PERFORMANCE ANALYSIS OF FORCED AIR COOLED CONDENSER (ACC) USING FLAT FINS

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ABSTRACT

Air cooled condensers are the best substitute for the water-cooled steam condensers because of decreasing availability of water, growing demand of water for both domestic and industrial use has brought an increased interest in use of Air Cool condenser. ACC is a direct dry cooling system where the steam is condensed inside air-cooled finned tubes. In present research rectangular fins which give maximum heat transfer rate employed over the steam tubes of ACC. Resistance Temperature Detector (RTD) is a positive temperature coefficient device, in which resistance increase with temperature. Platinum is one of the common RTD materials with a temperature coefficient of 0.00385 - 0.003923 Ω/Ω/°C and practical temperature range of - 200° to 600°C and can be extended to 1000°C is used to detect temperature. In presented work analysis is carried over a prototype model of ACC, which results improved heat transfer rate as well as phase change after employing rectangular fins.

1. INTRODUCTION

To condense the steam efficiently by saving specious water improved condenser is needed. In desert region thermal power plants insufficient water is available for evaporative cooling. Heat rejection is accomplished through the use of large air-cooled condenser units in which air is forced against several rows of long individually finned tubes with the help of large fans. The condenser tubes have fins on the outside surface in order to provide a large effective heat transfer surface area. In arid regions in particular, there just isn't enough water available to simultaneously satisfy the needs of power plants and people [1]. Improvement in air-side heat transfer coefficient is expected with reduction in plant cost. To improve heat transfer coefficient it should be needed to circulate the ambient air for condensing the steam, either use fans to move the air or leverage nature's draft [1]. Replacing the circular tubes with rectangular tubes. Deployment of rectangular fin surfaces has been shown to enhance heat transfer through increase area. The usage of rectangular fins instead of circular fins results in reduced form drag and increased tube-surface area for the same cross-sectional internal flow area. By optimizing the shape of the fins, the resulting vortices can minimize the size of the wake region and also improve the heat transfer increased without imposing additional pressure drop and fan power and thus it can beneficially use in thermal power plant.

In present research paper an attempt is made over prototype model to check the performance of forced air cooled condenser with incorporating rectangular fins.

2. LITERATURE SURVEY

For the same amount of heat transfer, the operation of air cooled condensers is more economic as compared with water cooled condensers typically air-cooled condensers are of the round tube and fin type. To improve the performance of air-cooled condensers multiple techniques can be achieved such as enhancements on inner pipe surface, changing the tube geometry from round to flat shape and external fins [2].

In order to achieve the desired rate of heat dissipation, with the least amount of material, the optimal combination of geometry and orientation of the finned surface is required. Among the geometrical variations, rectangular fins are the most commonly encountered fin geometry because of their simple construction, cheap cost and effective cooling capability. Two common orientations of rectangular fin configurations, horizontally based vertical fins and vertically based vertical fins, have been widely used in the applications. However, the horizontal orientation is not preferable because of its relatively poorer ability to dissipate heat [3]. As the availability of water required for wet-cooling systems becomes more limited, modern power plants are increasingly employing indirect dry-cooling towers or direct air-cooled steam condensers to condense steam turbine exhaust vapor. Direct air-cooled condenser units in power plants usually consist of finned tubes arranged in the form of a delta or A-frame to drain condensate effectively, reduce distribution steam duct lengths and minimize the required ground surface area. [4]

The potential of Resistance Temperature Detector (RTD) for the measurement of harsh temperature environments have been discussed. RTD is a positive temperature coefficient device, in which resistance increases with temperature. Platinum is one of the common RTD materials with a temperature coefficient of 0.00385 - 0.003923 Ω/Ω/°C and practical temperature range of - 200° to 600°C and can be extended to 1000°C. Though, Platinum is the primary choice in RTD for most industrial, commercial, laboratory and other critical temperature measurements the other RTD materials used are Copper, nickel and nickel iron alloys. However, platinum is the metal of choice for producing thin film RTDs because of its resistance to oxidation, best accuracy and it has chemical and thermal stability among the common RTD materials. In addition, platinum is the only RTD commonly available with a thin film element style to industrial standards.[5] Many papers reported on the design and development of platinum thin film RTDs and among them few researchers have analyzed the thermal hysteresis effects, thermal strain effects, thin film thickness effects,stagnation temperature [6], degradation effects at high temperature [7] and the long term stability [3, 8] of the platinum RTDs.

3. WORKING PRINCIPLE [1],[9]

The exhaust steam coming from turbine is condensate for reuse purpose as feed water. For this purpose ACC is use, in which steam enter in upper part of main steam tank which is made up of Copper material. To these main steam tank bundles of tube is attached in a parallel manner which is made of copper .To these bundle of tube a rectangular type aluminum fins are attach. Steam coming from the main steam tank to bundles of tube and gets condense into hot water in condensate tank by the forced convention with the help of centrifugal fan which is kept below the bottom of tubes. And finally condensate collected in condensate tank for further feeding to boiler.

4. COMPONENTS USED

4.1 Main steam tank

Steam is directly entering in a main steam tank whose material is Copper, Inlet temperature of steam is 95^0 c, Outer dia. is 06 mm, Inner dia. is 4.4 mm, Wall thickness is 0.8 mm , Thermal conductivity = 385 W/mk. Bronze coupling for the ease in assemble and disassemble of main steam pipe is used.

Fig. 1 Main steam pipe

4.2 Fins

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it [10]. The rectangular fins designed for temperatures less than 300 degrees Fahrenheit. This fin offers a certain degree of atmospheric protection of the tube wall against corrosion. The broad contact surface between the tube (copper) and the fining enhances heat transfer. This fin design is the most economical which results in a slightly higher level of tube corrosion protection and allowable design temperature. This fin is fabricated by forming an aluminum strip in rectangular-shape which is then tension wound around the primary tube. Each rectangular section is positioned against each other to ensure complete tube coverage. Also this manufacturing technology allows the use of relatively thin walled tubes.

Fig. 2 Aluminum Rectangular fins

4.3 Bundle of tubes

The bundles of copper tube are used in the air cooled condenser which is treated under heat treatment process to remove the stress concentration in the tube. Copper material posses high thermal conductivity as k=385kj/kgk. These tubes are located in between the main steam tank and condensate tank with making a slight inclination. These tubes are fixed to main steam tank and condensate tank with the help of T shape brass connector and having diameter of 6 mm (OD).The rectangular fins are attached to these tubes which corroborate to increase the heat transfer area.

Fig.3 Bundle of tube.

4.4 Axial flow fan

Axial fan used here is with marine grade aluminum housings, Flow rates ranges from 875 CFM to 100,000 + CFM. This fan is fully balanced for vibration-free operation blades are of polypropylene composite other specifications are listed below

Fig.4 Arrangement of fan

Table: 1 General specifications of axial fan used

Model No.	A12738V1HBT-55
Outline Dimension	127X127X38mm (5"X5"X1.5")
Rated Voltage	AC 115 V
Rated Current	0.32/0.26A
Power Consumption	24/20 W
Speed	2650/3100 RPM
Max. Airflow	107/123 CFM
Max. Static Pressure	0.33/0.38 INCH-H2O
Noise Level	47/50 dB(A)
Life	C°50,000/hrs at 25
No. of Blade	5 blades
Rotating Direction	Clockwise View From Label Side
Tolerance	± 10% , At Rated Voltage
Weight	562g
Motor Type	Shaded Pole Motor
Operating Voltage	85 to 125 VAC

4.4.1 Housing

Axial Ventilation Fans produced by Delta "T" Systems are specifically designed and built for the rigors of the marine environment - not adapted from other industries. Flanged housings of welded marine-grade aluminum provide lightweight and excellent corrosion resistance. Major assembly hardware is corrosion-resistant stainless steel for long life. An external junction box mounted on the housing exterior is provided for electrical connections.

4.4.2 Motor

High efficiency three-phase and single-phase direct drive-motors are utilized to provide quiet, continuous duty service. Our motors use an aluminum frame and multi-point "spider" or "pad" mounting for corrosion resistance, light weight and enhanced airflow characteristics. Available with "CE" Classification, 50 or 60 HZ, IP68 rating and optional I-EEE-45 Certification, these motors are designed for worldwide applications and can be provided in nearly any voltage configuration. Standard motor sizes from 1/4 HP (.19 kW) to 30 HP (23.4 kW) are available (world class EPAC). Larger motor sizes available on request.

4.4.3 Fan Hubs & Blades

Corrosion-resistant aluminum hubs are secured directly to the motor shaft using multiple locking methods to enhanced safety and reliability. Fan blades are non-corrosive polypropylene composite and are pitch adjustable to allow for a wide range of flows and duties. The high performance airfoil blade shape provides for exceptional flow characteristics and low sound levels. All fans are tested in accordance with AMCA Standard 210. Axial Ventilation fans have a non-overloading characteristic; the peak power input occurs within the range of normal operating pressures and is always exceeded by the motor rating.

5. RTD (RESISTANCE TEMPERATURE DETECTOR)[11]

The most linear, stable, and reproducible temperature sensors are the Platinum RTD, Resistance Temperature Detector. The RTD ís resistancevs temperature characteristics are stable, reproducible, and have a near linear positive temperature coefficient [6].These attributes establish RTDs as a de-facto industry standard. Temperature is determined by measuring resistance and then using the RTD is ‘R Vs T’ characteristics to extrapolate temperature. Typical elements used for RTDs are Nickel (Ni), Copper (Cu), and Platinum (Pt).The most common platinum RTDs are the 100-ohm or 1000-ohm, sometimes referred to as PRTs, Platinum Resistance Thermometers. RTDs have been specified by their value at zero °C “R (0)”, and appositive temperature coefficient ‘alpha’, which is averaged from 0°C to 100 °C. Over the years, both American and

European RTD standards have been developed to ensure that RTDs are interchangeable from manufacturer to manufacturer without any significant loss in accuracy. Platinum has long term stability [7], [11]. Platinum RTDs have been defined by standards such as; DIN 43760 (BS1904), IEC 751-1983, and JIS C1604. These standards specify RTD parameters, which include; R (0), alpha, tolerance classifications, and coefficients in the Callendar-Van Dusen mathematical model of resistance versus temperature.

6. HEAT REJECTION BY AIR COOLED CONDENSER

An Air cooled condenser, is simply a pressure vessel which cools a circulating steam within finned tubes by forcing ambient air over the exterior of the tubes [2]. The air cooled condenser rejects the total heat through a heat exchanger to the ambient air. A fan (s) blows ambient air across the finned coils of the heat exchanger undergoes a phase change converting into liquid within the heat exchanger by rejecting its heat to the ambient air.

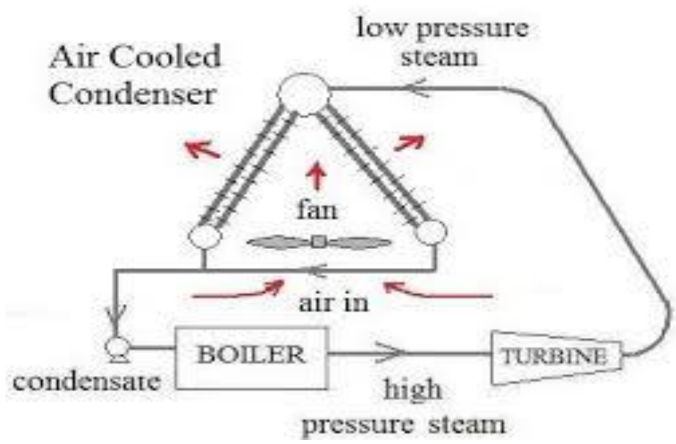

Fig.5 - An air cooled condenser rejecting heat to ambient air [2]

7. CALCULATION

Number of fins used = 120

Mass flow rate is calculated by [12]

$$m=\sqrt{\frac{hP}{kA_c}}$$

Convective heat transfer coefficient h = 1750 W/m^2k

Pressure P = 2(5+3)*10^{-2} = 16*10^{-2}m

Area A = 15 * $10^{-4}$$m^2$

Thermal conductivity k = 385 w/m-k

Mass flow rate m = 22.01

Heat transfer through Conduction [13]

Q for rec. fin = n* {k*A*m*(t_0-t_a)*tan h*(ml)}

For

n = 1, no. of fin

Where, t_0 = 95°C

t_a = 35°C

L = $5*10^{-2}$m

Putting all values, we get

Heat transfer (Q) for 1 fin = 0.613 kw

And similarly, for 120 no. of fins

Q = 120 * 0.613

Q = 73.575 kw

Heat transfer through Convection [13]

Q = h*A*∂T

By putting all the initial terms, we get

$\partial T = t_0 - t_a$

∂T = 60°C

Q = 157.5 watt

Q = 0.157 Kw

Total Heat Transfer = Q conduction + Q convection

Total Heat Transfer= 73.575+0.15

=73.732 kw

Therefore the total amount of heat transfer from ACC is 73.732 kJ per second.

8. RESULT

Heat transfer rate i.e. 73.732 kJ per second obtained, again at the same time phase change occurs and the temperature of the condensate water occurs is well above the temperature of ambient water which is directly read from the RTD i.e. 55^0 CC. This condense water is use as a feed water for boiler to reduce use of fuel and help to improve efficiency of system.

Fig 6. Fabricated Model

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