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Thermal Analysis of Superheater Platen Tubes in Boilers

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ABSTRACT

Superheaters are among the most important components of boilers and have major importance due to this operation in high temperatures and pressures. Turbines are sensitive to the fluctuation of superheaterstemperature;therefore even the slightest fluctuation in the outlet vapor temperature from the superheaters does damage the turbine axis and fins. Examining the potential damages of combustion in the boilers and components such as the superheaters can have a vital contribution to the progression of the productivity of boiler, turbine and the power plant altogether it solutions are to be fund to improve such systems. In this study, the focus is on the nearest tube set of superheaters to the combustion chamber.These types of tubes are exposed to a wide range ofcombustion flames such that the most heat transfer to them is radiation type.Here, the 320 MW boiler of Isfahan power plant (Iran), the combustion chamber, 16 burners and the platensuperheater tubes were remodeled by CFD technique. The fluid motion, the heat transfer and combustion processes are analyzed. The two-equation turbulence model of k-εis adopted to measure the eddy viscosity. The eddy dissipation model is used to calculate the combustion as well as the P-1 radiation model to quantify the radiation. The overheated zones of superheater tubes and the combustion chamber are identified in order toimprove this problem by applying the radiation thermal shields and knees with porous crust which are introduced as the new techniques.

Keywords: Boiler, Superheater platen, Combustion, Thermal shields, Porous crust.

NOMENCLATURE

A	coefficient for speed of fuel consumption	u,v,w	velocity components (m/s)
D	coefficient of mass influence	α_g	absorption coefficient of gas
F	body forces (N)	ε	turbulence dissipation(m2/s3)
G	turbulence generation term	ε_g	emissivity coefficient
g	gravitational acceleration	ρ	density (kg/m3)
h	enthalpy (J/kg.K)	τ_{ij}	tensor of stress (Pa)
$I(r)$	radiation flux in r-direction	μ_t	turbulent viscosity (m2/s)
K	kinetic energy(m2/s2)	Γ_k	sink (source) coefficient
m	mass of component (kg)	C_1, C_2, σ_e	empirical coefficients
p	pressure(MPa)	J	mass diffusion coefficient
S	diffusion coefficient	φ	energy dissipation due to viscosity
s	arbitrary direction (m)		
T	temperature (K)		
t	time (s)		

1. INTRODUCTION

The energy carriers, the provision of energy and its crucial contribution to the contemporary life are among the main concerns; as a result, the abundance of energy resources is a fundamental index of ranking countries as far as their level of development is conserved. Nowadays, various methods are adopted to produce electricity in different countries, each varying according to the potentialities, natural resources, policies and special regional parameters. Due to the necessity of advanced and costly technologies in the nuclear power plants, the confined limits of water resources throughout the various geographical regions and the low efficiency of the power plants operating on the infinite energy resources platform (solar, wind and tidal energies) in comparison with the other types of power plants, the gas-steam and combined cycle power plants are still in charge of the electricity production in different countries. Consequently, the ongoing studies investigation that leads to presentation of solutions and innovations which would help increase the efficiency in each section of these power plants is valuable and effective effort.

The outlet vapor from the drum of the boilers should be exposed to a higher heat in order to attain more energy and this is conventionally called "dry vapor" or "superheat". This take place inside the superheaters made of parallel tubes installed on the hot gases path. These tubes transmit the heat resulting from combustion to their inner vapor, and then the saturated vapor turns into superheat vapor and makes them ready to be transferred to the high-pressure flats of the turbine. Any unconventional curvature and tearing along the tubes path makes the boiler to deviate from the production circuit for a while. The most frequently reported problems in the majority of steam power plants are about this defect. As the inner temperature of steam generation boilers is very high, measuring equipments cannot be used to get informed about the fluid properties and facilities inside the boiler, so the role of Computational Fluid Dynamics (CFD) would be rather significant in remodeling these facilities and processes (Kaufman and Nicoud 2002). According to this computational method, reviewed the radiation heat transfer from a combustion chamber where the water-wall tubes were located (Abdullin and Vafin1994). The expression "water-wall tubes" refer to a collection of lateral tubes which form a monolithic wall as a result of their interconnection through the fins. Water in these tubes turns into vapor in the saturation zone. The investigation of (Ray *et al.* 2007) was included dimensional, hardness and tensile measurements in addition to accelerated stress rupture tests between 625 and 700 °C and micro-structural examination. (Jing-tao *et al.* 2006)To solve the problem of reheat steam temperature (RST) abnormal of the 300MW power station boiler unit, a method based on support vector regression (SVR) presented to model RST. Based on the data sampled on spot, RST was analyzed using support vector regression method. RST model is based on the statistical characteristics of the operating parameters and can reflect the potential relationship between RST and the operating parameters. For the units considered here, the RST is low and the temperature of reheater tube wall is high, tilt angles and desupreheater spray, etc. (Rahimi *et al.* 2006) remodeled the Bisotun power plant boiler and examined the radiation heat transfer to two flats of the superheater tubes while conducting a micro-structural and metallurgical assessment on the corrosion points of the tubes. In other investigation (Wu *et al.* 2013), the characteristics of outlet steam temperature and the metal temperature of the medium temperature platen superheater at different boiler loads was obtained in a 300MWCFB boiler, the result shows that the imbalance rate of tube mass flux is determined by the structure of header and tube. Generally Z type arrangement is one of the reasonable types of arrangement. (Manicam *et al.* 1998) designed an advanced model for the retrieval of non-consumable heat in the boiler. They indicated the temperature of gases and particles inside the boiler and on the walls. This modeling was similarly made to determine the dissipated heat from the boilers. (Kahrom et al. 2006) focused on the joining point of the weld inside the superheater tubes and the outlet header. After a micro structural examination on the damaged points, they used the simulation software to examine the slope of displacement created by the expansion and contraction of the header in various directions. They conducted that the impact of heat stress is caused by the excessive hotness of the tubes at the joining point. The location where the tube is welded to the header has the same situation. The proposal of the initial research (Falahatkar and Ahmadikia 2010) was to investigate the reason why the platen superheater tubes from a set of tubes installed at the boiler become damaged. The aforementioned boiler contains three types of superheaters called platen superheater, intermediate superheater and final superheater, respectively and ranked according to the order of their arrangement inside the boiler. Platen superheaters are principally important as they are the first set of superheater tubes which are located on the path of hot gases resulting from combustion; moreover they are situated at the closest position of superheater tubes to the combustion chamber. The frequent contact of the hot gases inside the boiler with the external surface of the tubes and the flow of high-pressure of superheat vapor within these tubes has caused the platen superheater tubes to undergo frequent heat stress. As a result, the heat stress, corrosion and fatigue could be the major factors causing destruction in the platen superheater tubes. According to the reports by the power plant, observing the destruction place of the tubes and the points of stress concentration in the helical tubes implies a thermal. In other words, observing some points of platen tubes that are being over-heated and prone to destruction indicate the initiation of the tubes' gradual destruction. So, if the thermal distribution inside the boiler in general and the distribution of heat on the tubes in particular are observed carefully on a regular basis, the probable destruction could be avoided and the lifespan of the tubes can be increased. Based on the results of the initial simulation in present study, the long and medium tubes of platen superheaters on the knees close to the outlet header would work with a temperature higher than their design temperature. Hence, the comparison of the temperature of these critical zones with the design temperature of the tubes shows a 96°c increase for the knees of long tubes and a 57°c increase for the knees of medium tubes. Functioning in the temperatures higher than the design temperature causes that rupture and destruction would happened on these tubes.

In this study, the 320 MW boiler of Isfahan power plant, Isfahan, Iran, was modeled by adopting the CFD technique. The focus here is on the heat transfer to the superheater tubes and the temperature field on tubes besides other transport phenomena calculations. In order to solve the overheated zone problem, using the radiation thermal shields and knees with porous crust are introduced as new techniques. By applying the thermal shields and the porous crust, the concluding results of modeling would display the range of temperature reduction on the knees located at the extreme position of these tubes which are known as the critical zones. The temperature of the outlet steam from Platen superheater with porous shell is higher than outlet steam from Platen superheater with radiation shields. The porous crust of Platen tubes is much less than the radiation shields.

2. EXPLICATION OF THE BOILER AND ITS ATTACHMENTS

A 320 MW boiler is analyzed in real scale according to the data on the boiler of the 4th unit of Isfahan's power plant. According to the complete map of the studied boiler (Isfahan Power plant Documents 2009), the length, width and the height of the boiler are 10.458 m, 11.658 m and 39.774 m, respectively. This boiler contains 16 gas burners with the capacity of using crude oil as the second fuel. These burners are set in four rows at the sides of the boiler. For more details, an overall view of the modeled power plant boiler is sketched in Fig. 1.

The burners of each row of the boiler are assembled with the angles of 37° and 46° of their lateral surfaces. This is an effective way that contributes to the formation of fire vortex in center of the boiler. This boiler contains a drum with the feature of one-stage reheat and is designed with the capability of burner angle variation from 0 to 30 degrees to the horizon. The volume of this boiler is about 4700 m3with a steam generation capacity of 1056 tons/hour at the maximum work load. Each burner contains two gas nozzles and three air channels. In order to mix gas with air in this boiler, the gas nozzles and the upper and lower air channels in each flat of the boiler burners are adjusted to angles of 5 and -5 degrees to the surface of horizon.

More details with respect to one of the flats where a burner is located and the modality of air channels' arrangement and fuel nozzles in each flat are introduced are shown in Fig. 2.

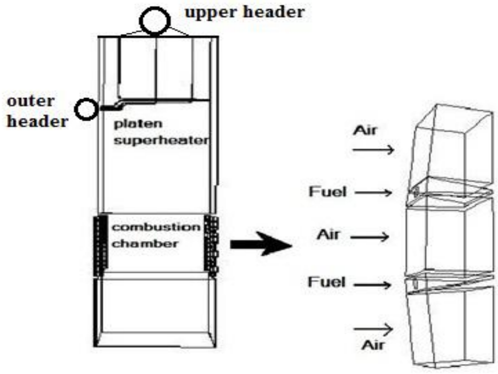

Fig. 1. An overall view of the analyzed boiler

This boiler has six banks of the superheaters' tubes in three categories: dual long tubes, dual medium tubes and dual short tubes. These tubes are designed by CATIA software with real size then transferred to the GAMBIT (Fig.3). The tubes are made of 14Cr5Mo stainless steel with 0.038m outer diameter and 0.028m inner diameter.

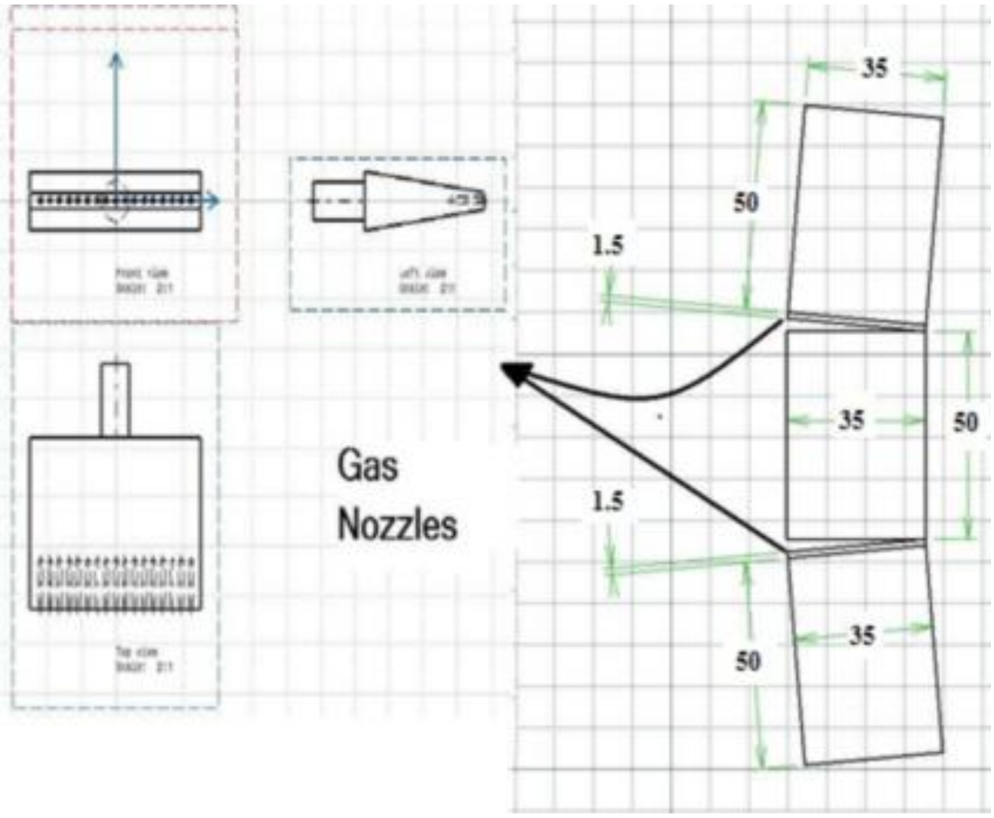

Fig. 2. Gas nozzles and air channels in each flat of the burners

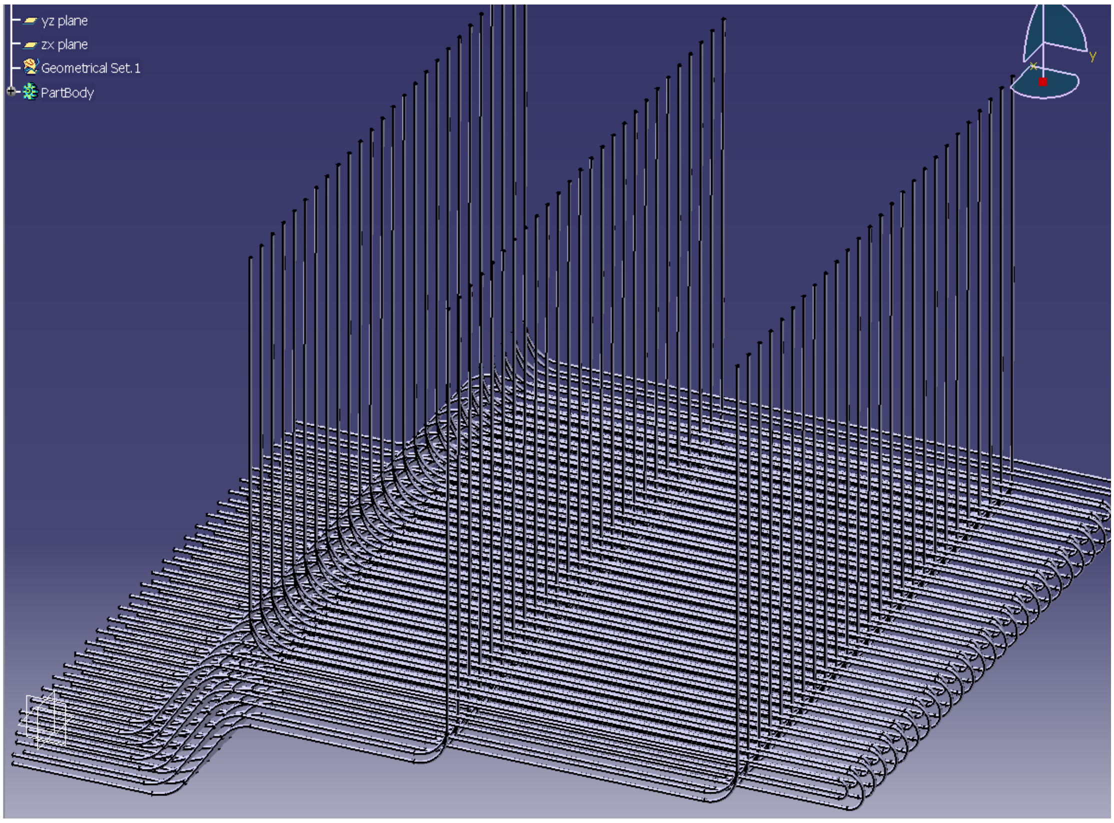

Fig. 3. Three types of the platen superheater tubes

This boiler has six banks of the superheaters' tubes in three categories: dual long tubes, dual medium tubes and dual short tubes. These tubes are designed by CATIA software with real size then transferred to the GAMBIT (Fig.3). The tubes are made of 14Cr5Mo stainless steel with 0.038m outer diameter and 0.028m inner diameter.

3. Governing Equation and Boundary Conditions and Methods of Solution

The subject boiler has more than 1.5 million control volumes with Tet/Hybrid elements and T/Grid type (quadrilateral or pyramidal) of mesh. Mesh generation process is performed using the GAMBIT software. Computational Fluid Dynamic (CFD) method is used for the numerical analysis. In the majority of codes oriented on the CFD method, Reynolds and Navier-Stokes equations are applied for remodeling the flow where defining the average time dependant properties (Versteeg and Malalasekera 1995).

Fluid flow equations: These equations (Continuity equation and momentum conservation equation) for gas mixture may be written as:

$$\frac{\partial}{\partial t}(\rho)+\nabla.(\rho V)=0 \qquad (1)$$

$$\frac{\partial}{\partial t}(\rho U_i)+\frac{\partial}{\partial X_j}(\rho U_i U_j)=-\frac{\partial P}{\partial X_i}+\frac{\partial \tau_{ij}}{\partial X_j} +\rho g_i + F_i \qquad (2)$$

where, τ_{ij} is the tensor of stress presented as:

$$\tau_{ij}=\left[\mu\left(\frac{\partial U_i}{\partial X_j}+\frac{\partial U_j}{\partial X_i}\right)\right]-\frac{2}{3}\mu\frac{\partial U_i}{\partial X_i}\delta_{ij} \qquad (3)$$

Porous media are modeled by adding a momentum source term to the standard fluid flow equations (Catapan *et al.* 2011). The source term is composed of two parts: a viscous loss term and an inertial loss term.

$$S_i=-\left(\sum_{j=1}^{3} D_{ij}\,\mu\upsilon_j+\sum_{j=1}^{3} C_{ij}\,\frac{1}{2}\rho|\upsilon|\upsilon_j\right) \qquad (4)$$

In order to model the turbulences governing flow, the two-equation model of k-ε are employed accordingly (Spalding 1976). This model includes the solution of transfer equations for the turbulence kinetic energy of k and its loss as ε.

The transport equations for turbulent kinetic energy k and dissipation of kinetic energy ε are:

$$\frac{\partial}{\partial t}(\rho k)+\nabla.(\rho V k)=\nabla.(\Gamma_k\nabla k)+G-\rho\varepsilon \qquad (4)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\nabla.(\rho V\varepsilon)=\nabla.\left(\frac{\mu_t}{\sigma_\varepsilon}\nabla\varepsilon\right)+C_1\frac{\varepsilon}{k}G-C_2\rho\frac{\varepsilon^2}{k} \qquad (5)$$

Eddy dissipation model is employed for the combustion calculations (Magnussen and Hjertager 1976). This model is predicated on the low-speed models and is the first one developed by (Spalding 1976). In the relevant code of this method, the speed of reaction's progress in turbulent combustion will be attributed to the failure of vortexes and the blend of their classes. It is assumed that this model the fuel and oxidant come in separate vortexes in turbulent flow and they are mixed when the bigger vortexes are turned into smaller ones and the smaller vortexes are disappeared as a result of viscosity in a way that the fuel and oxidant can be mixed. This model contains the solution of components' transfer equations as follows:

The conservation equation for species:

$$\frac{\partial}{\partial t}(\rho m_l)+\nabla.(\rho V m_l)=\nabla.\left[\left(\rho D+\frac{\mu_t}{\sigma_m}\right)\nabla m_l\right]+R_l \quad (6)$$

In the equation above, R stands for the speed of fuel consumption which will be defined on the basis of fuel vortexes' disappearance or oxygen vortexes' disappearance as follows:

$$R_f = A.\overline{m_f}.(\varepsilon / k) \quad (7)$$

$$R_f = A.(\overline{m_{O2}} / S).(\varepsilon / k) \quad (8)$$

The value of R_f is obtained from the two equations above and the smallest value is used in the calculations. The energy equation: The general equation of energy as:

$$\rho\frac{Dh}{Dt}-\nabla.k\nabla T-\nabla.(\sum_j Jh_j\nabla m_j)-a\mu\phi-\frac{Dp}{Dt}-S=0 \quad (9)$$

In the porous medium, the conduction flux uses an effective conductivity and the transient term includes the thermal inertia of the solid region on the medium (Hajisheikh and Vafai 2003):

$$\frac{\partial}{\partial t}[\gamma\rho_f E_f+(1-\gamma)\rho_s E_s]+\nabla.[\vec{\upsilon}(\rho_f E_f+p)]= \nabla.\left[k_{eff}\nabla T-\left(\sum_i h_i J_i\right)\right]+S_f^h \quad (10)$$

where E_f is the total fluid energy, E_s is the total solid medium energy, γ is the porosity of the medium and k_{eff} is the effective thermal conductivity of the medium.
Radiation Transfer Equation (RTE) for a gray environment at s-direction is written as follows:

$$\nabla.(I(r)r)=-(\alpha+s)I(r)+B(r)$$
$$B(r)=\alpha I_B+\frac{s}{4\pi}\int I(r')\varphi(r',r)d\Omega' \quad (11)$$

In order to solve the RTE, the P-1 radiation model is employed. For calculating the radiative properties of the mixture resulting from combustion, the Weighted Sum of Gray Gases model (WSGGM) is used. In order to create an accurate correlation between the pressure and speed in the continuity and momentum equations, the SIMPLE method is adopted. Applying the relevant equations and proper models to solve them in the calculative slope of the subject boiler (with real dimensions) is the first step. Next the identification of boundary or initial conditions of the analysis domain is taken into consideration according to the data gathered from the power plant (Table 1).Based on this data, the flowrate of each air channel stands at approximately 5.6 kg/s and each gas nozzle stands at approximately 0.47 kg/s. The inlet pressure of boiler would be considered to be atmospheric. The inlet gas temperature would be approximately 300 K and the inlet air temperature is about 600 K. A saturated steam with a pressure of 18.9MPa from drum enters the header box and after being distributed in the Platen tubes. This steam is heated inside the boiler by all modes of heat transfer. Finally, the steam is diverted from the platen superheater tubes into the junction header and collected. Temperature fluctuations from lower water wall Drum to the top Drum are 605 to 625 K ranges. Thus, constant average temperature or Dirichlet boundary condition is considered for the side walls of the boiler. Set of convergence criteriato calculate the residual of answers are presented in Table 2.

Table 1 Boundary or initial condition on analysis domain

Temperature at water wall tubes (side walls of boiler)	Pressure-temperature at inlet Platen tubes (short, medium, long)	mass flow at each gas nozzle	mass flow at each air channel	Temperature at each gas nozzle	Temperature at each air channel
615 *K*	18.9*MPa*-630 *K*	0.47 *kg/s*	5.6 *kg/s*	300 *K*	600 *K*

Table 2 Convergence criteria for calculate residual of various equations

Continuity Equation	Momentum Equation	Energy Equation	$k-\varepsilon$ Equation	RTE Equation	Species diffusion Equation
0.001	0.001	0.000001	0.001	0.000001	0.001

4. PRIMITIVE RESULTS AND DISCUSSION

After carrying out the 800 computational iterations and convergence of the equations answer, temperature of the products resulting from combustion inside the boiler reaches about 2340K (Fig. 4). The fluid flow and combustion in boiler of 320 MW power plant is simulated numerically (Fig. 4). Following the examination of the combustion process inside the boiler, the thermal analysis of platen superheater tubes was put on the agenda as the first set of superheater tubes exposed to a broad spectrum of flames resulting from combustion. The three types of platen superheater tubes with long, medium and short lengths are analyzed (Fig. 4).The Platen superheater tubes comprise the three set of twin tubes where each set constitute a single row of tubes with 100 tubes.

The main part of the heat transfer in the platen superheaters is of the radiation type, because they are located

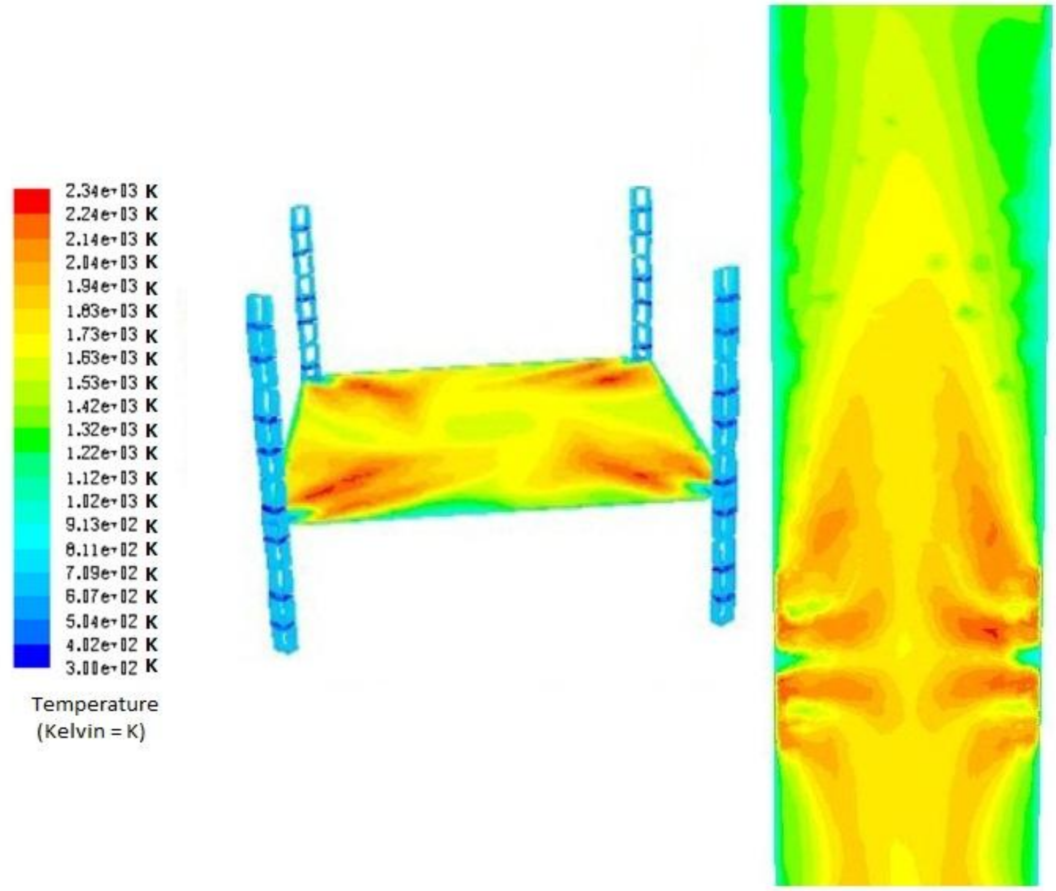

Fig. 4. Fluid flow pattern colored by the fluid temperature

at the nearest distance to the burners in comparison with the rest of superheater tube. It is fund that the convection heat transfer coefficient of the vapor in these tubes is low. The saturated vapor with temperature of 630K and pressure of 18.94 MPa flows into the platen superheater tubes from the upper header box. The superheat vapor flowing in these helical tubes undergoes a fall of pressure until the pressure of outlet header box reaches 17.73 MPa. However, the drop pressure through each tube varies according to its length and its proportional knees. In the consequential results of simulation, the three rows of the tubes under study realized the pressure of outlet header box with a proper accuracy. Considering the CFD calculations in this study, 38% of the inlet vapor passes through the short tubes, 34% moves across the medium tubes and 28% traverses the long tubes; therefore, the reported mass flow rate for the short, medium and long tubes stood at about 1.12, 1.01 and 0.81 kg/s, respectively. Based on this conclusion, the average speed of vapor in these three tubes would be 19.3 m/s, 17.5 m/s and 14.2 m/s were reported for the short, medium and long tubes, respectively. Since the mass flow rate in the short tubes is more than that of the medium and long tubes which causes the speed of vapor in short tubes to be consequentially more than speed of vapor in medium and long tubes, the value of convection heat transfer coefficient inside the short tubes would be also greater in compare with the medium and long tubes, that is the quantity of heat transfer from the crust of such tubes into the hot vapor inside them would be augmented. This inevitably leads to a temperature reduction in the crust of such tubes in extremely hot environment of the boilers' inner surface. The same results can be concluded with slighter intensity in support of the tubes with medium length in case of in. Now, with respect to the results obtained from numerical analysis and their comparison with the design temperature reported in Isfahan power plant documents. This fact has become unambiguous that thermally, where the temperature of medium and long tubes in zones such as the knees close to the outlet header would function in temperatures higher than the design temperature. The thermal variation of different types of platen superheater tubes is shown in Fig. 5. The pressure variation of superheat vapor in these tubes is shown in Fig. 6.

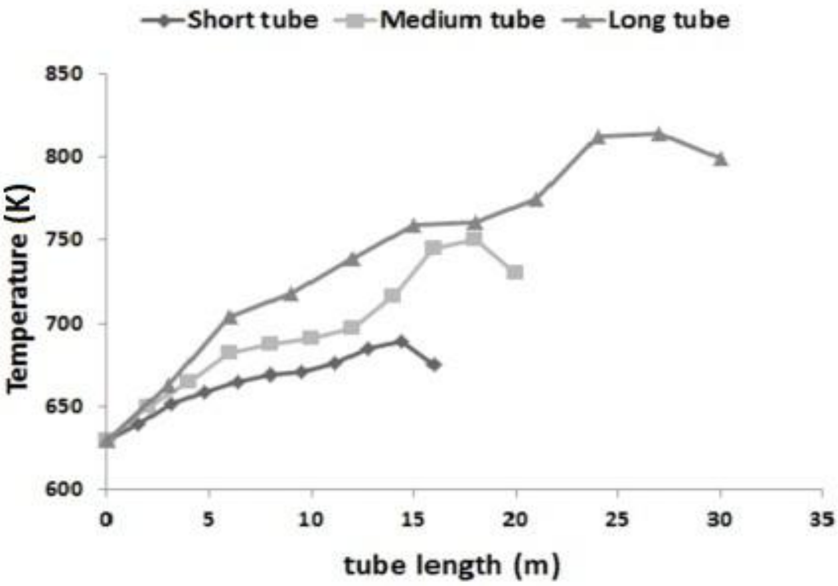

Fig. 5. Changes of temperature on superheater tubes without the thermal shields

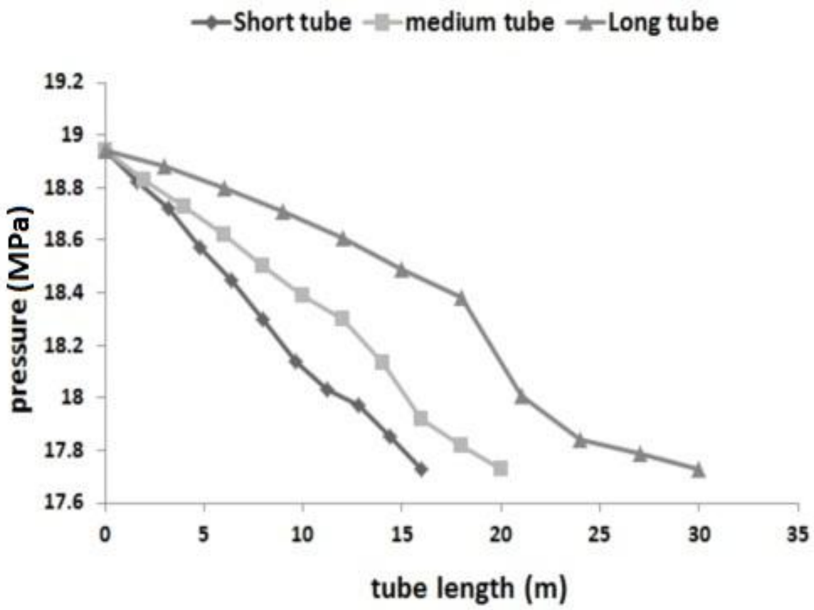

Fig. 6. Changes of vapor pressure inside the platen superheater tubes

5. SUGGESTED SOLUTION AND THE CONSEQUENTIAL RESULTS

Although In this section, the superheater tubes' crust temperature decline under certain physical circumstances localities is considered as one of the important factors in preventing them from being ripped or destroyed. For this purpose the following solutions are:

a) Changing the air channels and the fuel nozzles angle to the horizon with respect to the boiler tubes. One of the effective contributors in the thermal distribution inside the boilers is the modality of burners' arrangement or more precisely, the modality of air channels and fuel nozzles' arrangement. Here, the attempt is made to direct the thermal pyramid resulting from combustion, to the floor of the boiler by changing the air channels and fuel nozzles angle to the surface of horizon. For this purpose, the changes in angle are proposed to the manufacturer company (0 to 30 degrees). Then, with respect to the two facing paradoxical objectives, i.e. increasing the temperature of outlet vapor on one hand and decreasing the temperature of superheater tubes on the other, the optimal angle is predicted. Here, the temperature of outlet vapor from the superheater tubes and the temperature of tubes' surface are compared with from power plant data and the angle which could satisfy both the objectives is selected. For this purpose, twelve horizontal pages from the upper flat of the burners, i.e. a 14-meter height from the floor of the boiler to a 26-meter height which is a one-meter distance from the below of short platen superheater tubes were presumed.

Then the average temperature of each one of these pages was calculated. Consequently, the effect of this solution on the quantity of temperature variations inside the boiler and the specified zones was examined by changing the angle of the burners. With respect to the type of fuel (gas) and reach to the temperature needed for high pressure turbine, the optimum angles (5 to 10 degree) are predicted in between the angles that are offered by boiler composer factory (-30 to 30 degree). The heat pyramid is well decreased with changes in burner's angle toward the boiler floor (Fig. 7).

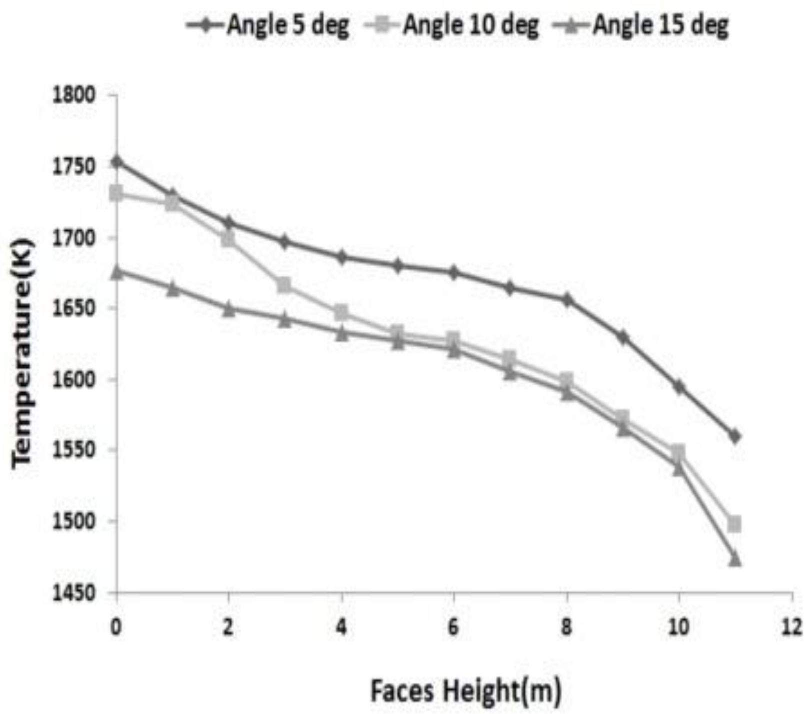

Fig. 7. Changes of temperature pyramid with change of burners angles

b) Using the thermal radiation shields for the critical zones thermally: after identifying the critical zones which are prone to the temperature maximization, the local thermal shields are used for this portion of the platen superheater tubes. Such shields can decrease the radiation heat transfer to the critical zones. Due to the fact that the main part of the heat transfer in the platen superheaters is carried out radiatively, the radiation thermal shields are found to be effective in moderating the temperature of critical zones. Moreover, they can have economical advantage as they are rather inexpensive and easy-to-use. Radiation shields are made of materials with low emissivity coefficient and high reflectivity or scattering coefficient like: steel thermal shields, ceramic thermal shields and thermal sheilds with FGM cover (Table 3).

Table 3 Properties of thermal shields

Emissivity Coefficient	*k* (*w/m.K*)	*Cp* (*J/kg.K*)	ρ (kg/m^3)
0.28	16	502	8030

In this study, only steel shields are used. After the application of a set of these thermal radiation shields on the knees of long and medium tubes of platen superheater, and comparing the temperature of three rows of the superheater tubes before and after using the thermal radiation shields, the effect of these shields are become evident for the temperature decrease in the critical bends (Fig. 8).Pit should be noted that thermal radiation shields were used only on final bends of medium and long tubes. A contour of temperature on the long tube from the platen superheater tubes is shown in Fig. 9, where a row of long tubes is shown below knees that have thermal shields.

c) Using the porous surface for the critical zones thermally: According to preliminary results obtained in this study, the bends and parts of tubes that are close to the outlet header is become overheated. In other words, with changing the angle of burners to the horizon with 10 degree or more, the horizon, the possibility of reducing temperature of the output steam to normal temperatures for Hi-pressure turbine is high.

Here, this problem is solved by applying the porous crust on the critical zone; therefore, some porous tubes with porosity of2PPI (2 porous per inch) and crust thickness of 30 mm is replaced in the critical zones. In this study, the porous crust is made of14Cr5Mo stainless steel. The overall view of porous tubes and the temperature contour of combustion products inside the porous crust are shown in Fig. 10. The temperature of critical zone of Platen tubes and hot gases resulting from combustion chamber, after using the porous crust is illustrated in Fig. 11. The conclusion of these results was reported in Tables 4 and 5.

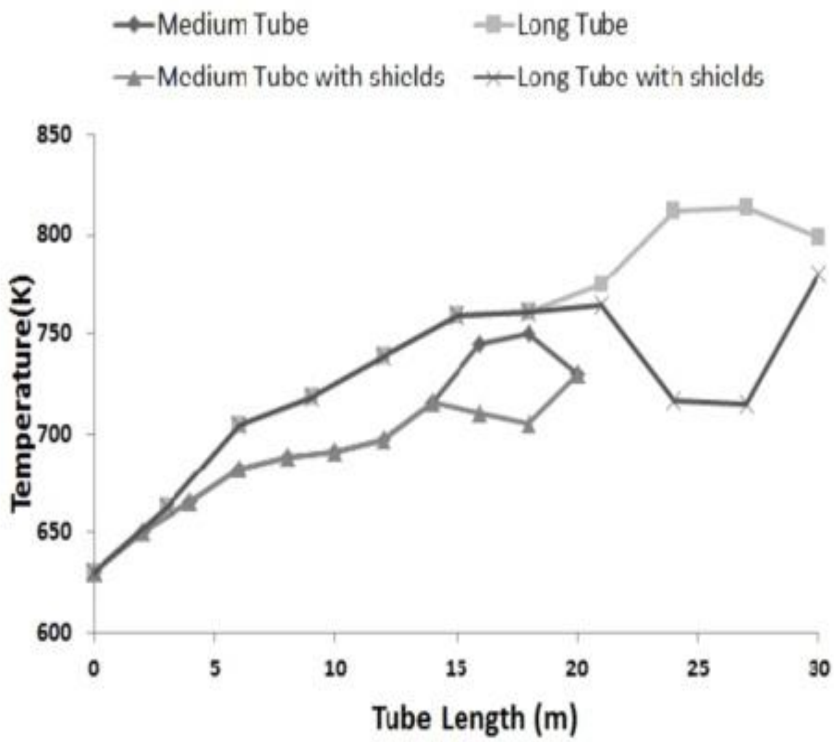

Fig. 8. Changes of temperature on platen superheater tubes with and without thermal shields

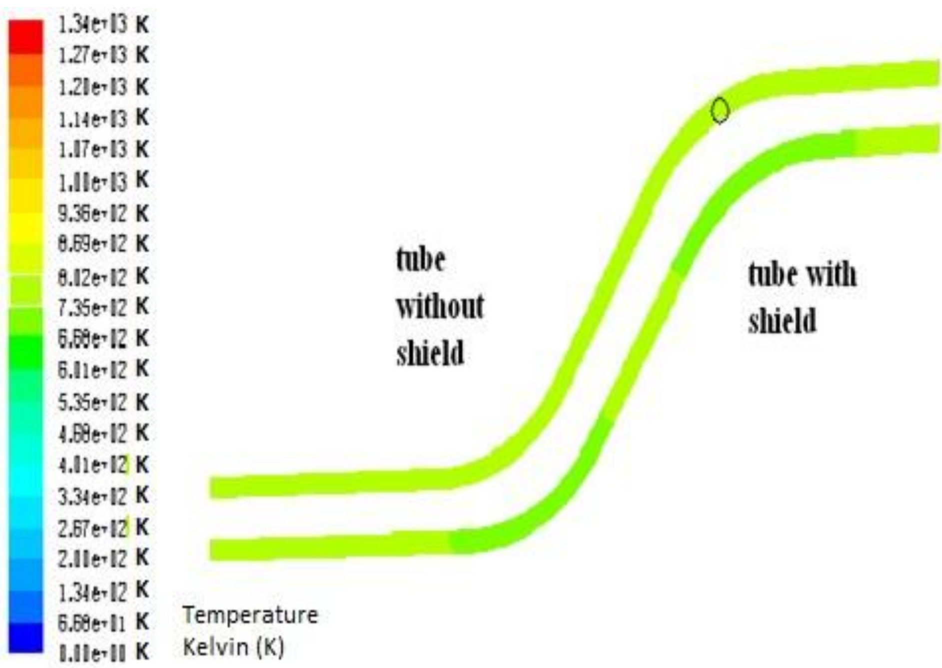

Fig. 9. Contours of temperature on the long tubes

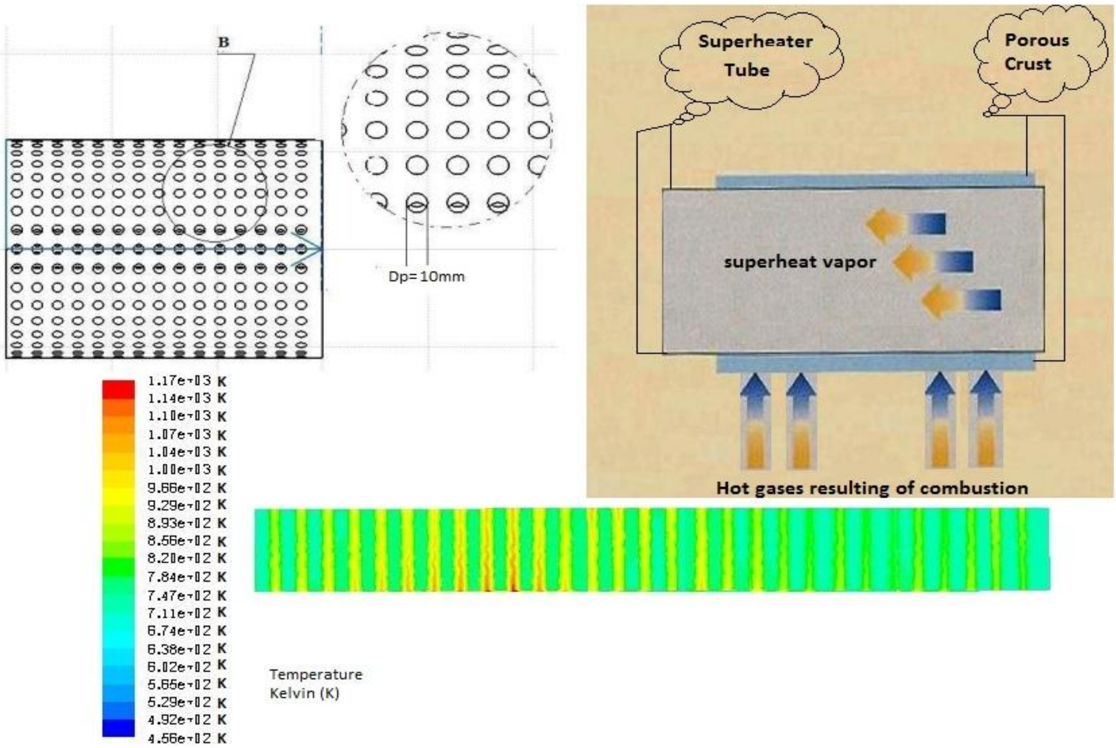

Fig. 10. Temperature contour of combustion products inside the porous crust

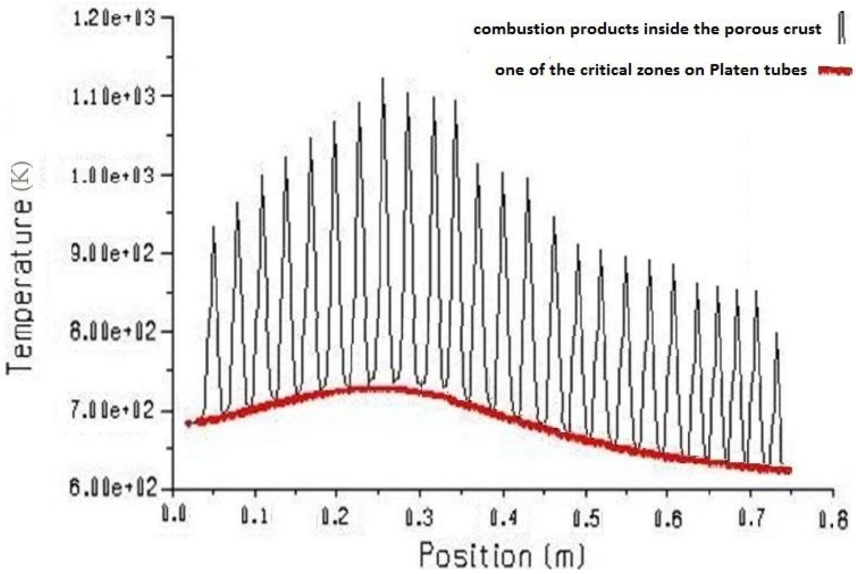

Fig. 11. Changes of temperature on critical zone with using the porous crust

Table 4 Comparing the temperature of output steam resulting from this investigation

		Short tubes	Medium tubes	Long tubes
Design temperature (Power plant's data)		663	663	663
Temperature of output steam from platen superheater tubes, *K* (present study)	Without thermal shields	668	720	794
	With thermal shields	--------	675	702
	With porous crust	--------	686	714

Table 5 Comparing the temperature of tubes crust resulting from this investigation with other papers

		Short tubes	Medium tubes	Long Tubes
Design temperature (Power plant's data)		710	710	710
Temperature of critical zones, *K* (present study)	Without thermal shields	685	767	806
	With thermal shields	--------	703	717
	With porous crust	--------	713	729
Temperature of critical zones, *K* (Rahimi et al.)	Without blow air	740	--------	810
	With blow air	680	--------	750

6. CONCLUSION

In this study, in order to solve the overheated zone problem on platen superheater tubes, using the radiation thermal shields and knees with porous crust were introduced as local solution. By applying the thermal shields and the porous crust, the concluding results of modeling would display the range of temperature reduction on the knees located at the extreme position of these tubes. By these methods, temperature reduction was reported 80K to 92K for steam inside the long tubes and 34K to 45K for steam inside the medium tubes. Also, on critical zones, temperature reduction was sensed 77K to 89K for final knees on long tubes and 53K to 63K for final knees on medium tubes. In other words, the temperature of the outlet steam from Platen superheater with porous shell is higher than outlet steam from Platen superheater with radiation shields. Temperature of porous crust on Platen tubes is less than the radiation shields. When the hot gas passes through the porous crust, in addition to radiant heat transfer, other forms of heat transfer to superheated steam in Platen tubes can be beneficial. According to the results obtained in under same circumstance (angle of burners = 5deg), using the thermal radiation shields to remove over heated points in comparison with the porous crust, are more successful. But by using the porous crust, the heat transfer rate to vapor inside the superheater is increased and there is less risk for temperature fluctuations before entering to the turbine.

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