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OPTIMIZATION OF THE ROTARY REGENERATIVE AIR PREHEATER, SUPPORTED BY AN INCREASE IN HEAT CAPACITY AND REDUCTION OF LEAKS IN THE SEALING SPACES.

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Abstract: *The work is a reconstruction of the rotary regenerative air preheater in order to increase energy efficiency. The increase in heat capacity was examined with minimalist changes in the surface geometry of the heat exchanger. The influence of air leakage through gaskets on the efficiency of the installation was also tested. All the researches were carried out for two qualities of fuel that come from a series of thermal and aerodynamic calculations, the optimal working conditions of the rotary regenerator in terms of energy efficiency of the plant were chosen. The results were verified by measurements performed at the plant after reconstruction..*
Keywords: *Rotary regenerative air preheater, steam boiler, thermal capacity, energy efficiency.*

1. INTRODUCTION

Increasing the economic efficiency of modern steam boilers is one of the main concerns of modern energy. Due to the large increase in fuel consumption, a constant improvement is needed for the combustion process and the process of using energy from flue gases.
The important factor that contributes to the saving of fuel in thermal power plants is the process of heating the air with the energy of the flue gases at the exit of the steam boiler. The lowering of the flue gas temperature will decrease the amount of energy that is irretrievably lost in the atmosphere. Heated air raises the oven temperature, which leads to better fuel combustion and a more intense evaporation process. The air heater significantly affects the efficiency of the steam boiler and is an indispensable component of power plants.
Due to their compactness, ease of cleaning and protection against corrosion and high energy transfer performance, rotary regenerative air preheaters are mostly implemented in coal-fired power plants. Rotary preheaters operate on a specific principle from the flue gas stream to the rotating air stream. It is composed of densely profiled tin sheets, where the tin sheets form the current space. Rotary generators represent the inevitable leakage of air into the flue gas stream, due to the existence of a spacing between the gaskets and the rotor and the pressure difference between the two currents.
This topic refers to the possibilities of increasing the thermal efficiency of rotary regenerative air preheaters in a steam boiler in a 350 MW power plant. The research was conducted on how much influence the heat capacity will increase with changes in the geometry of the matrix sheets on the amount of energy used. As a procedure to improve the working efficiency of the heating surface, the introduction of more efficient rotary sealing was also considered. For research purposes, an own thermal calculation code was developed for the considered steam boiler. The thermal calculation is based on the Normative method [1]. This allowed the execution of the qualitative selection of the tested methods to increase the working efficiency of the rotary regenerator and the selection of the optimal reconstruction of the heating surface during the regular annual review of the steam boiler.

2. WORKING CONDITIONS

Subject steam boiler was designed for combustion of lignite with lower heating value of *7326 kJ/kg*. Operational characteristics of the boiler are:
▪ Main steam mass flow rate, *D=277.8 kg/s;*
▪ Main steam pressure, p_s*=18.6 MPa;*
▪ Main steam temperature, t_s*=540 °C;*
▪ Reheated steam mass flow rate, D_r*=261.1kg/s;*
▪ Reheated steam pressure, p_{rs}*=4.375 MPa;*

▪ Reheated steam temperature, t_{rs}*=540 °C;*
▪ Steam temperature at the reheated inlet, t_r*=334 °C;*
▪ Feed water temperature, t_{fw}*= 205 °C.*

Two regenerative rotary air preheaters are mounted at the boiler outlet. The conditions require that the flow space for flue gases and air be identical. This was done by placing two sector plates in the middle of the rotor (Fig. 1). The diameter of the rotor is *12.13 m*. To allow easy replacement of low temperature corrosion damage, the rotor was divided into hot *(1.4 m)* and *cold (0.3 m)* groups. The sheet geometry of the hot and cold group is shown in Fig. 1. The sheet tip of the matrix of the existing hot group *(A) is t = 38 mm*, the thickness of the sheet *δ = 0.63 mm*, the total height of the matrix torque *x = 11 mm*, the height of the distance sheet *y = 3 mm*, and the height of the undulating sheet this *x - y = 8 mm*. Partial corrugated sheet height *30 °*, and the pitch of the sheet matrix of the rotating cold group *(A) is t = 38 mm*, and the thickness of the sheet *δ = 1.2 mm*. The total height of the matrix torque *is x = 14.2 mm*, while the sheet height is *x - δ = 13 mm*. The cold group sheets are smooth and the equivalent diameter is d_e*= 9.8 mm.*

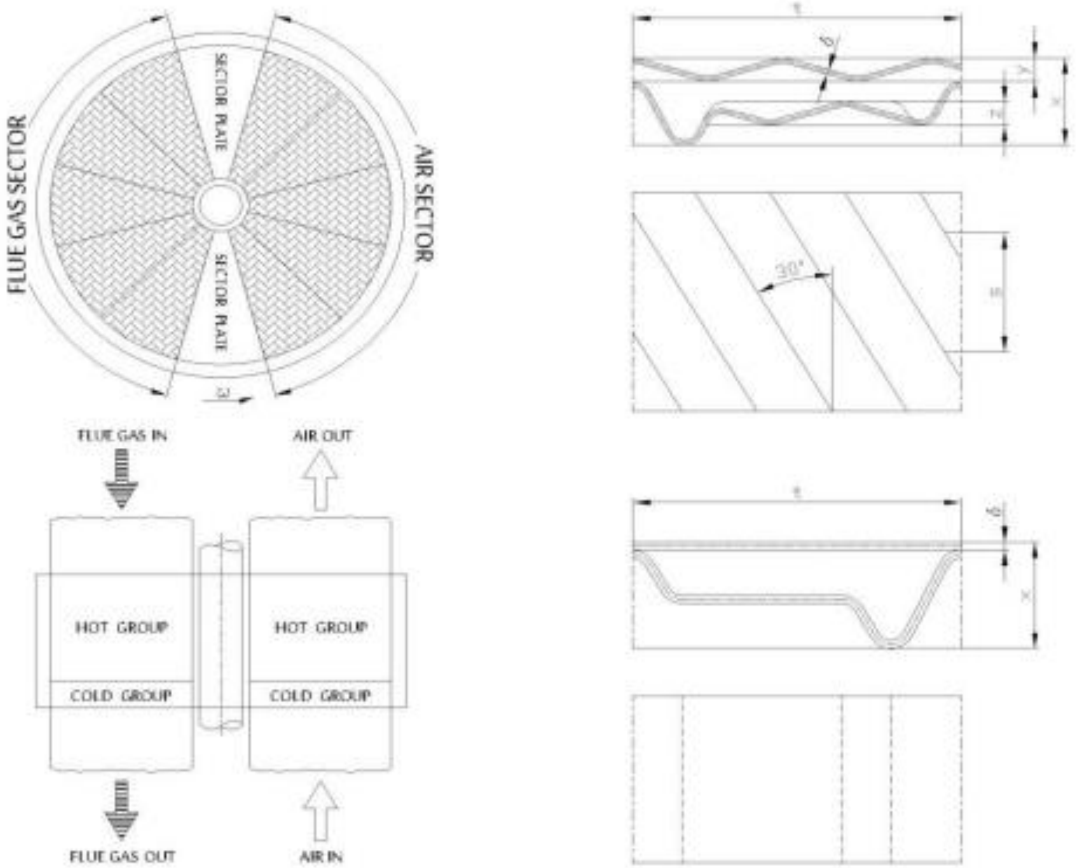

Figure 1. Geometry of matrix sheets: upper right - double undulated; lower right - notched plain

3. POSSIBILITIES FOR INCREASING THE EFFICIENCY OF THE ROTARY REGENERATIVE AIR PREHEATER

The impact of the methods for increasing the efficiency of the rotary regenerative air preheater on the efficiency of the steam boiler was studied analytically, being analyzed using its own code for thermal calculation. A series of calculations [2] were performed to examine the influence of the heat capacity of the rotating matrix and the contribution of a more efficient sealing to the operation of the steam boiler. Calculations were made for guaranteed coal and better quality coal *(8249 kJ / kg).*

4. RESEARCH ON THE INFLUENCE OF INCREASING HEAT CAPACITY

The heating surfaces of the rotary regenerative air preheater are made of rugged pipes, where the height of the matrix sheets is the element of resistance. The thickness of the viscous layer is about one millimeter for the operational conditions considered, which serves as a linear proportion for the process of heat exchange in these pipes [3]. Small changes in corrugation height cause a significant change in heat exchange characteristics. Therefore, during these analyzes the narrow limits allowed by the normative method were modified [4]. The distance between the ripples will determine the conditions of development and propagation of vortices and will affect the characteristics of heat exchange, therefore, has not changed in this paper. The increase of the heat capacity was achieved with minimal changes in the geometry of the matrix sheets. The total height of the matrix torque x and the height of the distance sheet y, are various parameters. Test case A refers to the designed parameters of the boiler. Test case B refers to the parameters of the existing air preheater boiler, where the projected geometry of the matrix was kept and only the sheet thickness was changed. All cases examined (B - D) were made with a modified sheet thickness and better quality fuel. Sheets used for the hot group are *δ = 0.6 mm* thick, and for the cold group, *δ = 1.0 mm* thick. Changing the heights of the matrix torque and the thickness of the sheets, which allowed the placement of an increased number of pairs of sheets, in the rotating group, as well as hot. Changes in the geometry of the matrix sheets have allowed the increase of the heating surface of the matrix and is the total mass. Table 1 shows the designed and varied geometric characteristics of the sheets for the hot and cold matrix group.

Table 1. Varied parameters for matrix sheets

Varied parameters	Unit	Hot group - double undulated			
		A	B	C	D
δ	mm	0.63	0.6	0.6	0.6
x	mm	11	11	10.6	10.25
y	mm	3	3	2.85	2.7
x-y	mm	8	8	7.75	7.55
Varied parameters	Unit	Cold group - notched plain			
		A	B	C	D
δ	mm	1.2	1.0	1.0	1.0
x	mm	14.2	14.0	13.6	13.25
x-δ	mm	13	13	12.6	12.25

The increase to heating surface of hot group of matrix is valued in percentages, compared to the existing matrix hot group B, in Table 2. That increase is *ΔC = 0.7 %, 3.9 % and 6.3 %.* The increase to heating surface of cold group of matrix is valued in percentages, also compared to the existing matrix cold group B, in Table 3. That increase is *ΔC = - 1.5 %, 3.3 % and 5.8 %.* Combining the hot and cold group of matrix resulted in four tested pairs A – D.

Table 2. Geometrical characteristics of regenerative air preheaters – rotory hot group

No.	Name	Nomenclature	Unit	Rotary matrix			
Hot group				A	B	C	D
1.	Type of matrix	-	-				
2.	Equivalent matrix diameter	d_e	mm	9.6	9.3	9.0	8.7
3.	Rotor diameter	D_u	m	12.13			
4.	Part of crossection for flue gas stream	x_1	-	0.403			
5.	Part of crossection for air stream	x_2	-	0.403			
6.	Coefficient of filling rotory crossection with hub and compartments	K_r	-	0.932			
7.	Coefficient of filling rotory crossection with matrix	K_i	-	0.87	0.88	0.87	0.87
8.	Number of rotory air preheaters per boiler unit	n	-	2			
9.	Flue gas flow section	F_g	m^2	75.52	76.39	75.52	75.52
10.	Air flor section	F_a	m^2	75.52	76.39	75.52	75.52
11.	Height	h	m	1.4			
12.	Overall heating surface per 1 m^3 of rotor, without hub and compartments	C	m^2/m^2	415	412	428	438
13.	Increase of the rotary heating surface	ΔC	-	1.007	1.000	1.039	1.063
14.	Heating surface	H	m^2	118893	118034	122618	125482

Table 3. Geometrical characteristics of regenerative air preheaters – rotory cold group

No.	Name	Nomenclature	Unit	Rotary matrix			
Hot group				A	B	C	D
1.	Type of matrix	-	-				
2.	Equivalent matrix diameter	d_e	mm	9.8	9.9	9.7	9.5
3.	Rotor diameter	D_u	m	12.13			
4.	Part of crossection for flue gas stream	x_1	-	0.403			
5.	Part of crossection for air stream	x_2	-	0.403			
6.	Coefficient of filling rotory crossection with hub and compartments	K_r	-	0.932			
7.	Coefficient of filling rotory crossection with matrix	K_i	-	0.80	0.83	0.83	0.83
8.	Number of rotory air preheaters per boiler unit	n	-	2			
9.	Flue gas flow section	F_g	m^2	70.84	73.49	73.49	73.49
10.	Air flor section	F_a	m^2	69.45	72.05	72.05	72.05
11.	Height	h	m	1.4			
12.	Overall heating surface per 1 m^3 of rotor, without hub and compartments	C	m^2/m^2	325	330	341	349
13.	Increase of the rotary heating surface	ΔC	-	0.985	1.000	1.033	1.058
14.	Heating surface	H	m^2	19952	20259	20934	21425

5. CONCLUSION

The analysis was performed for the operating efficiency of a steam boiler in the 350 MW thermal power plant, for different heat capacities and sealing conditions of the rotary regenerative air preheater. An increase in the heating surface was considered for minimal changes in the geometry of the matrix sheets. These representations allowed to increase the rotating mass of the regenerator and the heat capacity. In the analysis it was observed that the increase of the heat capacity of the matrix, with identical conditions of air infiltration in the steam boiler, leads to the increase of the efficiency of the air preheater and the steam boiler. The optimal matrix was tested under improved sealing conditions. The results of this test showed that the additional efficiency of the preheater increases, as does the efficiency of the boiler. The solution selected to increase the efficiency of the air preheater and the boiler was verified by measuring the boiler after reconstruction.

6. REFERENCES

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