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Review On Wind Effect And Axial Fan Performance Of Air Cooled Condenser For A Thermal Power Plant

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A B S T R A C T:- *Economic and environmental restrictions have resulted in an increase in the installation of air-cooled condensers (ACCs) in thermoelectric power plants located in arid regions. [7]Air-cooled condensers overcome one of the main issues facing the construction of Thermal power plants by replacing water with air as the medium for cooling of the steam turbine waste heat. [2]Forced flow air-cooled heat exchangers (ACHEs) as found in the petro-chemical, process and power industries use fans arranged in single or multiple fan rows to force air over finned tube bundles.Any flow disturbances or distortions experienced at the inlets of these fans tend to reduce the effectiveness of the ACHE.Air-cooled heat exchangers (ACHEs) which utilize large arrays of axial fans, commonly suffer from inlet flow losses related to off axisflow into the fans. [1] Forced draught air-cooled heat exchangers (ACHEs) are often arranged into banks consisting of multiple rows of fan-heat exchanger combinations. Fans on the outer edge of the banks are subject to severe cross-flow conditions as the air is swept past route to fans located deeper within the banks. The cross-flow conditions give rise to increased inlet flow losses. [3] The losses which are occurs in Axial fans are 'Secondary loss'. The various losses areidentified and a numerical example is given that clearly illustrates the significance of so-called "secondary losses" in a practical air-cooled condenser unit. It is shown that the sum of the "secondary losses" may be of the same order as that of the heat exchanger bundles under normal flow conditions. [1]*

1. INTRODUCTION

As per A.RupeshkumarV.Ramani [13] in the Dry cooling as the availability of water required for wet-cooling systems becomes more limited, modern power plants are increasingly employing indirect dry cooling towers or directair-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. A-frame direct air-cooled steam condenser units are normally arranged in multi-row or multiscreen arrays. Each street consists of three to five main condenser units with a dephlegmator or secondary reflux condenser connected in series. The addition of the dephlegmator increases the steam flow in the main condenser units to such an extent that there isnet flow of steam out of every tube. This inhibits the accumulation of non-condensable gases in the tubes that may lead to corrosion, freezing or areduction in the heat transfer capability ofthe system.
Unlike the thermal performance of wet-cooling systems, which are dependent on the wet bulb temperature of the ambient air, an air-cooled system's performance is directly related to the dry bulb temperature. The ambient dry bulb temperature is normally higher than the wet bulb temperature and experiences more drastic daily and seasonal changes. Although air-cooled systems provide a saving in cooling water, they experience performance penalties during periods of high ambient temperatures.
The use of air-cooled heat exchangers in industrial applications,such as for electrical power generation and chemical processing, has become increasing popular in recent decades due to economic and environmental considerations [6].In direct air-cooled condensers of a power generating unit, theenvironmental natural air replaced the water as the cooling medium. Numerous factors, including the meteorological and the geographic conditions, as well as the atmospheric environment, could affect the performances of the steam turbine unit directly. A series of problems must be taken into consideration to ensure the safe and efficient operation of the air-cooled power generating unit, such as the fouling on the surface of the fin-tube bundles of the air-cooledcondenser exposed to the atmosphere, the hot airrecirculation under the air-cooled island caused by the environmental wind, the high turbine back pressure caused by the extremely high air temperature in summer or the anti-freezing in winter chillness, and the optimal operation of axial flow fan cluster. There had several studies executed to explore the influences on the performances of ACC unit by means of the wind tunnel experiments or the numerical simulations. The experimental investigations to determine the influences of the inlet air flow distortions on the back pressure, and the air flow pressure losses in the air-cooled condensers were introduced either. It was found that the wind speed and direction, as well as the height of ACCs platform had significant impacts on the hot air recirculation. In addition, the performances of air-cooled system werenot only related to the performances of individual fan, but also the quantity and laying mode of the fan cluster [5].The air volume or mass flow rate is directly affected by the performance of the fans. Any flow distortions or disturbances at the entrance to the fans which adversely affect their performance will have a corresponding negative effect on the thermal performance of the air-cooled heat exchanger [2].The current industry standard for dry-cooling in thermoelectric power plants is the A-frame air-cooled

condenser (ACC), which typically reduces a plant's water usage by approximately 99% over that required by a once-through system. The installation of A frame ACCs has increased exponentially in the last 15 years. This has occurred despite the fact that they have been shown to suffer from significant design flaws such as susceptibility to wind effects, air-flow maldistribution, and non-uniform temperature profiles, all of which contribute to reduce ACC effectiveness [7]. Moreworryingly still, however, is the limited ability of current ACC designs to respond to variations in ambient temperature. Studies by both present the degradation in ACC performance as a result of increasing ambient temperature. With increasing in ambient temperature there is decreasing in performance of ACC fan. Deficiencies associated with current ACC designs can result in reduced steam turbine output and hence, a reduction in net plant output. Ultimately, this leads to a loss of operating income. Therefore, in light of these issues with current ACCs, there is significant scope and motivation for improvement in their design if they are to become the pre-eminent cooling strategy for future power-plants [7].

Long banks of ACHEs are, however subject to flow maldistribution at the fan inlets that adversely affects the operation of the axial flow fans which ultimately reduces the cooling capacity of the installation. The inlet flow losses associated with forced draught ACHEs have been the subject of a number of investigations [3].In order to reduce inlet flow losses, the use of bell-shaped fan inlet sections and restriction of the cross-flow velocity component at the fan inlet to less than half of the average velocity through the fan.Duvenhage et al. [8] numerically investigated flow distortions at the cylindrical fan inlets of a long forced draft ACHE consisting of two fan rows. The reduction in volume flow rate through the system associated with a decrease in platform height was successfully modelled. Numerical results showed a trend similar to the experimentaldata of Salta and Kroger [2], despite different geometry and fan inlets used.However, the domain for total power generating units with the environmental factors could be as large as hundreds of meters. It was difficult to obtain the local characteristics of the air-cooled system experimentally. In addition, because of the complex mechanisms of the numerous correlative factors, it was quite difficult to obtain the quantitative influencing degrees on the operating performances of the air-cooled power generating unit by the traditional mathematical models. As an alternative, the influencing factors could be selected from the experimental variables using the grey relational analysis approach, which was a method to analyze the relational degrees for the discrete series, as well as to magnify clarify the relations all factors [5].

P.J. Hotchkiss [4] studied that a reduction in ground clearance would decrease the flow inlet area around the perimeter of the installation, increasing the cross-flow component at the fan inlets. Fans on the perimeter of the array typically experience higher cross-flow velocities, with flow being drawn towards the interior by the inner fans, and are more likely to experience this type of flow-separation inlet loss. He studied that the inlet flow velocities are not as large as those near the edges losses are primarily due to acute off-axis flow into the fan, rather than flow separation. He is also noticed that the fan power consumption is not adversely affected by cross-flow conditions, while the reduction in fan static pressure characteristics may be represented by the dynamic pressure based on the cross-flow velocity component.

J.R. Bredell [9] stated in his paper that Axial flow fans located below an A-frame configuration of finned tube heat exchanger bundles, force a stream of ambient cooling air through the system. In so doing, heat from the condensing steam is rejected to the environment via the finned tubes. Owing to the dynamic interaction between the steam turbines and the ACSC, a change in the heat rejection rate of the ACSC will directly influence the efficiency of the steam turbines. Understanding and predicting the factors or mechanisms that can reduce the heat rejection rate of an ACSC is therefore essential.

Lei Chen [10] giving more attentions to the impacts of the A-frame plume chamber and axial flow fan configurations, as well as the crosswinds on the thermo-flow performances of air-cooled condensers. He stated that the off-axis flow distortion basically results in the performance deterioration of air-cooled condensers in the absence of winds, which is the weakness of the current air-cooledcondenser layout in nature. He also noted that Under windy conditions, this disadvantage of the air-cooled condenser layout becomes moreserious. The thermo-flow performances of the novel air-cooled condensers and the turbine back pressure of power generating units will be investigated and compared with the current air-cooled condensers, which can contribute to the optimal design of air-cooled condensers in power plants. It must be pointed out when ambient winds flow toward the finned-tube bundles, which is opposite to the blowing direction of axial flow fans, the thermo-flow performances of the proposed ACCs may be deteriorated.

According to L.J. Yang and M.H. Wang [11] ambient air is draught by axial flow fans to pass through the finned tube bundles, removing the heat rejection from the exhaust steam, so the ambient conditions, especially wind speed and direction, are the key issues for the thermo-flowperformances of air-cooled condensers. They studied on the performance of trapezoidal array of shell instead of rectangular array of ACC shell.

G. Barigozzi stated in his paper that the power consumption of all auxiliaries must be estimated accurately for any power plant design. While working with the ACC there is additional power requirement for axial fan. Fan performance again depends on many factors.It is necessary to remember that a mechanical draft CT uses fans to provide the required volume of airflow.Their cost is an additional expense to be considered. With respect to a natural draft CT, where the circulation is ensured by the density difference existing between the heated, moist air and the fresh air, the mechanical draft CT can be built with relatively less expensive materials but requires higher operation and maintenance costs. The major problems are associated with fogging and recirculation. However, the risk of recirculation is reduced if the fan is located on the top of the tower, because of the high discharge velocity. Furthermore, pumps with variable speed are required in order to guarantee the most favorable mass flow rate of cooling water. Another issue dealing with the operation of a CT is the

plume formation: when the atmosphere is too cold and humid to absorb the moisture in the exhaust air from the CT, it follows that the excess moisturecondenses and the water droplets become visible.
ZhifuGu andXuerei Chen[14] stated that the ACC platform is usually placed on top of the boiler house to avoid unfavorable wind effects. However, at larger power plants, it is impossible to place the ACC platform on the top of the buildings, due to the large size of the platform and the height of boiler houses. However, the ACC platform must be located close to the steam turbine house to maintain the efficiency of the power plant. He mentioned example of Matimba power plant (6 units of 665 MW each) in South Africa, the ACC platform is located just behind, and at the same height as, the steam-turbine house. This layout is typical of a large power plant using an ACC system. Problems arose at Matimba when the wind came from the direction of the buildings.

2. Factors Affecting Performance of the Air Cooled Condenser

- Wind Break Wall
- Wind Direction and its magnitude
- Diffusion
- Hot air Recirculation
- Plenum Height
- Walk way

2.1 Wind break wall

The effect of the wind and fan performance and recirculation of the hot air in Air Cooled Condenser (ACC) are investigated by Duvenhage and Kroger [17]. Duvenhage and Kroger [17] found that cross wind significantly reduced the air flow rate i.e. volumetric efficiency of axial fans and wind along the longitudinal axis causes increased in the hot plume recirculation as well as also it is responsible for the increase the air temp at the inlet of the axial fans. Royen and Kroger [18] numerically studied that and found that performance of axial fan is reduced due to recirculation of hot plume air by small amount. Wang [19] suggested that to avoid such hot air recirculation to improve the performance of axial fans and hence overall plant. Hotchkiss [20] investigated that the adverse effect of off axis inflow on the fan static pressure rise was attributed that lowered the volumetric efficiency of axial fans (AF). Mayer [3] found that inlet flow losses of periphery fan are dominated by the flow separation occurring around the tip of the AF inlet section. It can be avoided by the walk way at the edge of the AF platform.
Above researchers are show that wind effect on the performance of AF and hence on performance of the overall plant. Which included problems such as plume recirculation effect, tube bundle exhaust air flow, AF performance impact which, are major challenges related to the ACC performance. Some of the investigator suggests using the wind break wall to diminish all above problems and increase the performance of the AF for small amount and numerically proved [21]. But, most of the investigator done numerical solution without taking consideration of the turbine boiler buildings. L.J.Yang [22] suggest wind break wall mounted on the acc platform is considered to effective inn improvement of thermo flow characteristics of the ACC, but when the studies with the turbine and boiler buildings on power plants are carried out wind break wall shows some negative effect on performance of the ACC AF. L.J.Yang, X.Z.Du. [21] Investigated this by numerically model.

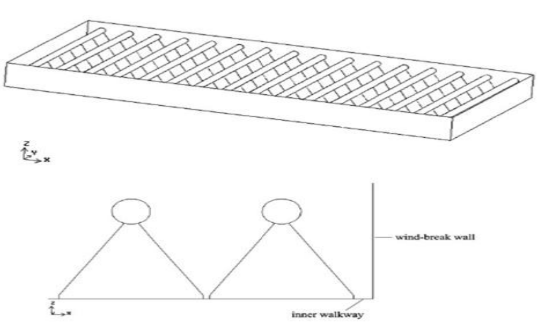

Figure 2. 1ACC Model with wind break elevation

Fig.2-1. shows the schematic of acc model and x, y, z direction receptively on ACC raw side, no fan in one raw, and plenum height from ground. Fig.2-2 Temperature contours and streamlines at a longitudinal cross section containing main building and condenser cell with wind speed of 9 m/s and characteristics direction of 90^0 suggested by the L.J.Yang [21]. It is observed from fig.2-2 That air temperature at upwind condenser cells. And this increase in inlet temperature is responsible for deterioration of the cooling capacity of the air through the upwind condenser cell. Also they [22] suggested it is clear from fig.2-2(a) there is no cooling air found to flow into the upwind condenser cells but the reversed flows from the outlet of the condenser cell to the inlet occurs which is again reducing the cooling capacity of air. L.J.Yang [22] shows from fig.2-2 (a and b) that the hot plume recirculation flow occurring for the condenser cell at the both sides.

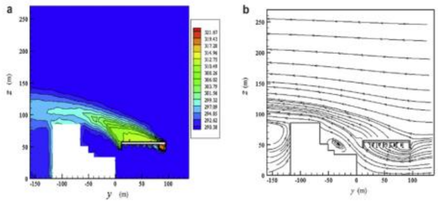

Figure 2. 2Temperature contours and streamlines at a longitudinal cross section containing main building and condenser cells wind speed of 9 m/s and characteristic direction of 900. (a) Temperature contours, (b) Streamlines

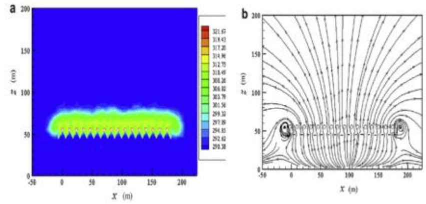

Figure 2. 3Temperature contours and streamlines at a transverse cross sectioncontaining condenser cells with wind speed of 9 m/s and characteristic direction of 900. (a)Temperature contours, (b) Streamlines

Also, from fig.2-3 Conclude that due to recirculation of hot plume there is increased in the inlet temperature of AF. X.Z.Du [21] summarized the above effects and numerically prove that the wind brake wall also effect the performance of the AFs and lowering small amount of performance when hot air plume increase the inlet temperature of the AFs inlet hence reducing the overall plant efficiency.

Xuelei Zhang and Haiping Chen [23] numerically investigate effect of windbreak mesh on thermo flow characteristics of ACC under windy conditions and make comparison between the results of them with different type of mesh.Xuelei Zhang [23] comparing the results of with and without wind break mesh and conclude the same effect which observed by L.J.Yang [21] as shown in fig.2-4 (a and b) and comparing the results it is found that static pressure at AF inlet is reduced and hence the volumetric effectiveness of AF decreases. Haipingchen [23] conclude that another change causing by windbreak wall that is he alleviation of reversed flow or 2-5 vortex flow in condenser cell, fig.2-5(b) clearly shows that reversed flow or vortex flow mainly at periphery AFs only.

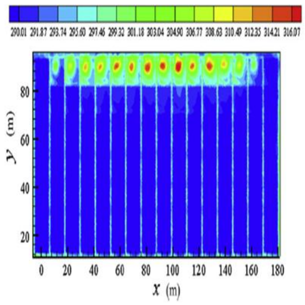

Figure 2. 4Temperature contours at the inlet of axial flow fans with wind speed of 9 m/s and characteristic direction of 90 degree

2.2 Wind direction and its magnitude

Fig 2-5 shows different wind directions for the ACC.The wind from the main buildings to ACC straightly, is mostly refer as the 90 wind direction and the wind coming perpendicular to the 90 wind direction i.e. from ground level to vertically known as the 0 wind direction. Y.P.Yang [24] numerically studied the characteristics for different wind direction.

Both fig. 2-6 and 2-7 are giving comparison for particular wind direction between different wind speeds for every ACC AF. The volumetric flow rate has a clear increase and decay characteristic of the wind effect are conspicuous along the wind direction. For row 1 which is known as upwind condense cell, the volumetric flow rate is very low even negative for some middle columns also. This is lead to poor in ACC performance of AF.

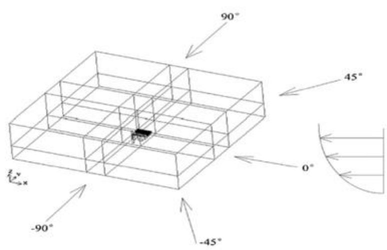

Figure 2. 5Different wind direction and wind angles

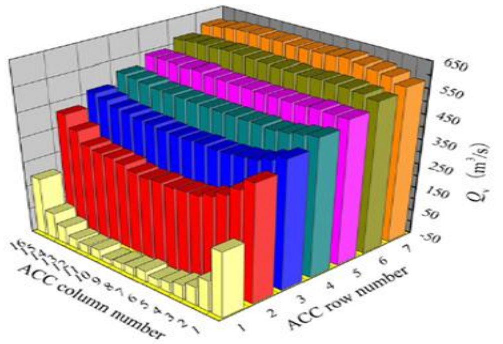

Figure 2. 6Volumetric flow rate of the condenser cells with wind speed of 9 m/s and direction of 90

Now comparing in the terms of the wind speed the with wind speed 3 m/s the variation of these variables for each condenser cell almost same as those for each condenser cell with wind speed 9 m/s. X.Z.Du. [24] Also found that by volumetric flow variation there is the inlet temperature for the for the condenser cells at the both sides of the middle or downstream rows is slightly higher than that in the center of those rows. Its shows the hot plume recirculation flows arise at the both sides of the middle rows. Royen and Kroger [18] agree with the conclusion that increase in inlet air temperature at both sides is deteriorated the thermo flow performance of air cooled condenser are mainly affected from the wind induced volumetric flow rate of AF decrease, but not the hot plume recirculation. And it is clear that wind direction 90^0 results in deficiencies in the thermo-flow performance for ACC AF [24].

2.3 **Diffusion**

X.Z.Du [21] shows the wind effects at different wind angle and different wind speed and concludes that wind effect responsible for the hot air plume recirculation and also increases in air inlet temperature of AF. But other than above two effects Diffusion effect will arise the temperature of the inlet for the windward AFs at low wind speed cases, while the internal fans will also be influenced under operation effect of high wind speeds [27]. Weifeng He studied the diffusion effect in terms of mechanism of the air temperature rise at inlet of AFs of ACC. Fig. 2-7 (a and b) shows temperature contour and the amplified view of the ACC row (Parallel section) at wind direction 0^0 for two different wind speed 2 m/s and 10 m/s. From fig2-8 Dong Han [27] found that the hot air under the windward fans comes from ambient inflow and air temperature rise under the diffusion effect of the hot outflow from the finned tube heat exchanger because of boundary between ambient air and the outflow around wind wall. It is found by Weiufeng He [27] that the ambient surrounded air with the high wind speed will flow together with hot air mass due to strong impact force compared to the case of low wind speed. Ambient air temperature contour amplified vector diagram or the profile at different two speeds is presented in fig 2-8. There is always recirculation found around the lateral columns, which contributes to rise of air temperature at lateral column. It is found that the recirculation of hot plume weakened at higher speed of wind. But with high speed of wind there is forming of small angel between the hot air mass and the horizontal plane at the inlet of ACC AF resulting in rise of air inlet temperature [27]. So the air at the AF inlet heated under the diffusion effect of the hot air around the ACC which lead to weakened heat transfer capacity.

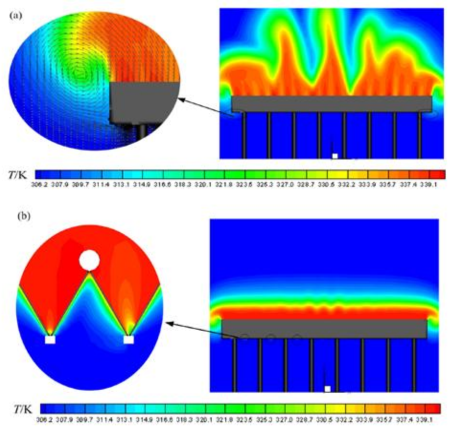

Figure 2. 7Temperature contour for the profile of ACC row (Perpendicular Section) for 00 wind direction with (a) wind speed 2 m/s (b) wind speed 10 m/s

2.4**Hot Air Recirculation**

The hot air recirculation is the factor which was investigated by researchers and found that the hot air recirculation of the hot air leads to increase the inlet temperature of AFs which again leads to lowering heat transfer capacity of ACC which affecting the turbine back pressure and hence whole plant efficiency is affected. So the hot air recirculation is significantly affecting the AFs performance. Hot air recirculation mainly occurs due to wind direction and its magnitude. Obviously some small amount of it occurs due to diffusion effect also observed by Dong Han [27]. Different wind angles how affect the hot air recirculation is presented in the fig2-8. And so the inlets of AFs at the boundary of ACC are suffers from the effect of hot air [13].

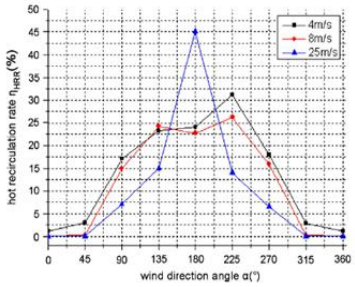

Figure 2. 8The related curve that the hot recirculation rate varies with the wind directions

2.5Plenum Height

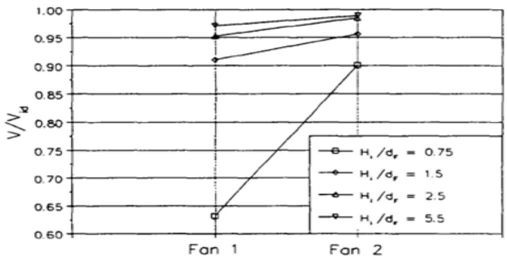

Figure 2. 9Volumetric effectiveness of individual fan units in an ACC having four fan rows

HongfangGu. [30] studied in his presented work about windbreak structure in ACC that plenum height also has impact on the ACC performance for particular static wind condition. Since the several literature shows to avoid the cross wind effect the installation of the windbreak wall is required then the plenum height considerably affect the AF performance. Since windbreak wall decrease the air flow rate for no wind condition or low speed condition, enough space around the platform should be ensured for that the plenum height is helpful [16].

Conclusion

From above review study it is proved that there are serval factors which are responsible for the getting down the performance of the air cooled condenser plan. The above listed factors and its effect are taken from reviewing of such a best researches of some last years. And by effort of this conclusion made is that for improving the performance of ACC one can take care of this all factors.

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