PERFORMANCE EVALUATION AND RECURRING JAMMING PROBLEM ANALYSIS OF AIR PREHEATER IN COAL-FIRED POWER PLANTS

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Abstract - ***Air preheaters make a considerable contribution to the improved overall efficiency of fossil-fuel-fired power plants. It is a heat exchanger that absorbs waste heat from exit flue gas in boiler and transfers the heat to the incoming cold air. In utility boilers it is used to heat the air required for combustion purpose as well as dry and transport coal. Thermal stress deformation is an inherent disadvantage of operating rotary air-preheaters, resulting in the leakage of fluids and a decrease in the efficiency of the preheated system. Leakage can negatively impact mill performance by limiting the amount of available hot primary air. This paper focuses on the recurring jamming problem of a Regenerative type air pre heater (model TZ-NFQI-3-2.2). Based on the results a method for online monitoring of the tightness of the radial seals is proposed.***

Key Words*: Air pre heater, Air leakage, Gas side efficiency, Seals, X-ratio*.

1. INTRODUCTION:

Rotary air preheater is one of the important energy recovery systems in the steam power plant which was first introduced in 1920 by Ljungstrom [1]. The main function is to primarily preheat the combustion air for rapid and efficient combustion in the furnace serving as the last heat trap for the boiler system, a regenerative air preheater typically accounts for over 10% of a plants thermal efficiency on a typical steam generator. Considering this, when evaluating the performance of an air preheater one should take into account all of the process variables.

A very good method to improve the overall efficiency of a thermal power plant is to preheat the air. If the incoming air for combustion is not preheated, then some energy must be supplied to heat the air to a temperature required to facilitate combustion. As a result, more fuel will be consumed which increases the overall cost and decreases the efficiency. There are many factors, which contribute to the deterioration of air preheater performance like high seal leakage, deterioration of heat absorption characteristics of basket elements due to fouling or plugging. When the rotor rotates, air leakages may exist, e.g., entrained leakage. Air leakage consumes extra energy from the fan in the boiler system and decreases the heat exchange efficiency of the air preheater [2]. B.J. Drobnic [3] analyzed the leakage flow through different leak paths; he showed that the leak path from the cool air to the hot flue gas exerted the most significant effect on the heat transfer efficiency. A method for calculating the mass flows of gas through the seals was also introduced [4], and an adjusting method to reduce the seal clearances in radial seals was further presented [5]. Gromovyk and Ivanik [6] determined the thermal stresses and displacements that occur in an elastic hollow ceramic circular cylinder when convective heat exchange occurs.

2. MODE OF HEAT TRANSFER IN APH

The process of heat transfer takes place in APH is Convection, it involves energy exchange between a bulk fluid and a surface or interface. Two kinds of Convective processes exist : (a) Forced Convection in which motion past a surface is caused by an external agency such as a pump or fan, and (b) Natural or Free convection in which density changes in the fluid resulting from the energy exchange cause a natural fluid motion to occur.

The Air Preheater is a regenerative type Rotary heat exchanger uses forced convection in which flue gases and air passes through a rotating cylinder filled with heat transfer surfaces (heating elements).The flue gas heat the rotating elements, which in turn preheat the air before it is re-circulated to the boiler. In the air heater, there is a heat recovery process .As the rotor revolves, the waste heat is absorbed from the flue gas streams and fresh air is heated by the accumulated heat.

3. WORKING PRINCIPLE OF REGENERATIVE AIR PREHEATER

The Regenerative Air Preheater absorbs waste heat from flue gas and transfers this heat to the incoming cold air by means of continuously rotating Heat Transfer Elements of specially formed metal plates. Thousands of these high efficiency elements are spaced and compactly arranged within 24 sector shaped compartments of a radially divided cylindrical shell called the rotor.

The housing surrounding the rotor is provided with duct connections at both the ends, and is adequately sealed by Radial & Axial Sealing members forming an Air Passage through one half of the Preheater and Gas Passage through the other.

As the rotor rotates, it slowly rotates the mass of heating elements alternatively through the air and gas passages. The heat is absorbed by the element surfaces while passing through the hot gas stream, and then as the same surfaces are carried through the air stream, they release the stored up heat to the air, thus increasing the temperature of the incoming air.

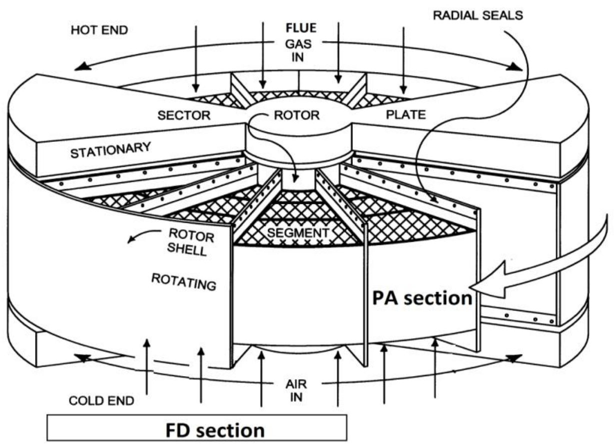

Fig-1: Typical tri-sector RAPH view

3.1 Leakages in rotary heat exchangers:

The basic element of a rotary heat exchanger's operation is a rotating matrix in a compact casing that transfers the heat from the hot flue gas to the cold combustion air. The rotation of the matrix requires an appropriate sealing system to prevent mixing of the flue gas and the air, commonly referred to as leakage.

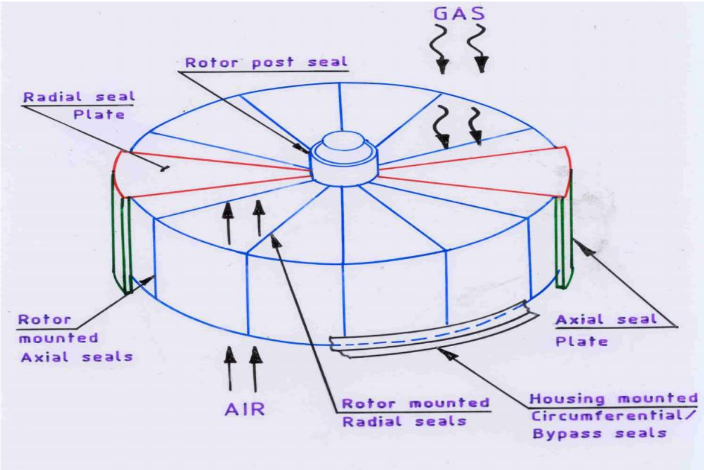

Fig-2: arrangement of seals around the rotor

The above figure shows the schematically shows a typical arrangement of seals around the rotor of a rotary heat exchanger. The seals in Fig. 2 prevent leakage due to pressure differences between certain locations in the heat exchanger.

The Radial seals are located along the edges of the radial division plates and bear against the Sector plates. The Axial seals are located axially along the outer edges of the radial division plates and bear against the axial seal plates. The Circumferential (or Bypass) seals are located in the housing around the periphery of the rotor and bear against the T bar attached to the periphery of the rotor. The Axial seal Plate to Sector plate seals is attached to the Axial seal plates and bear against the Sector plates. The Rotor post seals are attached to the ends of the Rotor Post and bear against the Sector plates.

3.2 Advantages of Seals:

a. Reducing and maintaining low air preheater leakage is vital to minimize the fan horsepower required to move the air and gas flows through the air preheater.
b. It also serves to reduce the dilution effect and corrosion potential of the leaving gas stream due

to mixing with colder air at the air inlet temperature.

c. Seals can wear due to soot blowing, corrosion, erosion, and contact with the static sealing surfaces on start up and/or shutdown.
d. Seal wear and seal settings should be checked at least once per year so that seals can be reset to proper clearances or replaced should they exhibit excessive wear.
e. Sealing plate surfaces may also wear due to contact with the seals and erosion, and they may also become out of level and out of plane.
f. Seal plate wear should also be repaired as soon as detected, and plate alignments should be verified every 3-5 years and reset as soon as the need is detected.

4. AIR HEATER PERFORMANCE:

Table -1: The rotary preheater technical characteristics

AIR PREHEATER	UNITS	@350MW
Flue gas inlet temperature	^{0}C	301
Flue gas outlet temperature	^{0}C	134
Flue gas quantity	t/hr	1063
Temperature of air entering air heater	^{0}C	46
Temperature of air leaving air heater	^{0}C	291
Calorific value of coal	Kcal/Kg	3300

4.1 Effects of leakage :

Air leakage has the largest single drawback on APH performance. Increased auxiliary power consumption, and higher-pressure differentials that can limit combustion air fan operation. Air heater leakage % can be determined using this procedure, which is defined as the weight of air passing from the airside to the gas side of the air heater. This index is an indicator of the condition of the air heater's seals. As air heater seals wear, air heater leakage increases.

The increase in air heater leakage increases the station service power requirements of the forced draft and induced draft fans, increasing unit net heat rate and at times limiting unit capacity.

$$\%\text{ of leakage (AL)} = \left(1 - \frac{\text{Total flue gas entering APH}}{\text{Total flue gas leaving APH}}\right) * 100$$

$$\%\text{ of leakage (AL)} = 1 - \left(\frac{1063}{1104}\right) * 100$$

$$= 3.81\%$$

4.2 Gas Side Efficiency:

Gas side efficiency is an indicator of the internal condition of the air heater. As conditions inside the air heater worsen (baskets wear, ash pluggage, etc), the air heater gas side efficiency decreases. This is generally accompanied by an increase in exit gas temperature and a decrease in air heater air outlet temperature, resulting in an increase in unit heat rate.

$$\text{Gas side Efficiency GSE} = \left[\frac{\text{Temp drop}}{\text{Temp head}}\right] * 100$$

$$\text{Tgnl} = \left\{\text{AL} * \frac{\text{Tgl} - \text{Tae}}{100}\right\} + \text{Tgl}$$

$$\text{Tgnl} = \left\{3.81 * \frac{134 - 46}{100}\right\} + 134$$

$$= 136.74$$

$$GSE = \left[\frac{\text{Tge} - \text{Tgnl}}{\text{Tge} - \text{Tae}}\right] * 100$$

$$\text{GSE} = \left[\frac{301 - 136.74}{301 - 46}\right] * 100$$

$$= 64.41$$

Collected Data:
Tgnl – Gas outlet temperature corrected for no leakage.
Tae – Temperature of air entering air heater = 46 ^{o}c
Tge – Temperature of gas entering air heater = 301 ^{0}c
Tgl – Temperature of gas leaving air heater = 134 ^{0}c

4.3 X-Ratio:

X-Ratio depends on the moisture in coal, air infiltration, air & gas mass flow rates, leakage from the setting and specific heats of air & flue gas. X-ratio does not provide a measure of thermal performance of the air heater, but is a measure of the operating conditions.

$$X - \text{Ratio} = \frac{\text{Gas Side Efficiency}}{\text{Air Side Efficiency}}$$

$$\text{Air Side Efficiency} = \left[\frac{(Tal-Tae)}{(Tge-Tae)}\right] *100$$

$$\text{Air Side Efficiency} = \left[\frac{291-46}{301-46}\right] * 100$$

=96.07

$$X - \text{Ratio} = \frac{64.27}{96.07}$$

=0.668

Collected Data:
Tae – Temperature of air entering air heater = 46 0c
Tal – Temperature of air leaving air heater = 291 0c
Tge – Temperature of gas entering air heater = 301 0c

4.4 Energy saved by APH in a 350 mw Boiler:

Heat energy by flue gas Q_f= M_f*C_f *(T2-T1)$_f$

= (1063x103) x 0.28 (301-134) Kcal/hr

≈48.93 x 106 Kcal/hr

[let us assume Q_f= Q_c for calculating the coal consumption]

Heat energy by burning coal Q_c = Mass of coal used * calorific value

= 48.93 x 106 Kcal/hr= (Mc) x 3300 Kcal/hr

Therefore Mc≈14.524 T/hr

So by using APH in boiler approx. 15T/hr coal is saving.

5. RECURRING JAMMING PROBLEM IN APH

Failure analysis:

During unit is running at elevated loads the heating elements called modules will gain high amount of heat and causes thermal expansion whereas casing at flue gas side and air side will differentially elongate because of temperature difference. Thus the clearance maintaining between the casing and module outer diameter is high at flue gas flow path comparatively air flow path. At this juncture there may be problem of jamming at air side. Due to this current dragging by the Electric motor is comparatively high from normal operation. Abnormal sounds coming from the APH.

Remedial measures to avoid recurrence of the problem:

Adjust the Axial seal at the air flow section so the clearance can be increased to the desire level and also adjust the radial seals to accommodate the thermal expansion taken place in the rotor as the allowable expansion of APH rotor is given in vertical direction.

If rotor comes into stand still condition go for manual turning and try for taking air motor into service.

6. OPERATION AND MAINTENANCE

a) Check whether the bearing lubricating oil pressure is between 0.33 and 1.6 MPa, the oil level is normal and there is no leak in system. Adjust the water outlet valve of air cooler to make the oil temperature between 30℃～40℃ and the differential pressure of oil filter is lower than 1.3 MPa.

b) Check and make sure that there is no abnormal sound in the air pre-heater and gear device.

c) Change oil of guide bearing oil system at least once a year.

d) The reducer box cannot leak in the operation. In continuous working, the working oil temperature shouldn't be higher than 80℃. Make working oil test after it is running for 3000 hours and change oil when necessary Leakage in the preheater can be checked during operation by analyzing flue gas for CO, drop across the air preheater.

e) Make frequent inspection and analysis on the oxygen quantity, flue gas and air temperature, air differential pressure and flue gas temperature difference at inlet and outlet of air pre-heater to determine the leak or dust block of air pre-heater and judge whether re-combustion occurs. Make inspection on air pre-heater if the temperature of any point rises by 10℃ abnormally.

7. CONCLUSION

Due to the differential thermal expansions between the casings and the heating elements, the clearances maintaining between the casing and module outer diameter is vary at different sections of APH. At this juncture there may be problem of jamming at air side. Adjust the Axial seal at the air flow section so the clearance can be increased to the desire level and also adjust the radial seals to accommodate the thermal expansion taken place in the rotor as the allowable expansion of APH rotor is given in vertical direction. This reduces the air leakage and max efficiency can be obtained.

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ACKNOWLEDGEMENT

The authors would like to thank GMR KAMALANGA ENERGY LIMITED, DHENKANAL (dist), ODISHA, INDIA for the technical support of this work.

BIOGRAPHIES

Mr. M. Srinivasarao received his B.Tech degree from GMR institute of Technology in 2011 and M.Tech from GMR institute of Technology in 2015.