APH PERFORMANCE IMPROVEMENT STUDY USING CFD MODELING IN 500 MW NTPC UNIT

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Abstract:

Air Pre-Heaters (APH) plays a very important role in utilizing the heat in flue gas in PC fired boilers. The primary air for conveying coal and secondary air for combustion is being pre-heated in APH. It plays a very important role in the performance of boiler, mills, combustion efficiency and ESPs. An effective heat transfer in APH improves the boiler as well as ESP capture efficiency. For a typical Ljungstrom Rotary APH, feedback from sites has indicated leakages, choking of baskets, erosion at outer baskets, cold end corrosion as major problems. Apart from seal leakages, the other significant yet neglected area relates to the flow of flue gas and air into the APH. Hence a flow analysis of Air (From PA fan discharge to PAPH inlet & From FD fan discharge to SAPH inlet) and Flue Gas (from Eco outlet to APH Inlet) using CFD modeling of "As Built" condition was done for a 500 MW unit of NTPC. The flow analysis has given insight into the existing flow patterns in the APH and indicated non-uniform flow of both Air and Flue Gas at PAPH & SAPH inlet. The flow pattern indicated higher flow on the SAPH inlet on the outer baskets toward the chimney side. Based on the existing flow situation, model of modified duct was prepared and optimized design and locations of Guide Vanes, Splitters and Gas Distribution Screen were identified to achieve the objective of uniform flow of Air and Flue-Gas at the entry of PAPH & SAPH with reduced pressure drop in the air and FG circuit. The uniform flow of PA/SA and FG into the APH is expected to increase the heat transfer efficiency of the APH as all the baskets will be swept by the respective fluid medium ensuring maximum heat transfer.

[Keywords: APH, Non-uniform flow, Gas Distribution Screen, Guide vanes]

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1. Introduction:

Air Pre-Heaters (APH) plays a very important role in utilizing the heat in flue gas in PC fired boilers. The primary air for conveying coal and secondary air for combustion is being pre-heated in APH with the exiting flue gas after it has transferred its energy to steam-water cycle in PC fired boiler. Thus APH plays a very important role in the performance of mills, combustion and ESPs. An effective heat transfer in APH improves the boiler as well as ESP capture efficiency. For a typical Ljungstrom Rotary Bi-sector Regenerative APH, the rotor containing heat exchanger baskets rotates around a vertical post (shaft) between the Air duct and flue gas duct. The air and flue gas are prevented from mixing by a set of sealing and sector plates arrangement. The flue gas from the economizer exit generally divides into two and enters the (i) Secondary Air Pre-Heater (SAPH) where the Secondary air is heated and (ii) Primary Air Pre-heater (PAPH) where the Primary air is heated. A typical arrangement is shown in Figure-1.

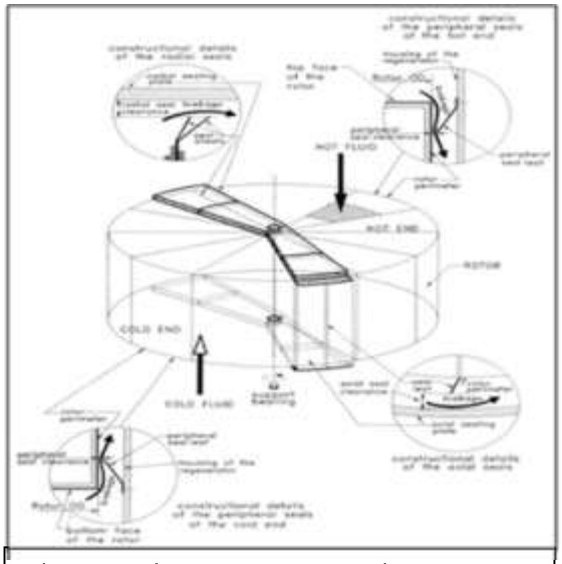

Figure-1: Ljungstrom Rotary Bi-sector Regenerative APH

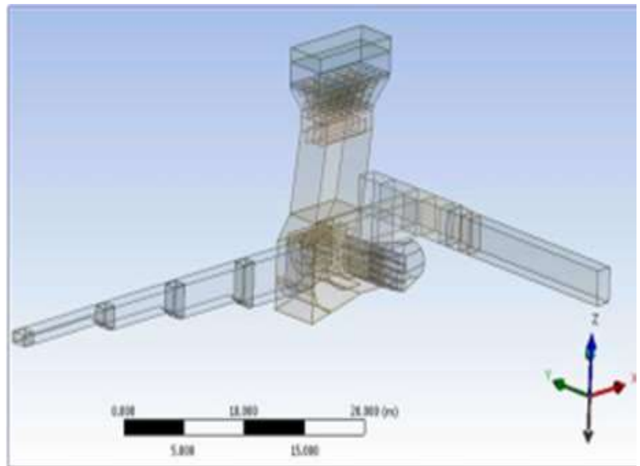

Figure-2.1: Isometric view of 3D model of air duct from PA Fan outlet to PAPH inlet

Feedback from sites has indicated leakages, choking of baskets, erosion at outer baskets, cold end corrosion as major problems. On closer analysis it is observed that apart from the leakage, the problems related to choking and erosion at the outer basket may be related to the flow profile of flue-gas/air into the APH. The observation is based on earlier experience of NETRA during CFD modeling studies and execution in Tanda and Vindhyachal for correcting flue gas flow pattern [Ref-1,2]. Hence, a CFD modeling study of the flue gas and air flow is carried out to understand the fluid flow pattern in the APH.

2. CFD Modeling of the Flue Gas Duct

Based on the air and flue gas duct drawings provided by site, 3-D model of the cold air duct from PA fan outlet to PAPH inlet, from FD fan outlet to SAPH inlet and FG duct from economizer outlet to PAPH/SAPH inlets are created as shown in Figure-2.1, Figure-2.2 & Figure-2.3 respectively.

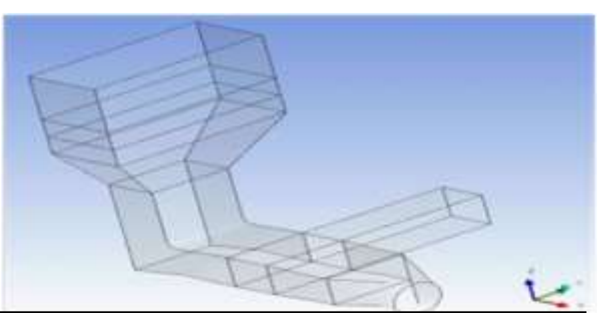

Figure-2.2: Isometric view of 3D model of air duct from FD fan outlet to SAPH inlet

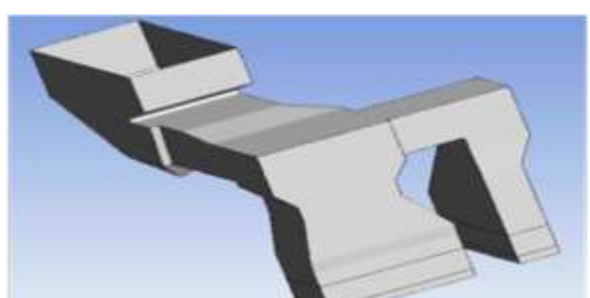

Figure-2.3: Isometric view of FG duct section from Economizer outlet to APHs inlet

3. Optimized modifications identified using CFD analysis

The flow pattern observed in the existing ducting indicated non-uniformity of flow on both air and flue gas duct and provided explanation to erosion of the outer baskets. The flow pattern was again simulated with optimized modifications where considerable improvement in flow pattern was observed. The optimized modification simulated which shows considerable improvement in flue gas and PA/SA flow is summarized in the following section.

3.1 Modifications in flue gas duct

3.1.1 Guide Vanes at Economizer outlet:

The flue gas moving downward after exit from economizer takes 90̊ turn and flows in horizontal duct before bifurcation to SAPH and PAPH. A guide vane at economizer exit helps smooth turning of the gases. The modification is shown in Figure 3.1a

3.1.2 Guide Vanes at inlet bend of SAPH:

The flue gas moving downward to the SAPH inlet is concentrated towards the outer basket on the wall blocking the flow. To take care of that a single guide vane is introduced as in Figure 3.1b

3.1.3 Guide Vanes at inlet bend of PAPH:

The flue gas moving downward to the PAPH inlet is concentrated towards the outer basket on the wall blocking the flow. To take care of that guide vanes are introduced as in Figure 3.1c.

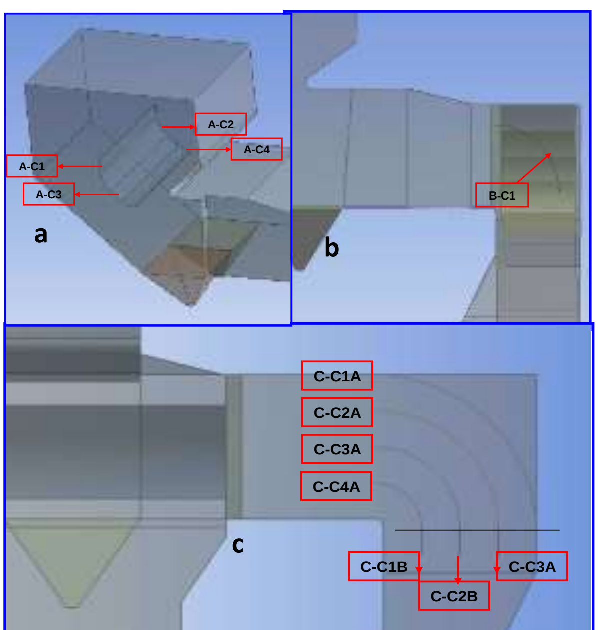

Figure 3.1 Optimized modification simulated in Flue gas duct from Economizer outlet to inlet of PAPH and SAPH

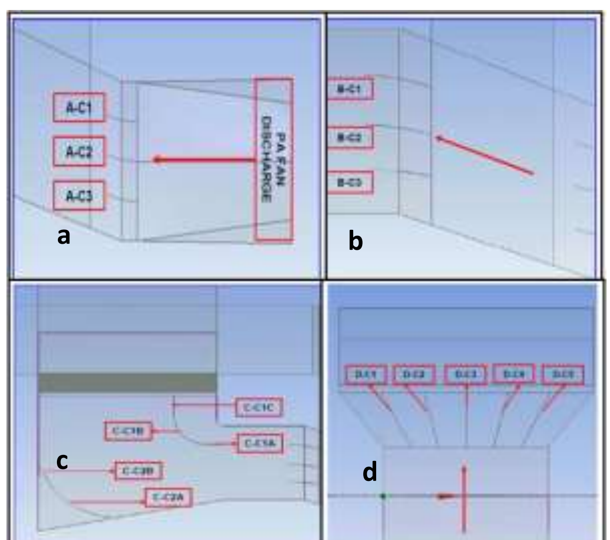

Figure 3.2 Optimized modification simulated in Air duct from PA fan to PAPH Entry

3.2 Modifications in duct section of PA fan outlet to PAPH

The modifications in the PA duct from PA fan outlet to inlet of PAPH are shown in Figures 3.2a, 3.2b, 3.2c and 3.2d. Figure 3.2a shows three guide vanes introduced in the discharge side of PA fan, Figure 3.2b shows the three guide vanes introduced before the 90^0 bend of the air duct. Figure 3.2c shows two guide vanes introduced at the 90^0 bend of the PA duct and Figure 3.2d shows five splitter plates introduced in the PA duct before it enters PAPH.

3.3 Modifications in duct section of FD Fan outlet to SAPH

The modifications in the SA duct after FD fan outlet to inlet of SAPH are shown in Figures 3.3a, and 3.3b and 3.3c. Figure 3.3a shows the two guide vanes introduced at the 90^0 bend and Figure 3.3b indicates the location of two GD screens introduced before the SA enters the SAPH.

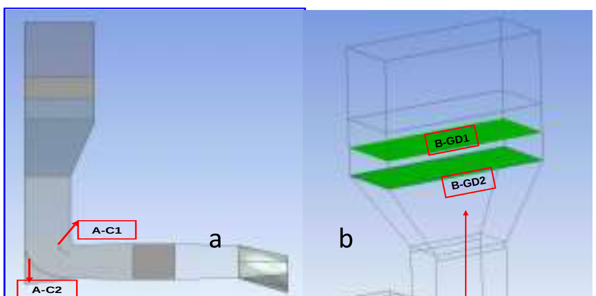

Figure 3.3 a,b: Optimized modification simulated in Air duct from FD fan to SAPH

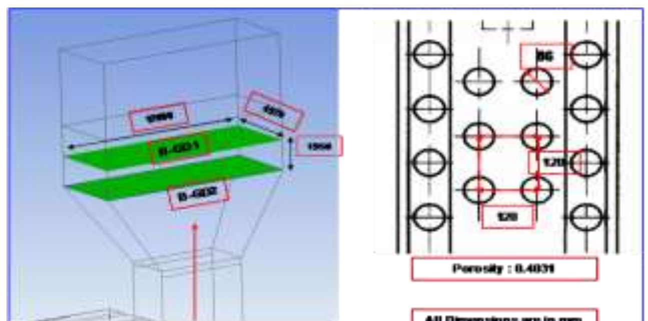

Figure 3.3 c Configuration of GD screen used for simulation in SA duct to the entry of SAPH

4. Discussion on the effect of modification on the PA, SA and Flue gas flow pattern to PAPH/SAPH

4.1 Effect of modification on PA duct flow into the PAPH

Figure 4.1 shows the velocity contour before and after the modification on a horizontal plane inside the air duct near PAPH cold end baskets. The contour in Figure-4.1a is for "As Built" case whereas in Figure-4.1b is for modified case. The plane at PA duct at the inlet of PAPH where flow is compared is shown in Figure-4.1c. The velocity scale for both the cases is shown in Figure-4.1d where red color is representing highest velocity and blue, the lowest. The modified case shows that highest occurring velocity has reduced and flow has become more uniform after insertion of the guide vanes and splitter plates. The reduction in peak velocity and more

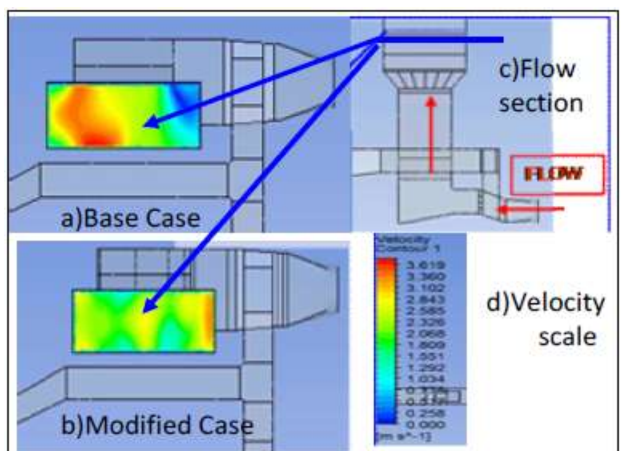

Figure 4.1 Comparison of velocity magnitude in base and modified case in PA duct to PAPH

uniformed flow in modified case should result in higher heat transfer across the PAPH baskets with lower pressure drop and reduced erosion and low PA fan power.

4.2 Effect of modification on SA duct flow into the SAPH

Figure-4.2 show velocity contours on horizontal planes after diffuser part and before inlet to the SAPH cold end. Figure-4.2a shows non-uniform distribution of velocity on the planes is clearly visible in the "As Built" case.

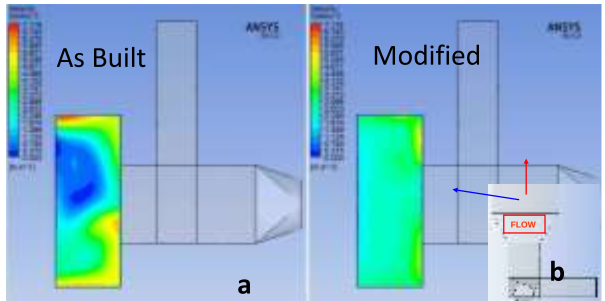

Fig 4.2 Comparison of velocity at SA duct from FD fan to SAPH inlet

The velocity in the "Modified" case has become highly uniform due to insertion of Gas Distribution Screens and guide vanes as shown in Figure4.2b. Due to this the SAPH baskets will receive air flow uniformly over it resulting in better heat transfer pickup from air to basket. The flow uniformity has also resulted in less pressure drop across the duct section

4.3 Effect of modification on Flue gas duct from economizer outlet to PAPH/SAPH

Figure 4.3a shows flue gas velocity profile on a vertical plane cutting across the SAPH and PAPH inlet duct. It can be observed that velocity is more uniform at the bottom of both the ducts ensuring better spread of flue gas flow over the APH baskets.

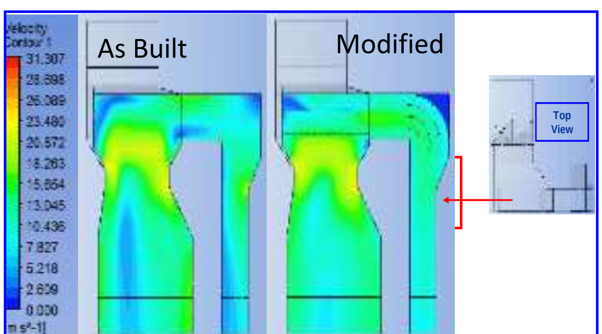

Fig 4.3a Comparison of velocity at FG duct inlet to SAPH and PAPH for base and modified case. The section seen is vertical plane passing through mid-section of PAPH/SPAPH

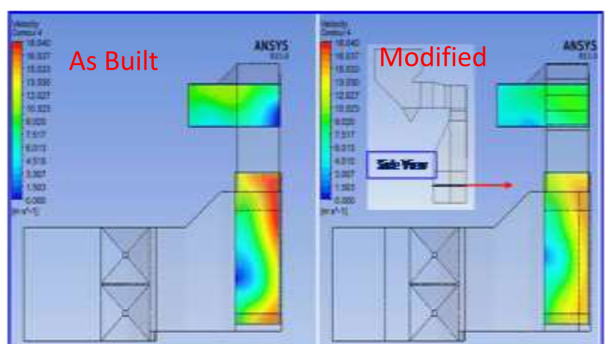

Fig 4.3b Comparison of velocity at FG duct inlet to SAPH and PAPH for base and modified case. The section seen is horizontal plane passing above the SAPH/PAPH FG entry

Figure 4.3b shows velocity contour of flue gas on a horizontal plane at the inlet of SAPH & PAPH. Non-uniform distribution of velocity can be observed at the inlet of both SAPH & PAPH. Insertion of guide vanes has made the flow more uniform in the case of "Modified Duct". Maximum velocity in the case of "modified" duct has also reduced. It can be observed from the flue gas flow pattern into the SAPH that the FG flow is more at the outer basket. In the modified case, the pattern remains same but the intensity on non-uniformity has decreased.

4.4 Summary of benefits observed from the modified flue gas pattern

The standard deviations of velocity at the observed sections are calculated for the base and modified cases and tabulated in Table-1. Standard Deviation of velocity is an indicator of uniformity of flow as it quantifies the scatter of data points. Lower Standard deviation implies better concentration of data around the Mean Value. From Table-1, it can be seen that values of standard deviation for all the three cases has reduced for modified duct. More uniform velocity implies better heat transfer.

Table-2 indicates that uniform velocity has been achieved in all the three cases without incurring additional pressure drop. Rather, pressure drop has decreased in all the three cases with maximum gain achieved is 29% reduction with modified Cold Secondary Air Duct.

Table-1: Standard deviation of velocity

	Air Side Inlet		Flue gas side	
	PAPH	SAPH	PAPH	SAPH
As built	0.92	1.42	2.45	4.18
Modified	0.36	0.32	1.58	3.09

Table-2: % Pressure drop reduction in modified case with respect to base case

	PA Duct	SA Duct	FG from Eco out to APH inlet
% Pressure drop	6	29	25

5. Summary **& conclusion:**

The current study shows the flow pattern of air and flue gas duct into the respective entry to APH and indicated localized velocity with non-uniformity. This is leading to non-uniform flow into the APH resulting in non-uniform heat pick-up and release by the baskets. Further the flow pattern of flue gas into the SAPH, which indicates higher flow towards the outer basket, explains site experience of erosion in outer basket. The modification tried out in simulation indicates that the flow can be made better which can decrease the fan power consumption and duct erosion and improve the heat transfer in the APH. The modifications are being studied for structural integrity and will be put up for approval for implementation in Ramagundam U#4 in the next overhaul in July-Sep 2017.

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7. References

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