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ANALYSIS AND PERFORMANCE TEST ON COOLING TOWER

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ABSTRACT
The primary objective of the study is to analyse the aerodynamic loads exerted on the cooling tower through wind analysis. This examination aims to comprehend the impact of aerodynamic forces on the structural integrity and stability of the cooling tower. Furthermore, the study encompasses thermal and fluid dynamic analyses to evaluate the heat dissipating rate from the cooling tower. The research considers the variables of heat exchanger temperature and air mass flow rate to comprehensively understand the heat dissipation process. By varying these parameters, the researchers aim to assess their influence on the efficiency of heat dissipation and optimize the cooling tower's performance. overall, this study contributes to advancing understanding in the field of thermal power generation by providing insights into the aerodynamic behaviour and thermal performance of cooling towers. The findings derived from this research could potentially inform the design and operation of cooling systems in thermal power stations, thereby enhancing their efficiency and sustainability.

Keywords Thermal Behaviour, Aerodynamic analysis, Performance Evaluation, Test analysis Simulation Modelling, Exergetic Analysis.

INTRODUCTION
The work describes a study focused on the utilization of cooling towers in thermal power stations, emphasizing their pivotal role in efficiently managing excess heat generated during electricity production processes. In this investigation, the dimensions of the cooling tower are derived from a research article, with a height of 120 meters and a bottom diameter of 95 meters. The study involves the creation of a geometric model using CATIA software, followed by simulation using ANSYS Fluent software. Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature. Common applications include cooling the circulating water used in oil refineries, chemical plants, power plants and building cooling.
Likewise, an industrial cooling tower operates on the principle of removing heat from water by evaporating a small portion of water that is recirculated through the unit. The towers vary in size from small roof-top units to very large hyperboloid structures that can be up to 120 meters tall and 95 meters in diameter, or rectangular structures. Smaller towers are normally factory-built, while larger ones are constructed on site. They are often associated with power plants in popular culture.
In a typical water cooling, water tower, warm water flows counter current to an air stream. Typically, the warm water enters the top of packed tower and cascades down through the packing, leaving at the bottom R.K. Singla, K. Singh, R. Das, Tower characteristics correlation and parameter retrieval in wet-cooling tower with expanded wire mesh packing, Applied Therm. Eng. 96 (2016) 240–249In this work, an experimental investigation is performed on a counter flow forced draft cooling tower with expanded wire meshed fill as packing material. The

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effect of controlling parameters such as the air and water flow rates on the performance parameters such as the range, water evaporation rate, heat rejection/gain rates, Merkel number, effectiveness and global heat and mass transfer coefficient has been analyzed and correlation is then subsequently developed for the Merkel number as a function of water and air flow rates. Next, an optimization problem is solved to simultaneously estimate the controlling parameters in order to satisfy a given Merkel number using differential evolution. It is found from the present study that many feasible combinations of controlling parameters satisfy a given value of the Merkel number, which may be useful to the operator for regulating desired conditions.

The hyperbolic cooling tower stands tall as an iconic structure in industrial landscapes, embodying efficiency and functionality. Its distinctive hyperbolic shape allows for maximum airflow, enabling the rapid cooling of water used in various industrial processes. These towers are integral to power plants, refineries, and other large-scale facilities, symbolizing the fusion of engineering innovation and environmental sustainability. A hyperbolic cooling tower is a towering structure designed to efficiently cool water used in industrial processes. With its distinctive hyperbolic shape, it maximizes airflow and enhances cooling efficiency, making it a crucial component in many industrial facilities. Cooling towers are essential components of power plants, helping to dissipate excess heat generated during the electricity generation process. By circulating water through the plant's systems and then releasing heat into the atmosphere through evaporation, they play a critical role in maintaining optimal operating conditions for power generation equipment.
A cooling tower Is a specialized heat exchanger that removes waste heat from a system by cooling a water stream to a lower temperature. It's commonly used in industrial processes and HVAC systems to dissipate heat into the atmosphere.

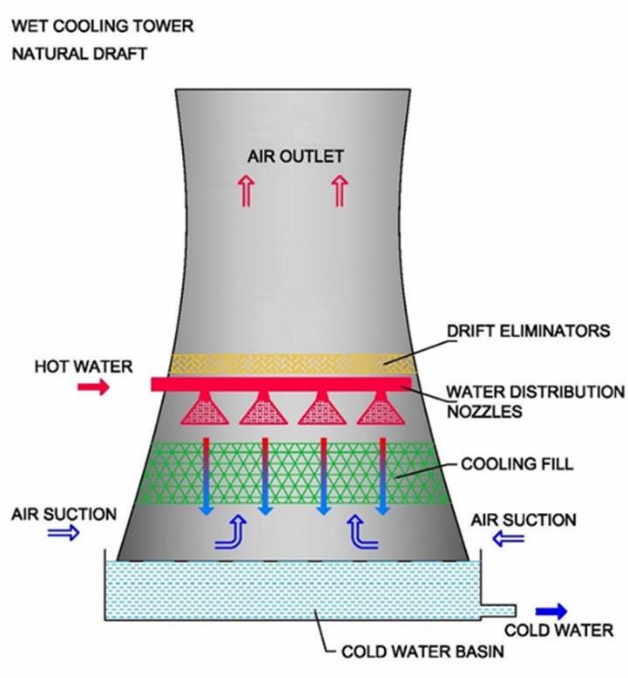

Fig: Cooling Tower

OBJECTIVE

The objective of this project is to enhance the efficiency, reliability, and sustainability of cooling tower systems in thermal power generation. This will be achieved by developing advanced structural designs and materials,

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optimizing heat transfer mechanisms, integrating renewable energy sources to reduce energy consumption and emissions, and deploying smart monitoring and control systems for real-time optimization. These efforts aim to advance cooling tower technology and promote more sustainable and efficient thermal power generation processes.

METHODOLOGY

The simulation software is trending now days in various industries which are mainly construction, shipping, automobile etc. This simulation software is developed by different companies depending on CAD. The companies are choosing and purchasing depending on cost, services and maintenance. But this software can be classified into three categories such as drafting, 3D modelling design and analysis software. In this work, CATIA and ANSYS software are used.

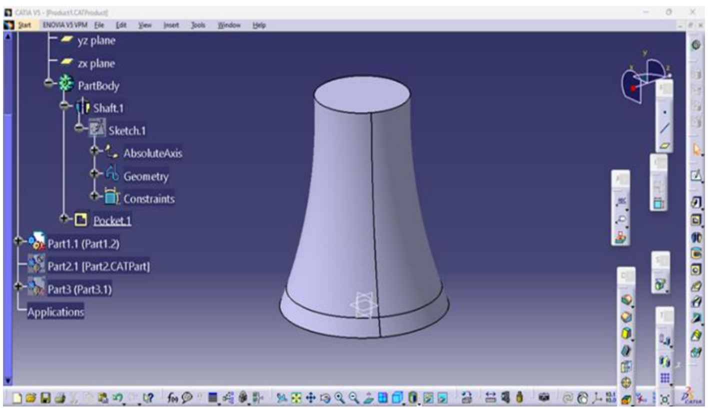
To solve experimentally for fluid flow related problem is a complicated task. To solve such problems, various kinds of sensors are required and at the same time air cannot be seen. But in CFD it is possible. To test experimentally on the air foil, forming geometry is complex work and also to find out the aerodynamic characters such as to detect lift and drag is required many sensing sensors. This will cause huge burden to the companies. So CFD is one of the sources to provide best results.

CFD PROCESS

From the beginning of geometry till gaining results; there are different types of steps included such as

1. Geometry formation related to the current work.
2. Applying meshing to the selected geometry.
3. Defining the materials
4. Choosing type of study either steady state or transient
5. Assigning material properties to cell zones
6. Applying boundary condition at inlet and outlet.
7. Requesting the output reports
8. Initializing the process
9. Run the analysis
10. Gaining output results such as pressure, velocity, lift, drag and moments.

The gathering of dimensions and geometry shapes is a difficult task so the work is depending in real time image. In this sketch module, image is imported. The image is scaled with the original size. Using that image, sketch is developed and converted into 3D model. At wings, more concentration is done because it is the key part of this work.



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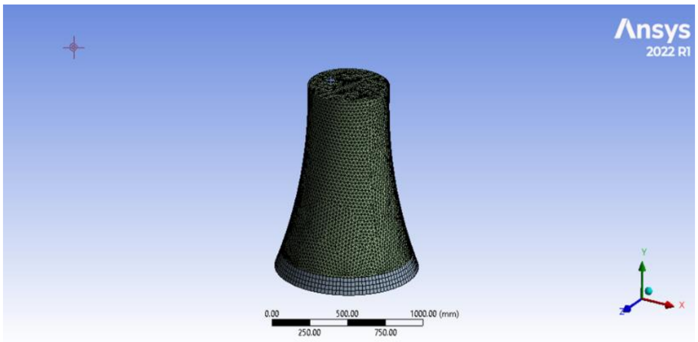
The model work is done is CATIA V5R20 software. Once the model is prepared it is saved as IGES file. Through this format, it is imported in ANSYS. Through this for complex geometry, instead of ANSYS it can be prepared in CATIA. The final model is seen below.

ANSYS DESIGN SOFTWARE

After completing of creating a cooling tower by using CATIA design software Cooling when modelled in modelling software is saved as IGES file format. This file is imported into ANSYS software. A series processing option is selected for the CFD solutions. The domain is planned as rectangle shape around the wing to give concentrated mesh. Near the air foil body a sub-domain is planned. With the help of sub-domain, number of elements is formed at that region. Fine meshing is providing at the geometry shape without any error. Once the geometry is imported, air domain is prepared in sketch model in the ANSYS. This problem is solved through symmetric model so only half of the wing model is considered. The prepared domain is a fluid and tower is solid. To separate them and to remove fluid in tower area, enclosure option is used. The main concentration is on the wing geometry so the wing is suppressed.

Once the domain is prepared, meshing is done. The geometry is complex, so tetrahedron element shape is preferred. The hexagonal shaped meshing provides good results compared to tetrahedron element. And within short time the problem is solved. But the problem is a complicated geometry that is why tetrahedron element is selected. At sub domain region, high density of element is formed and at outside, focus is done on low density element to control simulation time. The main concentration is on the wing boundary area, so in that region fine mesh is planned because of aerodynamic characters will be at that region. The final meshing geometry is shown below.



EXPERIMENTAL SETUP AND CONDUCTING TESTS

Drag force is also an important parameter to design the cooling tower and it should have minimum value always. The force which is resisting the vehicle forward motion is called drag force. In this problem, vehicle forward direction is +y direction. A plot monitoring is planned on car tower toward the –x direction.

The next parameter is pressure intensity on front wing. To gain this, a new scalar is created for wall of tower and results are selected as pressure in P and it was transformed based on symmetric plane to gain the full model from the half model. The velocity streamline plot is gained in this software from the derived parts. Here U and V resolution are taken as 50. The flow is considered from wall of car front wing. Using this, velocity distribution of air after crossing the tower can be seen. The velocity vector plot is gained in this software from the derived parts. A new plane is planned to check the velocity distribution at any required location. Thought this the velocity distribution of air before and after the car tower is known.

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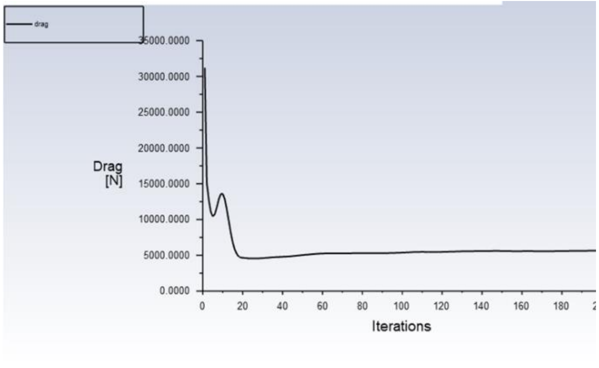
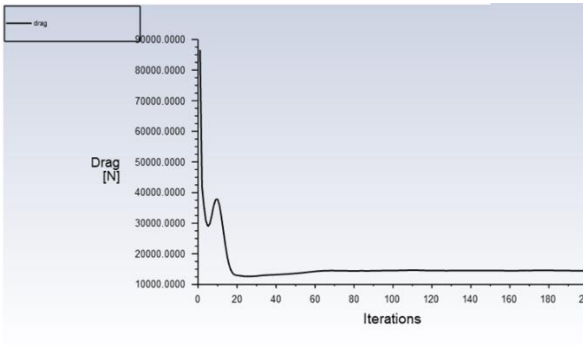
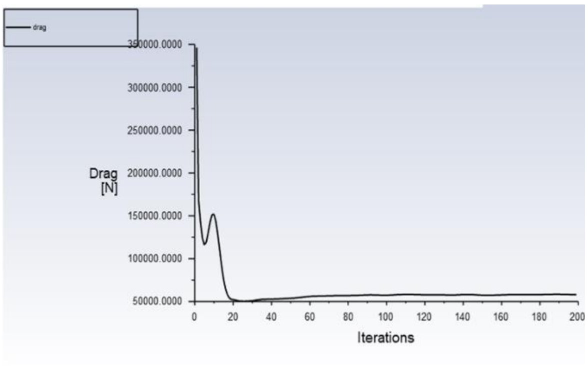


Drag Force plot

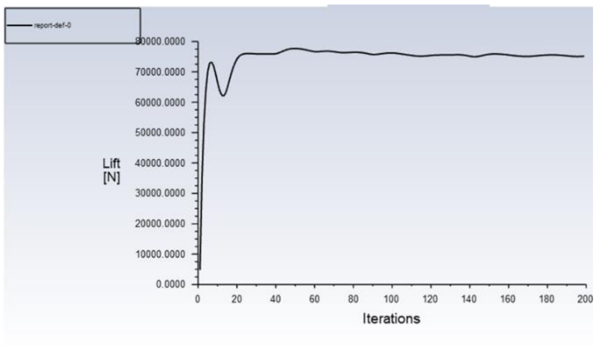


Lift force plot

The above image shows the drag Force plot. In this plot the x axis shows iteration number and y axis shows drag Force. At the starting of the processing time, air is hitting the tower and will create turbulence and a curve fluctuation is observed at the beginning of few iterations. After some iteration, it becomes idle. It continues till the problem is converged. The Force of drag reading 5000N is noted.
The above image shows the Lift force plot. In this plot the x axis shows iteration number and y axis shows Lift force. At the starting of the processing time, air is hitting the wing and will create turbulence and a curve fluctuation is observed at the beginning of few iterations. After some iteration, it becomes idle. It continues till the problem is converged. The coefficient of down reading 20000 N is noted.



Drag Force plot



Lift force plot

The above image shows the drag Force plot. In this plot the x axis shows iteration number and y axis shows drag Force. At the starting of the processing time, air is hitting the tower and will create turbulence and a curve fluctuation is observed at the beginning of few iterations. After some iterations it become idle. It continues till the problem is converged. The force of drag reading 50000N is noted.
The above image shows the Lift force plot. In this plot the x axis shows iteration number and y axis shows Lift force. At the starting of the processing time, air is hitting the wing and will create turbulence and a curve fluctuation is observed at the beginning of few iterations. After some iteration, it becomes idle. It continues till the problem is converged. The coefficient of down reading 80000 N is noted.

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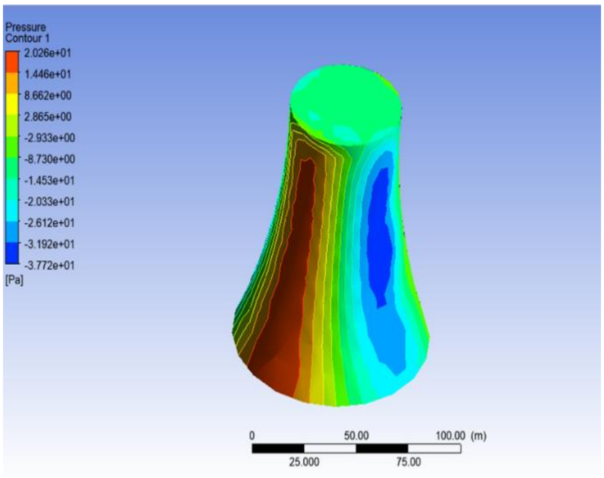

Fig: Pressure acting outside on cooling tower

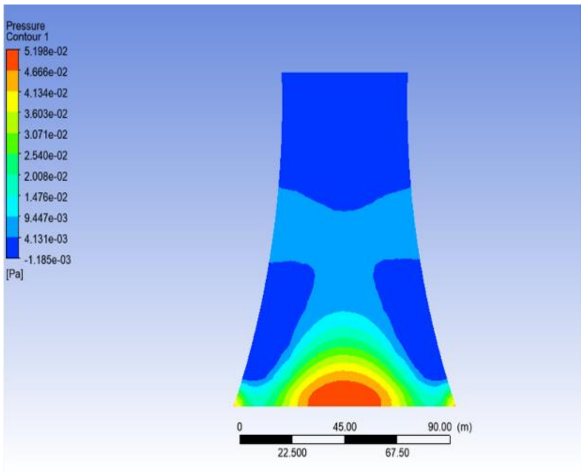

Fig: Pressure inside the cooling tower

These are the above figures tells the pressures acting outside and inside of the cooling cooling tower and after that figure tells us the stream line distribution on cooling tower and the temperature distribution inside the cooling tower.

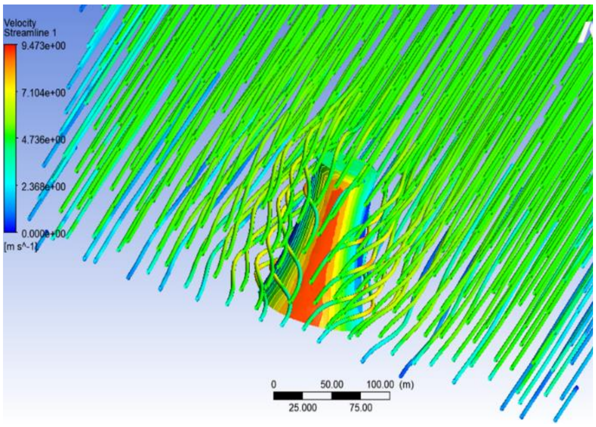

Fig: stream line distribution on cooling tower

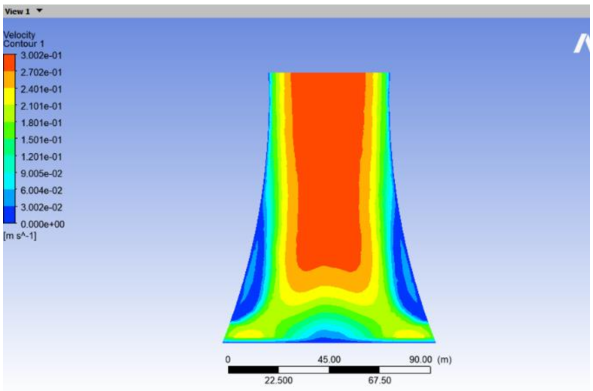

Fig: Temperature distribution inside the cooling tower

RESULTS AND DISCUSSIONS

The findings of these analyses are presented through tabular columns and graphs, offering a comprehensive visual representation of the data collected. These results serve as valuable inputs for engineers and designers, informing decisions related to optimizing cooling tower performance, enhancing energy efficiency, and ensuring operational reliability.

Overall, the integration of modelling, simulation, and analysis tools enables a thorough understanding of cooling tower behaviour under different conditions. This knowledge is instrumental in driving informed decision-making processes throughout the lifecycle of cooling tower projects, ultimately contributing.

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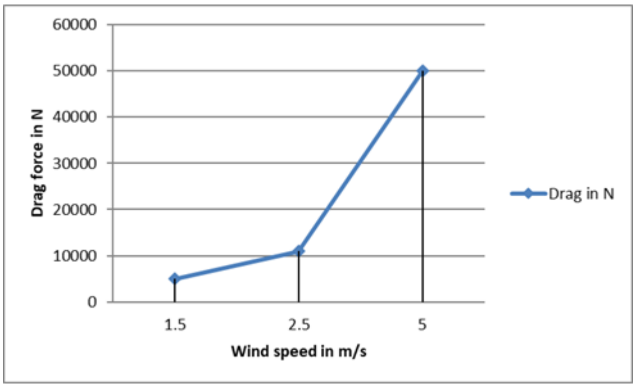


Graph: Drag force with wind speed.

Wind speed in m/s	Drag in N	Lift in N
1.5	5000	7000
2.5	11000	19000
5	50000	75000

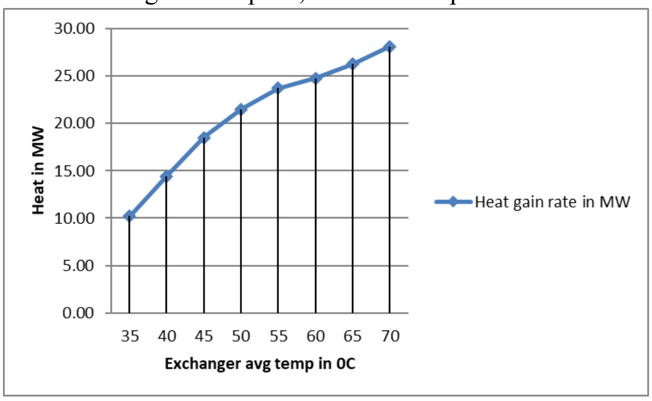
Table: Aerodynamic results for cooling tower

The graph and table provided offer insights into the aerodynamic analysis of the cooling tower, with the Y-axis representing the lift force and the X-axis denoting the air flow velocity. The study encompasses three distinct wind speed conditions: normal, moderate, and high speeds.

The provided graph and table illustrate the results of aerodynamic analysis conducted on the cooling tower, with the Y-axis representing the drag force and the X-axis representing the air flow velocity. The study incorporates three different wind speed conditions: normal, moderate, and high speeds.

Under normal wind conditions, a drag force of 5000 N is exerted on the cooling tower. As the wind speed increases to a moderate level, the drag force experienced by the cooling tower elevates significantly to 11000 N. In scenarios of high wind speed, the drag force peaks at 50000N. Despite the considerable variations in drag force across different wind speeds, the conclusion drawn from this analysis is that the cooling tower exhibits robust structural strength. The drag forces acting upon it, even at high wind speeds, do not appear sufficient to cause damage.

If the average temp of heat exchanger increases, the heat gain also increases. case, the temperature obtained theoretically will always be higher than the experimental Under normal wind conditions, the cooling tower experiences a lift force of 7000 N. As the wind speed escalates to moderate levels, the lift force substantially increases to 19000 N. In instances of high wind speed, the lift force peaks at 75000 N.



Graph: Heat gain rate for different heat exchanger avg temp.

The table presented offers insight into the relationship between the average temperature of the heat exchanger and the corresponding heat gain rate. As depicted, there is a clear correlation between these two variables: as the average temperature of the heat exchanger rises, the heat gain rate also increases.

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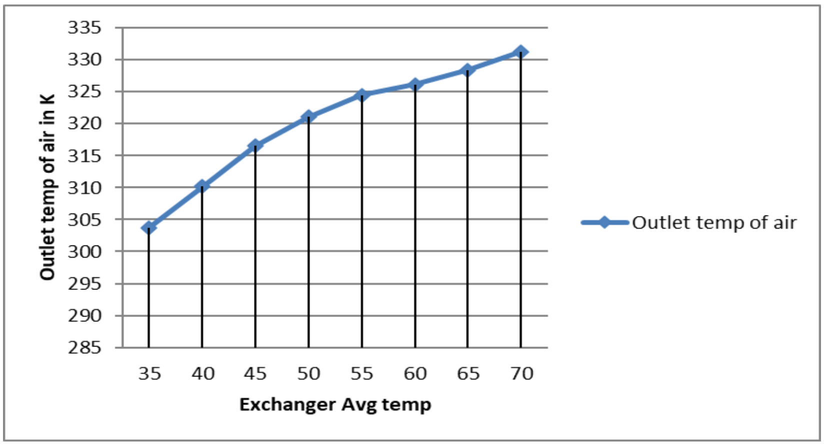
At a temperature of 35°C, the heat gain of the air measures 10.22 MW, while at 70°C, the heat gain increases to 28.12 MW. And the above table represent the heat exchanger average temp and Air outlet temp, in this if the average temp of heat exchanger increases, the outlet temp also increases.

Heat exchanger average temp	Outlet temp of air
35	303.73
40	310.2
45	316.5
50	321.1
55	324.5
60	326.1
65	328.4
70	331.27

Table: Air outlet temp for different heat exchanger avg temp.

Similarly, at an average heat exchanger temperature of 70°C, the outlet temperature of the air increases to 331.2 K. This demonstrates that as the temperature of the heat exchanger rises, the air exiting the cooling tower also experiences a corresponding increase in temperature.

Understanding these temperature variations is essential for assessing the performance of the cooling tower system. By analysing the relationship between the heat exchanger temperature and the resulting air outlet temperature, engineers and operators can make informed decisions regarding the operation and optimization of the cooling tower to maintain desired temperature levels and ensure efficient heat dissipation.



Graph: Air outlet temp for different heat exchanger avg temp.

In the provided graph, the x-axis denotes the average temperature of the heat exchanger in degrees Celsius (°C), while the y-axis represents the cooling tower air outlet temperature in Kelvin (K). At an average heat exchanger temperature of 35°C, the outlet temperature of the air measures 303.7 K. This indicates that the cooling tower effectively reduces the temperature of the air passing through it, as the air exits the tower at a lower temperature compared to its initial inlet temperature.

Similarly, at an average heat exchanger temperature of 70°C, the outlet temperature of the air increases to 331.2 K. This demonstrates that as the temperature of the heat exchanger rises, the air exiting the cooling tower also experiences a corresponding increase in temperature.

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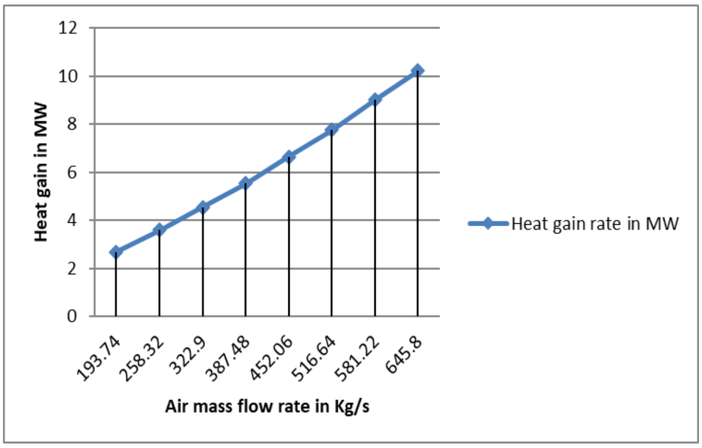

Graph: Air flow rate vs heat gain rate

For instance, at an airflow rate of 193.74 Kg/s, the heat gain is measured at 2.67 MW. Subsequently, as the airflow rate increases to 645.8 Kg/s, the heat gain escalates to 10.22 MW. This observation underscores the direct proportionality between the airflow rate and the heat gain rate within the cooling tower.

This relationship can be explained by considering the mechanism of heat transfer in the cooling tower. The airflow rate influences the rate at which heat is exchanged between the cooling medium (e.g., water) and the surrounding air. A higher airflow rate results in more efficient heat transfer, allowing for greater heat dissipation from the cooling medium to the ambient air passing through the tower. Consequently, as the airflow rate increases, more heat is absorbed by the air, leading to a higher heat gain rate.

Recognizing this correlation is crucial for optimizing the performance of cooling towers in thermal power stations. By controlling and adjusting the airflow rate, operators can effectively regulate the heat dissipation process and enhance the overall efficiency of the cooling system. Moreover, this understanding can inform decisions regarding system design and operational parameters, ultimately contributing to improved energy efficiency and cost-effectiveness in thermal power generation.

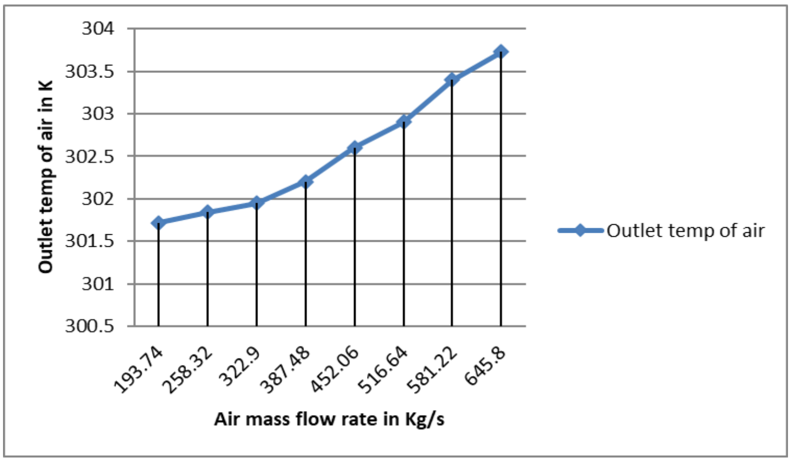

Table: Air flow rate vs Air outlet temp

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CONCLUSION

In Work, the comprehensive analysis conducted on the cooling tower system yields valuable insights crucial for its design, operation, and maintenance across various industrial applications, including thermal power stations. Firstly, the aerodynamic analysis reveals the cooling tower's robust structural strength, even under high wind speeds. Despite significant drag and lift forces acting upon it, the cooling tower demonstrates resilience, affirming its capability to withstand diverse environmental loads.

Secondly, the examination of heat gain rates with respect to changes in the heat exchanger's average temperature underscores fundamental principles of heat transfer. As the average temperature increases, so does the heat gain rate, highlighting the importance of efficiently dissipating excess heat from the system.

Additionally, the airflow rate analysis demonstrates a direct correlation between airflow rate and the table provided offers insights into the relationship between heat gain rate and air outlet temperature at different air flow rates. It is observed that as the air flow rate increases, the heat gain rate also increases. For instance, at an air flow rate of 193.74 kg/s, the heat gain is recorded at 301.72 K. Subsequently, with an increased air flow rate of 645.8 kg/s, the heat gain rises slightly to 303.73 K.

Interestingly, despite the increase in air flow rate, the rise in air outlet temperature is minimal. This finding suggests that while higher air flow rates lead to increased heat gain rates, they do not significantly impact the temperature of the air exiting the cooling tower. This observation underscores the efficient heat dissipation capabilities of the cooling tower system, which can effectively manage higher air flow rates without causing substantial changes in the outlet temperature.

Understanding this relationship is crucial for optimizing the performance of cooling towers in thermal power stations. By comprehending how changes in air flow rate affect heat gain rates and air outlet temperatures, engineers can fine-tune operational parameters to enhance cooling efficiency while maintaining stable outlet temperatures. This knowledge facilitates the design and operation of cooling systems that are both effective and energy-efficient, ultimately contributing to the overall performance and reliability of thermal power generation processes.

Overall, these findings provide essential guidance for engineers and stakeholders involved in cooling tower projects, informing decisions related to structural design, operational parameters, and energy efficiency enhancements. By leveraging this knowledge, cooling tower systems can be optimized to ensure reliable and sustainable performance in thermal power stations and other industrial settings, ultimately contributing to the efficient operation of these facilities and the broader energy landscape.

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