A STUDY OF HEAT EXCHANGER-ROTARY AIR PRE-HEATER

MAHALAKSHMI SIDDI
M. Tech Student
Department of Mechanical Engineering
Astral College of Technology & Research
Indore, India

PANKAJ AHIRWAR
Head of Department
Department of Mechanical Engineering
Astral College of Technology & Research
Indore, India

Abstract**:** Ljungstrom Air Pre-Heater is a regenerative type of heat exchanger used for preheating the combustion air, mainly in thermal power plant. The warm gas and cool air ducts are arranged to allow both the flue gas and the inlet air to flow simultaneously through the air preheater. The hot flue gas heats the rotor material and as the rotor rotates, the hot rotor section moves into the flow of the cold air and preheats it. The air pre-heater is not essential for operation of steam generator, but they are used where a study of cost indicates that money can be saved or efficient combustion can be obtained by their use. The decision for its adoption can be made when the financial advantages is weighed against the capital cost of heater in the present paper we have taken up the operation and performance analysis of ljungstrom air preheater 33.5v at 2110 (720) of 2x660 MW capacity NTPC Thermal Power Plant, Khargone, M.P. In analysis of performance preventive measures for corrosion of heating elements has been studied, and also air heater leakage, corrected gas outlet temperature and finally gas efficiency has been calculated. In comparison of ljungstrom & rothemuhle type air pre-heaters found that ljungstrom air pre-heater having better performance.

Keywords— Rotary Air Preheater, Ljungstrom With Rothemuhle Air Preheater, Efficiency module.

1. INTRODUCTION

A heat exchanger is a device used to transfer heat between two or more fluids. The fluids can be single or two phase and, depending on the exchanger type, may be separated or in direct contact.

The rotating-plate air preheater (RAPH) consists of a central rotating-plate element installed within a casing that is divided into sectors. There are three basic designs for the rotating-plate element.

1. The bi-sector design has two sectors.
2. The tri-sector design has three sectors.
3. The quad-sector design has four sectors.

Working Principal: The Rotating-Plate Air Pre-heater (RAPH) consists of a central rotating-plate element installed within a casing that is divided into sectors. There are three basic designs for the rotating-plate element

1. The bi-sector design has two sectors.
2. The tri-sector design has three sectors.
3. The quad-sector design has four sectors.
4. As the name implies the tri-sector pre-heater design has three sections. Use for flue gas. One for primary air (used for drying and transport of coal through mill to the burner) another for secondary air (additional air for combustion around the burners).
5. These helps in avoiding wastage of heat pick up by air due to primary air flow and help in selecting different temperatures for primary air and secondary air. Whatever is not utilized in primary air can be picked up by secondary air stream.
6. Thousands of these high efficiency elements are spaced compactly arranged with in 12 sectors shaped compartments for heater size from 24.2 to 27 inches, and 24 sector shaped compartments for heater size from 28 to 33 of radially divided cylindrical shell called the rotor.
7. The housing surrounding the rotor is provided with duct connections at both ends and is adequately sealed by radial and axial sealing members forming an air passage through one half of the pre-heater and a gas passage through the other. As the rotor slowly revolves the mass of the elements alternatively through the air and gas passage, heat is absorbed by the element surfaces passing through the hot gas stream.
8. These are the same surfaces are carried through the air stream. They released the stored up heat thus increasing the temperature of the incoming combustion or process air.
9. The Ljungstrom air pre-heater is more widely used than any other type of heat exchanger for comparable service. The reasons for this world wide acceptance are its proven performance and reliability, effective leakage control, and its adaptability to most, any fuel burning process. It is both designed and built to operate

over extend periods with durable, uninterrupted service. Simplicity of design also makes it easy and economical to maintain while in operation and at scheduled outages.

Salient Features of RAPH: This application for over fifty years. The Howden Air Pre-heaters are designed around external insulation. The housing and ducts are structurally independent of the rotor. Finite element analysis has been used in the generic design of the rotor which is free to expand in all directions such that thermally induced stresses are kept to a minimum during all modes of operation. Centre column or bottom girder support Custom designed and optimized to suit arrangement and client preference.

Sealing system: The sealing system has evolved to have static sealing surfaces set to achieve minimal gaps with the moving seals at operating conditions combined with labyrinth multiple seals. The Howden VN sealing concept maintains low design leakage between outages. Where the application requires Hot End actuated sector plates, advanced systems are available.

Centre drive system with inverter speed control: The shaft mounted center drive employs a high ratio gearbox with the option of multiple electric motors and an air motor. The drive system is completely removed from inside the air preheater and doesn't require the time-consuming installation and outage replacement of pin racks.

Low maintenance: Conceptual and detailed design targets the achievement of simplicity and minimal maintenance. Fixed sealing surfaces and centre drive greatly reduce maintenance by removing actuators and pin racks.

Standard spherical roller bearings with oil bath lubrication: Standard proprietary rolling element bearings with bath lubrication using extremely high viscosity oil have been used by Howden in cooling systems are employed at the hot end bearing.

High availability: The major cause of reduced availability in air pre-heaters is due to element fouling. Careful element selection to suit the application, cold end temperature control and the use of the correct cleaning system maintains very high availability.

Cleaning systems: Unlike tubular or plate recuperative heat exchangers, fouling does not cause deterioration in heat transfer in a rotary regenerative heat exchanger. Fouling increases pressure differentials and consequently fan power and leakage. Several proven cleaning systems are available to suit the degree of fouling and space restrictions, including:

i. Semi retractable steam soot blowers
ii. Fully retractable multi-fluid (air/steam and LP & HP water) soot blowers
iii. Semi retractable HP water washing

APH Performance Indices:

1) **Leakage:** Weight of air passing from air side to gas side (Gas Out Flow – Gas in Flow)
2) **Air Temp Rise:** Increase in temp of air in passing through the AH = Tao-Tai
3) **Gas Temp Drop:** Decrease In Temp of Gas in passing through the AH = Tgi-Tgo
4) **Temp Head:** Temp of gas entering minus temp. of air entering AH=Tgi-Tai
5) **Gas side efficiency:** Ratio of gas temp drop to temperature head.
6) **Air side efficiency:** Ratio of air temp rise to temperature head.
7) **X-Ratio:** Ratio of the heat capacity of air passing through the AH

Testing: For evaluating the performance of air pre-heaters, just making a single point measurement of temperature and O2 is not sufficient. The performance test is to be conducted as per test code 2ASME PTC 4.3. This exact testing will be useful in finding solutions for improvement.

Improvements: To make successful air pre-heaters availability and efficiency improvements during plant outage, equipment inspection and evaluation studies of the operating parameters is necessary. Every air pre-heater is unique in design and operation environment. Efficiency improvement studies of a rotary air pre-heater consists typically of an expert site visit during shut down, for the purpose of thorough inspection and gathering pertinent data Report dealing inspection results, recommendations, potential performance improvement and estimated cost implementation. Once the plant is convinced of the improvements, effort should be taken for the implementation of the accepted suggestions in the immediate available opportunity. Experience shows that in air pre-heaters, the improvements leads to a short payback period. Hence it is worth to implement the improvements.

Plant Enhancement: With the growing demand for enhanced performance and life extension of plant, Howden has the engineering expertise and experience to provide cost effective site solutions. Our research and development coupled with long standing links with specialist suppliers, enables us to improve the performance of our own products as well as that of equipment supplied by other manufacturers.

Upgrading or enhancing an air pre-heater is usually one of the most cost-effective ways of improving boiler performance. Dramatic results can be achieved by either increasing thermal performance or reducing leakage. Before retrofitting FGD and/or plant downstream of the boiler, it is always worth investigating air pre-heater leakage, which can create unnecessary demands elsewhere in the system. Improving the air pre-heater sealing system can significantly reduce the size and cost of the FGD plant, with obvious cost savings.

The use of Selective Catalytic Reduction (SCR) equipment also makes special demands on rotary regenerative heaters that greatly benefit from specific adaptations to help them cope with the more arduous fouling environment. In many cases, heat recovery can be increased by installing higher performance elements, or increasing their overall depth, or both. Leakage reduction can make significant savings in fan power consumption. Each retrofit project is based on a thorough analysis of the prevailing situation as well as a concise determination of the target performance.

2. THEORETICAL FORMULATIONS

Calculations of Ljungstrom air pre-heater: The method determines air pre-heater as per this procedure is the volumetric method this is an empirical approximation of air heaters leakage with an accuracy of + / - 1%.

Air Leakage:

Air Leakage = {(O2gl – O2ge)/(O21ge– O2gl) }*0.9* 100

______________ eq. (1)

GAS SIDE EFFICIENCY:

$$T_{gnl} = \left[AL \times C_{pa} \frac{(T_{gl} - T_{ae})}{(100 \times C_{pg})} \right] + T_{gl}$$

____________________eq. (2)

Air heater Gas side efficiency:

$$\text{Gas side efficiency } GSE = \left[\frac{(T_{ge} - T_{ngnl})}{(T_{ge} - T_{ae})} \right] \times 100$$

____________________eq. (3)

Air Side Efficiency:

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})} \right] \times 100$$

____________________eq. (4)

X-Ratio:

X-Ratio= Gas Side Efficiency / Air Side Efficiency

____________________eq. (5)

Pre heater Primary Air side efficiency:

$$\text{Primary Air side efficiency} = \left[\frac{(T_{ge} - T_{ae})}{(T_{ge} - T_{ae})} \right] \times 100$$

____________________eq. (6)

Calculations of Rothemuhle Air Pre-Heater: Collected data:

Air Leakage:

Air Leakage = {(O2gl – O2ge)/(O21ge– O2gl) }*0.9* 100

______________ eq. (7)

Gas Side Efficiency:

$$T_{gnl} = \left[AL \times C_{pa} \frac{(T_{gl} - T_{ae})}{(100 \times C_{pg})} \right] + T_{gl}$$

____________________eq. (8)

Air heater Gas side efficiency:

$$\text{Gas side efficiency } GSE = \left[\frac{(T_{ge} - T_{ngnl})}{(T_{ge} - T_{ae})} \right] \times 100$$

____________________eq. (9)

Air Side Efficiency:

$$\text{Air Side Efficiency} = \left[\frac{(T_{al} - T_{ae})}{(T_{ge} - T_{ae})} \right] \times 100$$

____________________eq. (10)

X-Ratio:

X-Ratio= Gas Side Efficiency / Air Side Efficiency

____________________eq. (11)

Pre heater Air side efficiency:

$$\text{Primary Air side efficiency} = \left[\frac{(T_{ge} - T_{ae})}{(T_{ge} - T_{ae})}\right] \times 100$$

____________________eq. (12)

3. NUMERICAL STUDY AND DISCUSSION

Calculations of Ljungstrom air pre-heater:

From eq. (1)
Air Leakage AL = {(13–10) / (21–13)} * 0.9 * 100 = **33.75%**

Collected Data:

AL – Air heater leakage

O2ge – Percentage of O2 in gas entering air heater: 10

O2gl – Percentage of O2 in as leaving air heater: 13

Secondary air (SA) leaving air heater = 308.5°c

Primary air (PA) leaving air heater = 317.9°c

From eq. (2)
Tgnl = [(33.75*1.023 *(123-42)/(100*1.109) +123=**148.21°C**

Collected Data:

Tgnl – Gas outlet temperature corrected for no leakage.

Cpa – The mean specific heat between temperature

Tae and Tgl = 1.023 KJ / kg °k

Cpg - The mean specific heat between temperature

Tgl and Tae = 1.109 KJ / kg °k

Tae – Temperature of air entering air heater = 42°c

Tge – Temperature of gas entering air heater = 341°c

Tgl – Temperature of gas leaving air heater = 123°c

From eq. (3)
Gas side efficiency = [(341-1480/(341-42)] x 100=**64.4%**

From eq. (4)
Air side efficiency = [(317.9-42)/(341-42)]x 100 =**92%**

Collected Data:

Tae – Temperature of air entering air heater = 40°c

Tal – Temperature of air leaving air heater = 302°c

Tge– Temperature of gas entering air heater = 331°c

From eq. (5)

X-Ratio = (64.4)/(92) = **0.7**

From eq. (6)
Primary air side efficiency = [(341-154.32)/9341-51)] * 100 = **64.37%**

Calculations of Rothemuhle Air Pre-Heater:

From eq. (7)
Air Leakage AL=[(9-4)/(21-9)] x 0.9 x 100 =50%

From eq. (8)

$$T_{gnl} = \left[AL \times C_{pa} \frac{(T_{gl} - T_{ae})}{(100 \times C_{pg})}\right] + T_{gl}$$

$$T_{gnl} = \left[\mathbf{50} \times 1.023 \times \frac{(\mathbf{186\text{-}45})}{(100 \times 1.109)}\right] + \mathbf{186} = \mathbf{251.03^{o}c}$$

Collected Data:
Tgnl– Gas outlet temperature corrected for no leakage.
Cpa – The mean specific heat between temperature
Tae and Tgl = 1.023 KJ / kg °k
Cpg - The mean specific heat between temperature

Tgl and Tae = 1.109 KJ / kg °k

Tae – Temperature of air entering air heater = 45°c

Tge – Temperature of gas entering air heater = 341°c

Tgl – Temperature of gas leaving air heater = 186°C

From eq. (9)

Gas side efficiency = [(341-251.03) / (341-45)]*100 = **30.39°C**

From eq. (10)

Air side Efficiency= [(302-45) / (341-45)] * 100 = **86.82%**

From eq. (11)

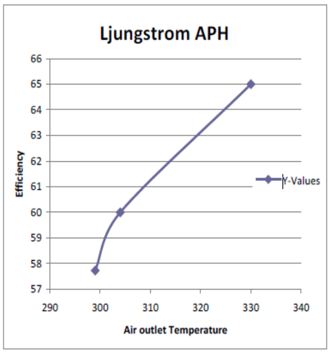
X-Ratio = (30.39)/(86.82) = **0.35**

From eq. (12)

Primary air side efficiency = [(341 – 251.05)/341-45)] * 100 = **30.38%**

From this comparison air leakages in Rothemuhle are higher than Ljungstrom and air side, gas side efficiencies are less in Rothemuhle.

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT (IJSREM)
VOLUME: 03 ISSUE: 08 | AUGUST -2019 ISSN: 2590-1892



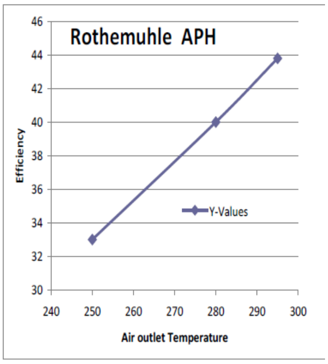


Fig. 1 Pre heater Air side efficiency

4. CONCLUSIONS

As per collected data, air pre heaters, leakages & performances are calculated. From this comparison air leakages in Rothemuhle are higher than Ljungstrom and air side, gas side efficiencies are found less in Rothemuhle. The broad conclusions that can be made from the present study are summarized as follows:

1) By comparing Rothemuhle with Ljungstrom air leakages are more; gas side efficiency and air side efficiencies are less in Rothemuhle air pre-heater.
2) The Thermal performance of the Ljungstrom air pre-heater is better than Rothemuhle.
3) After leakages reducing in Ljungstrom by replacing VN seal plates & on time purging & proper maintenance.
4) The Thermal performance of the air pre-heater is improved.
5) Load on the fans are reduced thus power consumption is reduced and cost is reduced.
6) Fuel consumption is also reduced, thus fuel is saved and cost is reduced.

5. FUTURE SCOPE OF DISSERTATION

The use of Selective Catalytic Reduction (SCR) equipment also makes special demands on rotary regenerative heaters that greatly benefit from specific adaptations to help them cope with the more arduous fouling environment. In many cases, heat recovery can be increased by installing higher performance elements, or increasing their overall depth, or both. Leakage reduction can make significant savings in fan power consumption. Each retrofit project is based on a thorough analysis of the prevailing situation as well as a concise determination of the target performance.

6. REFERENCES

1) STI Group broucherpp "front page" edition 12th july 2014|setxind| downstream/industrial-heat-exchangers|
2) sistemas.eel.usp.br|docentes/arquivos|5817712/LOQ4086|saari/ "heatexchangrdimensioning" .pdfpage:16-23
3) "Mechanics, Materials Science & Engineering", December 2017 – ISSN 2412-5954
4) Romina Ronquillo/ "understanding-heat-exchangers"/ page 1-10/thomasnetarticles,process-equipment.
5) Jennifer Mayo/ "criteria-for-selecting-a-heat-exchanger"-for-your-process/ Jan 29, 2015
6) P. Rodriguez Director, Indira Gandhi Center for Atomic Research Kalpakkam, India/ "Selection of Materials for Heat Exchangers"/ HEB 97, Alexandria , Egypt Apri l 5-6, 1997
7) Larsen And Toubro Erection Manuals for "Rotary Air PreHeater", Vol 1, page 50-70.
8) Larsen and Toubro Howden,U.K brochure on "Air preheaters"
9) Manivel .J, Manimaran .L, Thiyagarajan .M, Satheeshkumar .P; "Performance Analysis of Air heater,International journal of Advance research ideas and Innovations in technology"| ISSN:2454-132X|Impact factor:4.295 Volume3,issue2.
10) Larsen And Toubro O & M Manuals for "RotaryAirPreHeater", Vol 2, page 1130-1150.
11) M.Srinivasa Rao, performance evaluation and recurring jamming problem analysis of "air preheater in coal-fired power plants", International Research Journal of Engineering and Technology (IRJET),Volume: 02 Issue: 05 | Aug-2015
12) B.J.Drobnic," A numerical model for the analyses of heat transfer and leakage in a rotary air preheater", International Journal of Heat and Mass Transfer 49 (2006) 5001-5009.
13) Dr.TK.Ray presentation in NTPC seminar in the year 2013 annual meeting.
14) cDriscoll, J.M. et. al, "ASME Performance Test Codes Test Code for Air Heaters", USA, 1968.
15) Larsen And Toubro O & M Manuals for "RotaryAirPreHeater", Vol 2, page 1301-1350.
16) Dr.TK.Ray presentation in NTPC seminar in the year 2013 annual meeting.
17) APH broucher by GEECO Enercon pvt ltd
18) Larsen and Toubro Howden,U.K brochure on "Air preheaters".