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# NUMERICAL ANALYSIS OF ROTARY AIR PREHEATER: A REVIEW

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**Abstract** - ***The Ljungstrom air preheater is a regenerative type heat exchanger used for preheating the combustion air, mainly in steam power plant. The warm gas and cool air ducts are arranged to allow both the flue gas and 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. If the incoming air is not preheated, then some additional energy must be supplied to heat the air to a temperature required to facilitate combustion. Due to this, more fuel will be consumed which decreases overall efficiency of the power plant. In this paper different techniques used to optimize the process parameters of rotary regenerator are discussed.***

***Key Words:*** *Rotary air preheater, Preheater performance, Element profile*

## 1. INTRODUCTION

Air preheater is the device used to heat the air supplied for the combustion with the help of hot flue gases. The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the heat lost in the flue gas. As a result, the flue gases are conveyed to the chimney at a lower temperature, allowing simplified design of the conveyance system. It also allows control over the temperature of gases leaving the chimney to meet the emission regulations.

There are two types of air preheater in thermal power stations. In recuperative air preheater the heat exchange between the carrier and the air to be heated takes place continuously through the walls of the heating surface that separate them. In regenerative air preheater the heat exchange is accomplished by the alternate heating and cooling metallic or ceramic fixed or rotating surfaces of the preheater.

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]. Warren published his studies on Ljungstrom air preheater and base on the experimental results confirmed a minimum reduction of 10% in power plants fuel consumption [2].

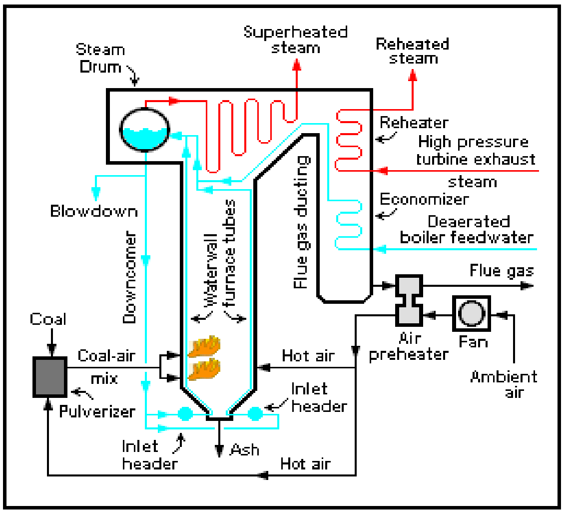

**Fig -1**: Layout of steam power plant

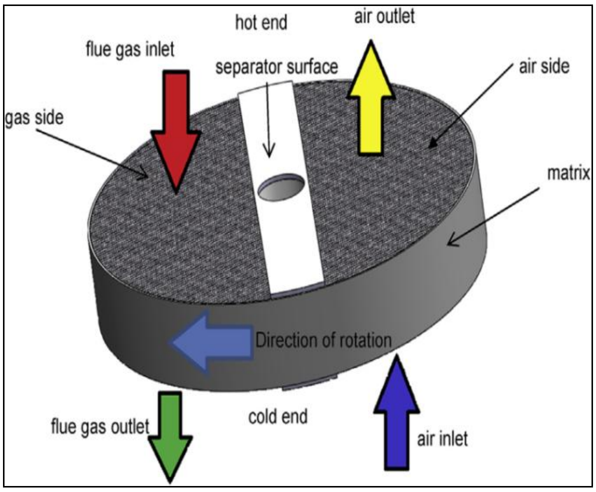

**Fig -2**: A view of rotary air preheater

## 2. FLUENT SOFTWARE

Armin Heidari-Kaydan, Ebrahim Hajidavalloo investigated RAH in 3-D and treating it as a porous media [3]. They presented temperature distribution for different conditions. They discussed effect of parameters such as rotational speed of the matrix, fluid mass flow, matrix material and temperature of the inlet air on the performance of the preheater. To simulate flow and heat transfer, Navier-stoke equations are used. To solve Navier-stoke equations FLUENT 6.3 software was used. They compared experimental and fluent results. They found that increasing rotational speed increases efficiency rapidly up to certain limit after that no any significant change in efficiency with rotational speed. Material also affects the efficiency of RAH. Material with more thermal diffusivity, give higher efficiency. Air and gas flow rate increase results in reduced efficiency. Air and gas inlet temperature does not affect efficiency.

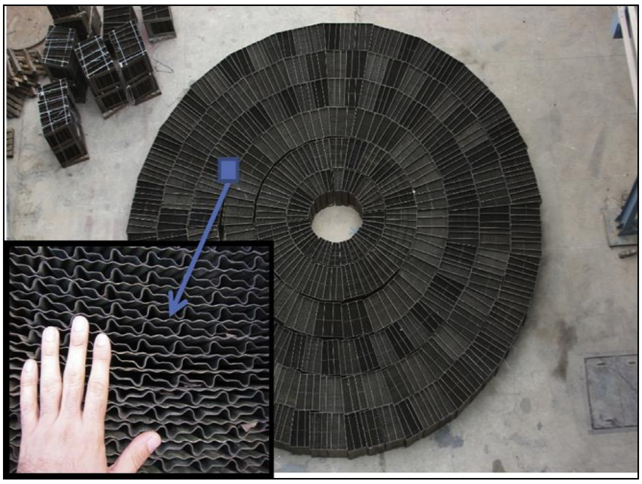

**Fig -3**: Actual shape of the plates used in the matrix

## 3. FINITE VOLUME FORMULATION

Jonathan Dallaire optimized the thermal performance of a rotary heat exchanger considering internal structure as porous media [4]. The objective is to maximize the rotary heat exchanger's heat transfer rate per unit surface area. They considered length and porosity as a variable. Two different porosity geometries have been investigated, a series of parallel channels and a packing of spheres. For numerical calculations finite volume formulation is used. The numerical results are validated by an extensive scale analysis. The performance of the RHE was nearly doubled by allowing the porosity of the matrix to be unevenly distributed over the length. Performance of the RHE increased with increase in length. The future scope of this work is to extend the study in 2-D and 3-D and consider the factors such as fouling, frosting and leakages.

## 4. COLD FLOW STUDY

Sreedhar Vulloju tested air preheater elements using cold flow studies [5]. He proved that performance of Ljungstrom air preheater is dependent on the heat transfer element profiles. It is necessary to develop element profiles with lesser pressure drops for efficient heat transfer with lower power consumption to improve overall efficiency of power plant. Two types of element profiles used are FNC (Flat notched crossed) and DU (Double Undulated). These profiles were tested using residual time test and Cold flow study. There performance was compared at different Reynolds number. Residual time test concluded that FNC elements have more residual time compared to DU elements, so it has more heat transfer coefficient. The fluid pumping power is directly proportional to the pressure drop in the fluid across element. They concluded that performance of the FNC elements is more than DU elements.

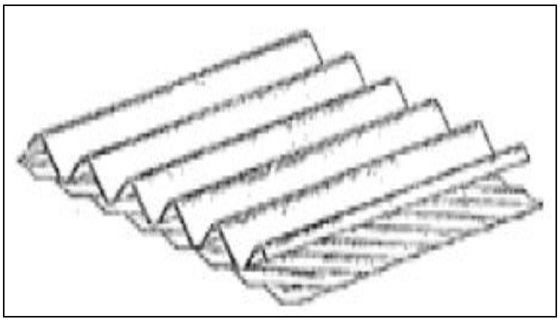

**Fig -4**: FNC element profile

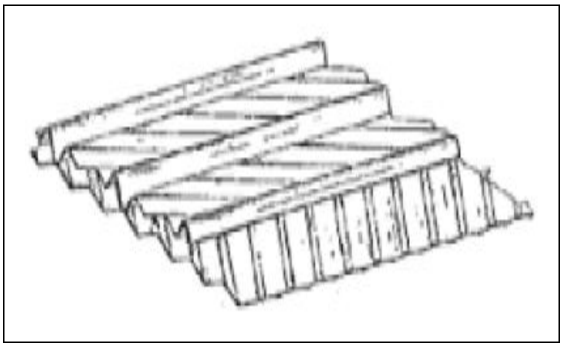

**Fig -5**: DU element profile

## 5. GENETIC ALGORITHM

Saeid Jafari optimized operational conditions of the rotary regenerator using genetic algorithm optimization technique [6]. They took thermal effectiveness as objective function. Decision variables were volumetric flow rates of cold and hot air streams, matrix rotational speed, heat transfer surface area. At optimum condition numerical and experimental values are compared and acceptable match was found between two. Maximum effectiveness occurred at the maximum mass flow rate of hot stream and minimum mass flow rate cold stream. Also effectiveness increases with rotational speed up to a certain value after which no considerable change in effectiveness with speed. Increasing the hot stream temperature resulted in increased effectiveness.

## 6. 1-D AND 3-D NUMERICAL MODEL

Sandira ELJŠAN shows how operation parameters of an regenerative air preheater can be optimized to increase its efficiency and consequently the overall efficiency of a steam boiler [7]. Installation of air preheater reduced fuel consumption by as much as 25%. In modern utility boilers preheater contributes up to 20% of the overall boiler efficiency and 2% of total investment. For every 20$^0$c drop in flue gas temperature, the boiler efficiency increases by 1%. In this paper 1-D and 3-D numerical models of heat transfer are used to estimate the preheater performance. 1-D model uses 3 energy balance equations. n3-D model uses a set of differential equations of continuity, momentum and energy. This paper only optimized rotational speed. Author found that with increasing rotational speed up to certain optimum point air preheater efficiency and overall efficiency of boiler increases after that increasing speed results in decreased efficiency. In order to truly optimize preheater, all parameters (load, solid filling geometry and rotational speed) should be taken into account at the same time.

## 7. COMPUTATIONAL CONTINUUM MECHANICS

Sandira Alagi made use of the commercial CCM (computational continuum mechanics) solver to obtain results [8]. The results are displayed in the form of the temperature distribution within the preheater solid elements and fluid flow of both the hot combustion products and cold air. The results of both the 1-D and 3-D calculations and field measurement are compared and good agreement was achieved. The result of this study is the development of an effective procedure for computer calculation of processes in a Ljungstrom air preheater to optimize its parameters. 1-D model is adequate and simplifies the problem statement significantly and speed up calculation. 3-D model serves for the better understanding of processes. The experimental results confirmed the validity of both numerical analysis methods. In order to apply numerical methods, the authors have developed a general and flexible grid generation procedure.

## 8. SEMI ANALYTICAL METHOD

Hong Yue Wang employed semi analytical method to investigate the 3-D heat transfer of the tri-sectional rotary air preheater [9]. The main focus was on the temperature change of fluids and temperature distribution of the matrix. Semi-analytical method is based equations generated by trapezoidal rule. Standard numerical results and semi-analytical results for the temperature distribution of the metal matrix are compared. To validate simulation results of the semi-analytical method, an experiment was carried out. Considerable reduction in the amount of computational effort required when using semi-analytical method instead of standard numerical methods. Precision and convergence are better than standard numerical methods.

## 9. CONCLUSIONS

As a part of this research work, an extensive literature review have been carried out on Rotary air preheater by studying numerous research papers. The most related research papers on effect of different parameters using different study methods are thoroughly studied and explained in this present work. The work of different authors is summarized below;

**Table -1:** Summary of results

| Sr. No. | Study | Parameter | Effect/Result |
|---|---|---|---|
| 1) | FLUENT software | Rotational speed | Increasing rotational speed increases efficiency up to certain limit after that no significant change in efficiency. |
| | | Material | Material with more thermal diffusivity, give higher efficiency. |
| | | Air & gas flow rate | Air and gas flow rate increase results in reduced efficiency. |
| | | Air & gas inlet temp | Does not affect efficiency. |
| 2) | Finite volume formulation | Porosity | Uneven porosity along length nearly doubles the RHE performance. |
| | | Length | Performance increases with increased length |
| 3) | Cold flow study | Element profile | Performance of FNC is more than DU elements. |
| 4) | Genetic algorithm | Mass flow rate | Max. Effectiveness at max. mass flow rate of hot stream and min. mass flow rate of cold stream. |
| | | Rotational speed | Effectiveness increases with speed up to certain point after that no |

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|---|---|---|---|
| | | | significance change. |
| | | Hot stream temp. | Increasing hot stream temp. resulted in increased effectiveness. |
| 5) | 1-D & 3-D numerical model | Rotational speed | Increasing rotational speed increases efficiency up to certain point after which efficiency decreases. |
| 6) | CCM | | Temp. Distribution within solid elements and fluid flow of hot gases and cold air. |
| 7) | Semi analytical method | | Precision and convergence in semi-analytical method is better than standard numerical methods. |

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