on oil coolers and heat exchangers also highlight that the performance of the heat exchanger should be assessed by combining temperature difference with other thermal performances such as Logarithmic Mean Temperature Difference (LMTD), heat transfer coefficient, and effectiveness, not just by the outlet temperature (Tol, 2025; Khroufi et al., 2025; Irannezhad et al., 2025).

It is crucial to identify lubricating oil as the minimum heat capacity fluid in this study in order to interpret the effectiveness. In this research, the heat capacity of the hot fluid (Ch) was 33.13 kW/°C, and the heat capacity of the cold fluid (Cc) was 40.603 kW/°C. In this case, Ch was smaller than Cc, so the lubricating oil became Cmin. This means that the amount of heat that could be transferred was restricted by the heat capacity rate of the lubricating oil, not the cooling air. This is in line with the effectiveness method where the correct Cmin has a significant impact on heat exchanger performance interpretation. As a result, the effectiveness of 41.4% is related to the capability of the cooler to transfer heat with respect to the maximum possible heat transfer limited by the oil side.

The new shell side analysis also confirms the technical interpretation of the cooler performance. The shell side flow was turbulent (Reynolds number: 68,600). This condition is the reason for the relatively high shell side heat transfer coefficient (308 W/m²°C), as turbulence increases fluid mixing and decreases the thermal boundary layer thickness. This is in accordance with recent works that flow velocity and flow regime play an important role in convective heat transfer in cross flow and air cooled heat exchanger systems (Mahay & Yadav, 2025; Tanougast & Hriczó, 2025; Wang et al., 2023). But the total heat transfer coefficient was 30.61 W/m²°C, suggesting that the total heat transfer performance was still affected by the total thermal resistance of the oil side, air side, tube wall and fouling layers.

The heat transfer rate of 992.57 W (or 0.993 kW) indicated that heat transfer actually occurred while operating the Lube Oil Cooler Fan. But this is only the heat transfer rate for the specific operating condition, not a fixed heat transfer rate for all operating loads. Recent literature using LMTD and effectiveness based analysis also highlights that the heat transfer rate is dependent on fluid properties, correction factors, flow geometry, heat transfer surface area and temperature difference (Kumar et al., 2022; Bhattad et al., 2024; Nishat et al., 2026). . Thus, the outcome of this study is a field-based thermal performance estimate, which can be used as a starting point for assessing the cooler performance and future monitoring.

Fouling is still an important consideration in the overall heat transfer coefficient. While the cooler was claimed to be in "good condition", an allowance for fouling was included because the accumulation of deposits or contaminants on the heat transfer surfaces can increase the thermal resistance and decrease the heat transfer efficiency. This aligns with recent research that fouling influences the operation of a heat exchanger by increasing resistance, decreasing heat transfer efficiency and modifying the thermal characteristics of the heat exchanger during prolonged operation (Huang et al., 2026; Roy et al., 2026; Kumar et al., 2025). In this context, the low value of effectiveness should be considered as a technical reference for regular inspections, surface cleaning, and temperature (oil and air) monitoring.

The results suggest that the Lube Oil Cooler Fan is working properly but can be improved. The prime technical implications include the maintenance of steady air flow, clean heat transfer surface, check of oil and air flow rates, and re-analysis with various operating loads. These are in line with recent studies on oil cooler (or heat exchanger) performance, which highlight that actual performance will depend on flow conditions, surface cleanliness, ambient temperature and heat transfer surface (Shinde et al., 2026; Marzouk et al., 2025; Vieira et al., 2025). In this context, the main contribution of the present study is not only the determination of the 41.4% effectiveness, but also that the field thermal analysis can be used to predict the operational aspects that should be attended to ensure the reliability of the gas turbine lube oil system.

Conclusion

The thermal analysis shows that the Lube Oil Cooler Fan on GT 1.1 at PT XYZ was able to reduce the lubricating oil temperature from 61°C to 49°C, while the cooling air temperature increased from 32°C to 53.5°C. This confirms that heat transfer occurred from the lubricating oil to the cooling air during operation.

The calculation results show that the tube side heat transfer coefficient was 40.71 W/m²°C, the shell side heat transfer coefficient was 308 W/m²°C, and the overall heat transfer coefficient was 30.61 W/m²°C. The heat transfer rate was 992.57 W, or approximately 0.993 kW. The heat capacity rate of the lubricating oil was lower than that of the cooling air, so the lubricating oil was identified as the minimum heat capacity fluid.

The thermal effectiveness of the Lube Oil Cooler Fan was 41.4%, indicating that the cooler was able to perform its function, although its performance remained moderate. Therefore, routine monitoring of inlet and outlet temperatures, stable airflow control, and periodic cleaning of heat transfer surfaces are recommended to maintain and improve cooling performance.

Acknowledgment

The authors would like to express their sincere gratitude to PT XYZ for providing access to operational data and supporting the field observation process related to the Lube Oil Cooler Fan on GT 1.1. The authors also thank the Department of Mechanical Engineering, Politeknik Negeri Medan, for its academic support during the preparation of this study. Appreciation is also extended to all parties who contributed directly or indirectly to the completion of this research article.

References

Andriani, G., Pio, G., Salzano, E., Vianello, C., & Mocellin, P. (2025). Evaluating the thermal stability of chemicals and systems: A review. The Canadian Journal of Chemical Engineering, 103(1), 42-62.

Bahri Pratama, A., Qadry, A., Fan Saragi, JH, Putra Dairi Boangmanalu, E., & Taruyun Hudeardo Sinaga, F. (2023). Analysis Efficiency and Effectiveness of Heat Transfer Rate in Double Pipe Type Heat Exchanger with Direct Current . Mesil Journal (Electro Civil Machines) , 04 (02).

Banihabib, R., Lingstädt, T., Wersland, M., Kutne, P., & Assadi, M. (2024). Development and testing of a 100 kW fuel-flexible micro gas turbine running on 100% hydrogen. International Journal of Hydrogen Energy, 49, 92-111. https://doi.org/10.1016/j.ijhydene.2023.06.317

Barmavatu, P., Heeraman, J., Das, M. K., Mangalaraja, R. V., & Srinivasnaik, M. (2026). Synergistic integration of micro-channels and thermal storage systems for energy efficiency enhancement in heat transfer applications-a critical review. Journal of Thermal Analysis and Calorimetry, 1-23. https://doi.org/10.1007/s10973-025-15165-w

Bhattad, A., Atgur, V., Rao, B. N., Banapurmath, N. R., Manavendra, G., Sajjan, A. M., ... & Hussien, M. (2024). A simplified LMTD approach to assess the effectiveness of a chevron-type plate heat exchanger. Journal of Thermal Analysis and Calorimetry, 149(21), 12205-12217. https://doi.org/10.1007/s10973-024-13573-y

Egeten , HSF, Sappu , FP, & Maluegha , B. (2014). EFFECTIVENESS OF PLATE TYPE HEAT EXCHANGER P41 73TK AT LAHENDONG PLTP UNIT 2. Online Journal of Mechanical Engineering Poros , 3 (1).

Fauziyyah , AD, & Nashira, A. (2025). ANALYSIS OF HEAT TRANSFER EFFICIENCY IN GAS COOLER IN OIL AND GAS SEPARATION FACILITY OF COMPANY X. RAPI National Symposium .

Gao, C., Huang, Z., Yu, A., Xiao, H., & Zhang, Z. (2026). Similarity theory-driven dimensionless parameter migration framework: Digital twin approach for cross-condition gas turbine performance monitoring. Applied Thermal Engineering, 129712. https://doi.org/10.1016/j.applthermaleng.2026.129712

Hatte, S., Stoddard, R., & Pitchumani, R. (2022). Generalized analysis of dynamic flow fouling on heat transfer surfaces. International Journal of Heat and Mass Transfer, 188, 122573.

Huang, T., Huang, X., Xiaoming, F., Ziye, L., & Zhang, Z. (2026). Research Progress on Thermophysical Properties and Convection Heat Transfer Enhancement of Molten Salts. Energies, 19(5), 1230. https://doi.org/10.3390/en19051230

Ilyunin, O., Bezsonov, O., Rudenko, S., Serdiuk, N., Udovenko, S., Kapustenko, P., ... & Arsenyeva, O. (2024). The neural network approach for estimation of heat transfer coefficient in heat exchangers considering the fouling formation dynamic. Thermal Science and Engineering Progress, 51, 102615. https://doi.org/10.1016/j.tsep.2024.102615

Irannezhad, N., Rossetto, L., & Diani, A. (2025). Optimization considerations in the design of shell and tube condensers implementing enhanced tubes: Experimental and theoretical analysis. Applied Thermal Engineering, 273, 126408.

Julius, O. I., Kwelle, S. H., & Johnson, N. (2025). Unlocking the Functional Mechanics of Gas Turbine Plants: Enhancing Reliability, Efficiency, and Environmental Sustainability. Jurnal Teknik Indonesia, 4(02), 56-121.

Khroufi, K., Mokhnache, K., & Djafer, A. (2025). How students can master the concept of heat exchangers. South Florida Journal of Development, 6(5), e5368-e5368. https://doi.org/10.46932/sfjdv6n5-089

Kindra, V. O., Rogalev, A. N., Kovalev, D. S., Ilin, I. V., & Levina, A. I. (2025). Research and development of high temperature gas-cooled reactor nuclear power plants for combined production of electricity, heat and hydrogen. International Journal of Hydrogen Energy, 148, 149968. https://doi.org/10.1016/j.ijhydene.2025.06.158

Kumar, D. V., Vijayaraghavan, S., & Thakur, P. (2022). Analytical and experimental investigation on heat transfer and flow parameters of Multichannel louvered fin cross flow heat exchanger using iterative LMTD and∊-NTU method. Materials Today: Proceedings, 52, 1240-1248. https://doi.org/10.1016/j.matpr.2021.11.045

Kumar, S., Rathore, K., Sahu, M. K., Sharma, M. P., Mishra, K. N., & Banerjee, D. (2025). Heat Exchanger Classifications and Their Areas of Application. In Advanced Applications in Heat Exchanger Technologies (pp. 30-63). CRC Press.

Lv, X., Hong, P., Wen, J., Ma, Y., Spataru, C., & Weng, Y. (2025). Highly efficient operation of an innovative SOFC powered all-electric ship system using quick approach for ammonia to hydrogen. Frontiers in Energy, 19(3), 365-381. https://doi.org/10.1007/s11708-025-0974-8

Mahay, N., & Yadav, R. K. (2025). Experimental study on hydro-thermal behavior of water, ethylene glycol-based Cu/Ni bi-metallic nanofluid in an air-finned cross-flow heat exchanger. Journal of Thermal Analysis and Calorimetry, 150(18), 14403-14421. https://doi.org/10.1007/s10973-025-14333-2

Marzouk, S. A., Abou Al-Sood, M. M., El-Said, E. M., Younes, M. M., & El-Fakharany, M. K. (2025). Comprehensive review of heat transfer enhancement through constructal theory. Journal of Thermal Analysis and Calorimetry, 150(22), 18089-18127. https://doi.org/10.1007/s10973-025-14630-w

Maulana, F., & Lesmana, IGE (2021). Analysis Improvement Effectiveness of Exchange Tool Calories Plate Type After Cleaning of Turbine Cooling Oil System . SEMNASTERA .

Naidu, S. S., Korapati, P., Trisha, N., Vedadri, G., & Jahnavi, G. (2024, April). Turbine Lube Oil Monitoring and Analysis Using IOT. In 2024 International Conference on Expert Clouds and Applications (ICOECA) (pp. 463-470). IEEE. https://doi.org/10.1109/ICOECA62351.2024.00087

Nishat, A. R., Dev, A., Biswas, A., & Aich, A. (2026). Compact Spiral Plate Heat Exchanger: A Comparison with Conventional Alternatives on Scaling and Fouling Mitigation. ASHRAE Transactions, 132, 37-46. https://doi.org/10.63044/w26dev01

Osintsev, K. V., Pshenisnov, N. A., & Pshenisnov, A. I. (2024). Analysis of operation of the oil-supply system of steam turbine before and after maintenance. Thermal Engineering, 71(9), 726-733. https://doi.org/10.1134/S0040601524700319

Pratrityo , R., Sukandi, A., & Belyamin , D. (2025). Analysis Lube Oil Cooler Damage Based on Efficiency Using the FMEA Method on Compressors at PT. Kilang Pertamina Internasional Refinery Unit III Plaju . Proceedings A of the National Seminar on Mechanical Engineering. Jakarta State Polytechnic , 405–411. http://prosiding.pnj.ac.id

Rantaujaya , A., Gusri Akhyar Ibrahim, and, Mechanical Engineering , J., Engineering, F., Lampung, U., & Lampung, B. (2025). TESTING AND PERFORMANCE ANALYSIS OF CROSS-FLOW HEAT EXCHANGER (SHELL AND TUBE) IN COFFEE DRYING MACHINE OF TULEN COFFEE FACTORY. FEMA JOURNAL OF MECHANICAL ENGINEERING | , 3 (2). https://doi.org/10.23960/fema.v3i2.8238

Rizal, M. (2017). ANALYSIS OF THE IMPACT OF DECREASE IN LUBE OIL COOLER PERFORMANCE ON TURBINES AT THE BELAWAN PLTU .

Roy, A., Kumar, S., Das, K., Kumar, A., Ebihara, A., Wang, C. T., & Katiyar, V. (2026). Next-Generation Per and Poly-Fluoroalkyl-Free Graphene Oxide Modified Cellulose Ether Charge Separator for Antibiotic Micropollutant Removal and Energy Recovery in Hospital Wastewater-Fed Microbial Fuel Cell. Journal of Polymer Science. https://doi.org/10.1002/pola.70044

Samie, B., Azad, M. T., Salehi, G., & Lari, K. (2025). Energy, exergy, and exergoeconomic evaluations of a combined cycle with three configurations for heat recovery steam generator. Journal of Thermal Analysis and Calorimetry, 150(7), 5495-5515. https://doi.org/10.1007/s10973-025-14134-7

Shinde, S., Kumkar, D., Kumbhar, A., Kumbhar, S., Madewar, R., Kumbhar, S., & Kadam, A. (2026, March). Long-term performance and reliability of heat exchangers. In AIP Conference Proceedings (Vol. 3369, No. 1, p. 040025). AIP Publishing LLC. https://doi.org/10.1063/5.0320691

Siagian , S. (2016). ANALYSIS OF THE EFFECTIVENESS OF SHELL AND TUBE TYPICAL HEAT EXCHANGER DEVICE RESULTING FROM STUDENT PLANNING ON A LABORATORY SCALE (Vol. 12).

Syarief , A., & Mahesa, R. (2021). ANALYSIS OF TURBINE OIL COOLER PERFORMANCE IN PLTU ASAM ASAM UNIT 1. TEKNIK INFO , 22 (1), 79–98.

Tanougast, A., & Hriczó, K. (2025). Advancements in Heat Exchangers for Improved Engine Cooling: A Comprehensive Literature Review. Periodica Polytechnica Transportation Engineering, 53(4), 431-439. https://doi.org/10.3311/PPtr.37123

Tol, H. İ. (2025). Development of a UA-Independent Effectiveness–Thermal Length Modelling for Heat Exchanger Performance Prediction. International Journal of Energy Horizon (IJEH), 1(2), 80-89.

Vieira, A. J. M., Silva, Y. D., & Frutuoso, L. F. A. (2025, October). Heat Exchangers Performance Monitoring and Intervention Planning Supported by Real-Time Calculations. In Offshore Technology Conference Brasil (p. D031S036R009). OTC.

Wang, J., Deng, X., Jia, D., Lei, J., & Xie, G. (2023). Numerical investigation on effects of rib shapes on oscillating flow and heat transfer in heat exchanger channels. Thermal Science and Engineering Progress, 42, 101919.

Wibowo, AK, & Dwiyantoro , BA (2014). Numerical Study Improved Cooling Performance on a Lube Oil Cooler Gas Turbine In Series and Parallel with Variation Capacity Lube Oil Flow . POMITS ENGINEERING JOURNAL , 3 (2), 169–173.

Yusmaini, N. A., Suzaimi, N. D., Abuhabib, A., Almanassra, I. W., Bagastyo, A. Y., Adnan, F. H., ... & Hamzah, S. (2026). Electrocoagulation strategies for oily wastewater treatment: a review on process efficiency and optimization. International Journal of Environmental Science and Technology, 23(3), 227. https://doi.org/10.1007/s13762-025-06847-x

Zhang, S., Gu, W., Zhang, X. P., Lu, H., Lu, S., Ding, S., ... & Zhao, S. (2023). Steady-state security region of integrated energy system considering thermal dynamics. IEEE Transactions on Power Systems, 39(2), 4138-4153. https://doi.org/10.1109/TPWRS.2023.3296080