Research and propose the bottom ash and slag cooling method for circulating coal fired boiler

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Summary: Present, our country is developing Heat power plants with CFB technology. Coal amount after burning will become ash and slag at boiler bottom with average temperature in 600°C and needs to be cooled in 80°C. This cooling equipment system must be imported from foreign countries. Therefore, author group proposed bottom ash and slag cooling technology using indirect water and heat exchange accounting method.

Keywords: Boiler bottom ash and slag cooling technology , heat exchange equipment.

1. Overview on bottom ash and slag cooling technology [5]

At present, there are many slag ash cooling technologies at CFB boiler bottom as follows:

1.1 Bottom ash and slag cooling method with direct water

Work principle: When boiler capacity is large, position of pin is replaced by ash and slag boat with big capacity, then slag ash and water mixture is pumbed to reservoir and ash yard. Strong point of this method is quick cooling, however, its weak point is using a lot of water and this method can polute the environment, occupying much area and can not reuse waste heat.

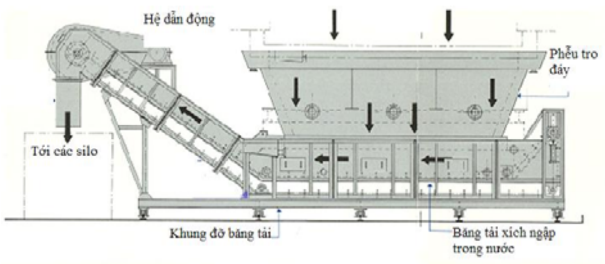


Figure 1.1. Priciple diagram of bottom ash and slag cooling method using direct water

1.2 Bottom ash and slag cooling method by direct cool air

Work principle: Hot ash and slag from bottom boiler is poured to iron conveyer and transported to air aspiration chamber under acoustic pressure (Figure 1.2). Therefore, hot ash and slag is cooled and air is dried up to 80°C and collected for heat reuse purpose. At present, this method has been not used in Vietnam yet.

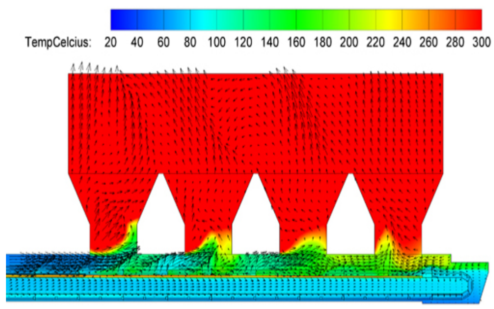
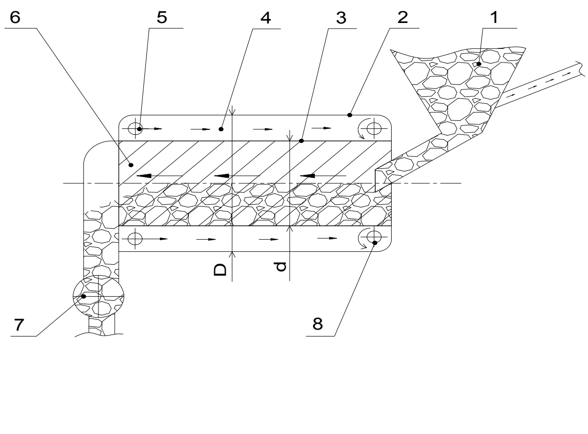


Figure 1.2. Priciple diagram of bottom ash and slag cooling method using direct cool air

1.3 Cooling method using indirect water for circulating fired boiler



Work principle: Slag and ash is cooled by Heat transformation from drum (6) through cylindrical wall (3) to cool water in water jacket (4).

1.4. Propose the ash and slag cooling method: From above analysis, we can choose bottom ash and slag cooling method with indirect water because of following advantages: The equipment is ligh and compact and can reuse waste heat from slag ash to heat water according to environmental standards.

Figure 1.3. Priciple diagram of bottom ash and slag cooling method using indirect water

2. Theoretical basis to account heat exchange in boiler bottom ash and slag cooling equipment

2.1 Convection heat exchange method: Convection heat exchange process happens when solid surface contacts with liquid one (Description on figure 2.1), according to Fourier law, relation transmission heat quantity (Q) and heat exchange condition is defined as formula [3]:

$$Q = -\lambda \int_F \mathrm{grad}\, t_f \, dF \qquad (2.1)$$

In reality, it is difficult to defilne $\mathrm{grad}\, t_f$. Therefore, we usually apply Newton formular to account:

$$Q = \alpha F (t_f - t_w),\ \mathrm{W} \qquad (2.2)$$

In which: F – Heat exchange surface; $\Delta t = (t_f - t_w)$: Heat difference (In which: t_f – liquid temprature, t_w- wall surface temprature); α - Heat emission coefficient.

From the equation (2.2) of surface element dF, the form will be:

$$\alpha = \frac{dQ}{(t_f - t_w)dF} = \frac{q}{t_f - t_w}, \mathrm{W} / m^2.degree \qquad (2.3)$$

In which: t_w – surface temprature; t_f – liquid temprature; ω – Movement speed of liquid; λ – heat conductivity factor of liquid; c_p – isobaric heat capacity of liquid;

ρ – density of liquid; μ – viscosity of liquid; φ – form of heat exchange surface; l_1, l_2, l_3 – dimension of heat exchange surface.

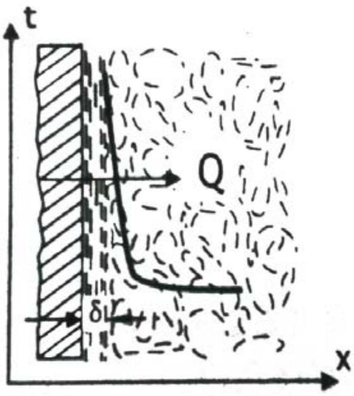


Figure 2.1. Temprature change in boundary layer when liquid absorbs the heat

2.2 Differential equations of exchange convection heat

Because convection exchange process relates to movement of liquid, it must be used equations to show. These equation includes [4]:

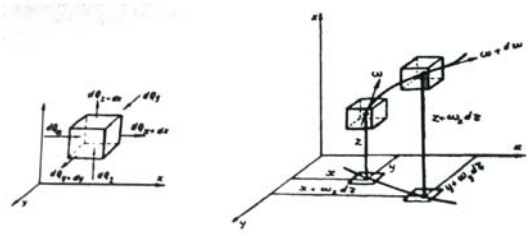
2.2.1 Heat transfer differential equation: Next to solid surface is unmovable liquid layer, it can be used Fourier Law and Newton Law: .

$$\alpha = -\frac{\lambda}{t_f - t_w}\left(\frac{\partial t}{\partial n}\right)_{n=0} \qquad (2.4)$$

In which n calorific surface normal

If accounting α requires temperature gradient and it can use energy equation.

2.2.2 Energy equation: In the liquid, we get a parallelepiped volume cell with margin of dx, dy, dz (Figure 2.4), for physical parameter elements λ, c_p



and ρ is a constant. Energy equation of liquid element moved as [1] is (2.6):

Figure 2.4. Element model of liquid

$$\frac{\partial t}{\partial \tau}+\omega_x\frac{\partial t}{\partial x}+\omega_y\frac{\partial t}{\partial y}+\omega_z\frac{\partial t}{\partial z}=a\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}\right) \quad (2.5)$$

If $\omega_x=\omega_y=\omega_z=0$, energy equation will become of heat conduction different equation of solid.

2.2.3 Movement equation

At that time, speed distribution is defined as Newton's second law: *"A force acting on a body is equal to the acceleration of that body times its mass"*. Force acting on a liquid element (figure 2.5) includes: gravity force, friction force and pressure force. Equation (2.6), (2.7), (2.8) are also called Nave-Stock equation; system 3 of this equation is differential movement equation of viscous liquid without pressure: Elevation view on x, y and z axis of general force on the element will be:

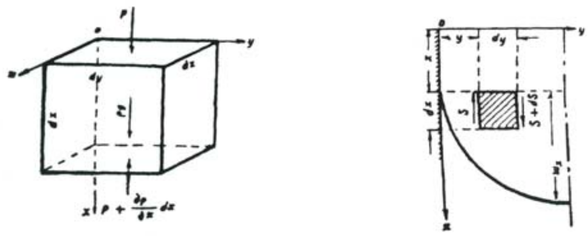


Figure 2.5. Mathematic model of force on

$$\rho\frac{D\omega_x}{d\tau}=\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2\omega_x}{\partial x^2}+\frac{\partial^2\omega_x}{\partial y^2}+\frac{\partial^2\omega_x}{\partial z^2}\right) \quad (2.6)$$

$$\rho\frac{D\omega_y}{d\tau}=\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2\omega_y}{\partial x^2}+\frac{\partial^2\omega_y}{\partial y^2}+\frac{\partial^2\omega_y}{\partial z^2}\right) \quad (2.7)$$

$$\rho\frac{D\omega_z}{d\tau}=\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2\omega_z}{\partial x^2}+\frac{\partial^2\omega_z}{\partial y^2}+\frac{\partial^2\omega_z}{\partial z^2}\right) \quad (2.8)$$

2.2.4 Continuous equation: Liquid flow of an element of parallelepiped with sides: dx, dy, dz (Figure 2.6), we consider liquid mass going through this element according to 3 directions x, y, z in time dτ.

Liquid mass going volume element dxdydz is unchanged, according to [3]: Pontinuous equation of typ:

$$\left[\frac{\partial}{\partial x}(\rho\omega_x)+\frac{\partial}{\partial y}(\rho\omega_y)+\frac{\partial}{\partial z}(\rho\omega_z)\right]dvd\tau=-\frac{\partial\rho}{\partial\tau}dvdt \quad (2.9)$$

When: ρ=const, Continuouse quation following:

$$\frac{\partial\omega_x}{\partial x}+\frac{\partial\omega_y}{\partial y}+\frac{\partial\omega_z}{\partial z}=0 \quad (2.10)$$

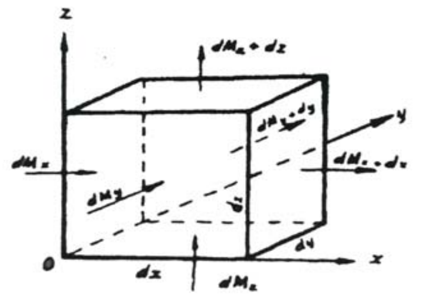


Figure 2.6. Model of liquid element liquid element

2.2.5 Single-valued condition: Differential equation needs single-valued condition, including: Geometric condition; physical condition; boundary condition and time condition.

2.3 Heat transfer through cylindrical wall [1]

On the basis of technical proposal at (1.4), it shows that tubular cooling equipment with heat transfer

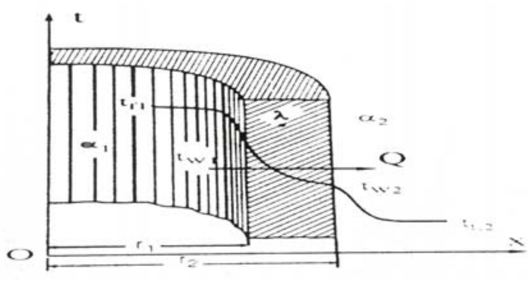


Figure 2.7. Heat transfer model through cylindrical wall

through abutment wall. It supposes that there is a abutment wall with length of L, internal diameter d_1 external diameter d_2, the wall has heat conduction factor λ. Heat liquid in the pipe has temperature of t_{f1}, cold liquid outside the pipe has temperature of t_{f2}. Temperatures of 2 wall surfaces unknown : t_{w1} and t_{w2} (Figure 2.7). Heat dimension coefficient of hot liquid is α_1 and that of cool liquid is α_2. According to [3], heat dimension coefficient of k_L for liquid is:

$$k_L = \frac{1}{\frac{1}{\alpha_1 d_1} + \frac{1}{2\lambda}\ln\frac{d_2}{d_1} + \frac{1}{\alpha_2 d_2}}, \text{ W/m degree} \qquad (2.11)$$

In which: heat transfer resistance: $\frac{1}{2\lambda}\ln\frac{d_2}{d_1}$ and heat emission resistance: $\frac{1}{\alpha_1 d_1}$ and $\frac{1}{\alpha_2 d_2}$.

For multilayer wall: $$\frac{1}{k_L} = \frac{1}{\frac{1}{\alpha_1 d_1} + \sum_{i=1}^{n}\frac{1}{2\lambda_i}\ln\frac{d_{i+1}}{d_i} + \frac{1}{\alpha_2 d_{n+1}}} \qquad (2.12)$$

$$q_L = k_L \pi \left(t_{f1} + t_{f2}\right), \text{ W/m} \qquad (2.13)$$

If we know q_L replace it to the formula (2.13) we alternatively find t_{w1} and t_{w2}:

$$t_{w1} = t_{f1} - \frac{q_L}{\pi}\frac{1}{\alpha_1 d_1} \quad \text{and} \quad t_{w2} = t_{f2} - \frac{q_L}{\pi}\frac{1}{\alpha_2 d_2}$$

3. Conclusion: Base on over analysis, we can go to following conclusion:

- Choose bottom ash and slag cooling technology for circulating coal fired boiler using indirect water cooling method by equipment shel and tube type;
- Applied convention heat exchange differential equations to account unknow tempratures of 2 wall serfaces: t_{w1} và t_{w2} as basis to account necessary heat quantity to transfer through tube wall;
- Above proposed accounting method can be applied to account design of bottom ash and slag cooling equipment for circulating coal fired boiler which requires necessary real application to replace imported equipments in our country.

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