CONTROL OF THE WATER TEMPERATURE AT ECONOMIZER FOR THE 420 t/h BOILER

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Abstract: In this papers I study the water temperature of the economizer. The 420 t/h boiler, fueled by lignite, whose mathematical model is created, is a part of the thermal block of 50Mw, and is feeding a condesation turbine and adjustable plugs. The economizer is the type that lacks partial vaporization, the water temperature at the exit from this being inferior to the saturation temperature. The water goes through the economizer from the bottom up, against the burning gases. These simulations were made using the Matlab Simulink libraries.

Keywords: boiler,economizer,temperature, pipe, heat, burning gases

1. A DESCRIPTION OF THE BOILER. GENERAL MATTERS

The 420 t/h boiler, 13.7 Mpa, 823 K, is desingned to function with the turbogenerator group with D-type counterpressure of 50 MW. It is a natural circulation boiler with two ways for the gases placed as a semi-Π. The boiler is suspended at its topmost side by a metallic construction, allowing free dilation downwards.
The boiler will use two types of fuels:
- lignite, with a medium inferrior calorical power of 1550 kcal/kg and the characteristics indicated in the lignite analysis;
- fuel oil, with a calorical power of 9250-9400 kcal/kg and the characteristics indicated in the fuel oil analysis.

1.1 The economizer

It is a heat exchange surface (through convection) and is placed in the II way of the burning gases. It has the role of preheating the feeding water which enters the boiler from 503K (230^{o}C) to 592 K (319^{o}C).
The water goes through the economizer from the bottom up, against the burning gases.
Constructively speaking, the economizer is made up of two packs of coils. The lateral step of coils is 80mm. It is sistained in the gas path way through pipes. This economizer is formed of the following elements:
- entry collector
- 128 double coils
- exit collector

The surface of the economizer is of 5567m^2. In full load it is has a global coefficient of heat exchange of 44.9 kcal/m^{2}hgrad, and a medium temperature difference of 138^{o}C and recives 34.50Gcal/h; the enthalpy of the water at the entrance is 237.2 kcal/kg and at the exit is 321 kcal/kg.
The pipes ar 32*4mm in diametre and 32*5mm. Both parts of the economizer have a metallic wight in pipes of over 237 tons.
The length of the pipes makes up the surface which is evaluated at 79000 m, adding to a total interior volume of about 33m^3.

2. THE TECHNOLOGICAL PROCESS

The economizer is the type that lacks partial vaporization, the water temperature at the exit from this being inferior to the saturation temperature. The heat giver by the gases to the economizer wall is given by the equation:

$$Q_{Ec,g} = K_{Ec} \cdot M^{0.61}\left(T_{ge} - T_m\right)$$

with:

$Q_{Ec,g}$ - the heat given by the burning gases to the economizer
$M^{0.61}$ - the flow capacity of the burning gases
T_{ge} - the temperature of the burning gases
T_m - the temperature of the metal pipe of the economizer
K_{Ec} – constant

2.1. The equations of the economizer

Taking into account the things showed after fgure 1 we have the following equations for the economizer, which in a first stage are approximated with one exchange surface.

a. The continuity equation in the economizer for the water:

$$M_{wi} - M_{we} = \frac{d(V_{Ec} \cdot \rho_{We})}{dt} \quad (1)$$

M_{wi}, M_{We} – the flow capacity of the water, entry and exit from the economizer
V_{Ec} – the volume in the economizer for the water
ρ_{we} – the density of the water (exit)

b.Thermal ballance equation for the water:

$$M_{wi} \cdot h_{Ec,i} + Q_{Ec} - M_{we} \cdot h_{Ec,e} = \frac{d(V_{Ec}\rho_{we}h_{Ec})}{dt} \quad (2)$$

c. Heat ballance for the pipe walls:

$$Q_{Ec,g} - Q_{Ec} = m_{Ec} \cdot c_m \frac{dT_m}{dt} \quad (3)$$

where:
m_{Ec} - the weight of the metallic pipes
c_m - the specific heat of the metallic pipes
T_m - the temperature of the metal pipe of the economizer
$Q_{Ec,g}$ - the heat given by the burning gases to the economizer

d. Heat amount give by the water to the wall, by convection:

$$Q_{Ec} = \left[2900(1 + 0.014T_{Ec})M_{wi}^{0.85}\right] \cdot A(T_m - T_{Ec}) \cdot F \quad (4)$$

or:

$$Q_{Ec} = K_{Ec} \cdot M_{wi}^{0.85}\left(T_m - T_{Ec,e}\right) \quad (5)$$

$$K_{Ec} = 2900\ (1 + 0.014\ T_{Ec})A^{0.85} \frac{F}{\rho_w^{0.85}} \quad (6)$$

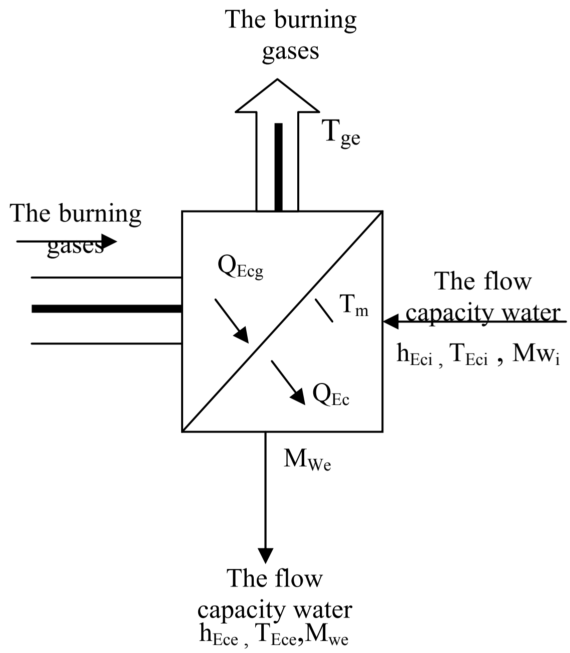

Fig.1 The scheme of the economizer

Note:
$T_{Ec,e}$ – the temperature of the water of the economizer, at exit
A – the section from flowing of the water
ρ_w – the water density

e.Variation of the enthalpy of the water by the temperature:

$$h_{Ec,i} = \frac{\partial h_{Ec,i}}{\partial T_{Ec,i}} \cdot \Delta T_{Ec,i} \quad (7)$$

f. Variation of the enthalpy of the water at the exit:

$$h_{Ec,e} = \frac{\partial h_{Ec,e}}{\partial T_{Ec,e}} \cdot \Delta T_{Ec,e} \quad (8)$$

g. Variation of the specific density of the water at the exit:

$$\Delta\rho_{Ec,e} = \frac{\partial \rho_{Ec,e}}{\partial T_{Ec,e}} \cdot \Delta T_{Ec,e} \quad (9)$$

h. The amount of heat given by the burning gases to the pipe metal:

$$Q_{Ec,g} = K_{Ec,g} \cdot M^{0.61}\left(T_{g,e} - T_m\right) \quad (10)$$

The above equations are nonliniar and can be liniarizer for small variations aroung the regime state.

2.2 The numerical equations of the economizer

The boiler economizer is made of two bodies. As the constructive data is known, the economizer is considered one entity.

a.Continuity equation for the water:

$$M_{wi} - M_{we} = \frac{d\left(V_{Ec} \cdot \rho_{w,e}\right)}{dt} \qquad (11)$$

M_{wi}=420 t/h

M_{we}=420 t/h

V_{Ec}=33 m^3

ρ_w=1:0.0013746 kgf/m^3

b.Thermal ballance equation for the water:

$$M_{wi}h_{ec,i} + Q_{Ec} - M_{we}h_{Ec,e} = \frac{d\left(V_{Ec} \cdot \rho_{We} \cdot h_{Ec,e}\right)}{dt} \qquad (12)$$

At 100% load:

Q_{Ec}=34.5 Gcal/h

$h_{Ec,i}$=237.2 Kcal/Kg

$h_{Ec,e}$=321 Kcal/Kg

c. Heat ballance for the pipe walls:

$$Q_{Ec,g} - Q_{Ec} = m_{Ec}c_m \frac{dT_m}{dt} \qquad (13)$$

At 100% load:

T_m-T_{Ec}=20°

m_{Ec}=237000 Kg

c_m=0.114 Kcal/Kg.grd

d. Heat amount ceased to the water by the wall, by convection:

$$Q_{Ec} = K_{Ec}M_{Wi}^{0.85}\left(T_m - T_{Ec}\right) \qquad (14)$$

At 100% load:

$$Q_{Ec} = K_{Ec}M_{wi}^{0.85} \cdot 20$$

M_{wi}=420 t/h

K_{Ec}=1.415*10^{-2} Gcal/grd.t.h^{-1}

e, f, g. Variations of the enthalpy and specific weight of the water.

h.Heat amount given by the burning gases to the pipe metal:

$$Q_{Ec,g} = K_{Ec,g}M^{0.61}(T_{g,e} - T_m)$$

2.3 The liniarized equations

For the simplified case, they are liniarized around the 100% load and we obtaine the equations for the economizer:

a.Continuity equation for the water:

$$\Delta M_{wi} - \Delta M_{we} = V_{Ec}\frac{d\Delta\rho_{Ec,e}}{dt}\frac{3600}{1000}$$

with:

V_{Ec}=33m^3

$$M_{wi} - M_{we} = 118.8\frac{d\Delta\rho_{Ec,e}}{dt}$$

ΔM_{wi}, ΔM_{we}- the flow capacity of the water, entry and exit from the economizer, t/h

Δ ρ_w – the specific density of the water, at exit, kg/m^3

t-time (s)

b.Thermal ballance for the water:

$$\Delta M_{wi}\overline{h}_{Ec,i} + \overline{M}_{wi}\Delta h_{Ec,i} + \Delta Q_{Ec} - \overline{h}_{Ec}\Delta M_{we} -$$
$$- \overline{M}_{we}\Delta h_{Ec} = V_{Ec}\overline{\rho}_{Ec,e}\frac{d\Delta h_{Ec}}{dt} + V_{Ec}\overline{h}_{Ec,e}\frac{d\Delta\rho_{Ec}}{dt}$$

Numerical:

$$0.2372\Delta M_{wi} + 0.420\Delta h_{Ec,i} + \Delta Q_{Ec} - 0.3210 \cdot$$
$$\cdot \Delta M_{we} - 0.420\Delta h_{Ec} = 86.4\frac{d\Delta h_{Ec,e}}{dt} + 38.1\frac{d\Delta\rho_{Ec,e}}{dt}$$

Q_{Ec}- the flow capacity heat

h_{Ec}- the enthalpy of the water at the exit to the economizer

c. The heat ballance for the pipe walls:

$$\Delta Q_{Ec,g} - \Delta Q_{ec} = 97.265\frac{d\Delta T_m}{dt} \qquad (15)$$

d. Amount of heat given to the water by convection:

$$\Delta Q_{Ec} = K_{Ec}(\overline{M}_{wi})^{0.85}(\Delta T_m - \Delta T_{Ec}) +$$
$$+ 0.85K_{Ec}(\overline{M}_{wi})^{-0.15}(\overline{T}_m - \overline{T}_{Ec})\Delta M_{wi}$$

$$\Delta Q_{Ec} = 1.415 \cdot 10^{-2}(420)^{0.85}(\Delta T_m - \Delta T_{Ec}) +$$
$$+ 0.85 \cdot 1.415 \cdot 10^{-2}(420)^{-0.15} \cdot 20\Delta M_{wi}$$

$$\Delta Q_{Ec} = 1.7249(\Delta T_m - \Delta T_{Ec}) + 0.0698\Delta M_{wi}$$

e. The variation of the enthalpy of the water depending on temp.

Starting from the 7th equation:

$$h_{Ec,i} = 1.14\Delta T_{Ec,i}$$

f.Variation of the water enthalpy at the exit, at 100% load:

$$\Delta h_{Ec,e} = 1.77\Delta T_{Ec,e}$$

g. Amount of heat given by the burning gases to the metal of the pipes, at 100% load:

$$\Delta \rho_{c,e} = -3.54\, \Delta T_{Ec,e}$$

2.4 The model of the economizer

Equation of the economizer:

1. $$\Delta M_{wi} - \Delta M_{we} = a_1 \frac{d\Delta\rho}{dt}$$

a_1=118.8

2. $$a_2 \Delta M_{wi} + a_3 \Delta h_{Ec,i} + \Delta Q_{Ec} - a_4 \Delta M_{we} - - a_5 \Delta h_{Ec,e} = a_6 \frac{d\Delta h_{Ec,e}}{dt} + a_7 \frac{d\Delta\rho}{dt}$$

a_2=0.2372
a_3=0.420
a_4=0.3210
a_5=0.420
a_6=86.4
a_7=38.1

3. $$\Delta Q_{Ec,g} - \Delta Q_{Ec} = a_8 \frac{d\Delta T_m}{dt}$$

a_8=97.265

4. $$\Delta Q_{Ec} = a_9 (\Delta T_m - \Delta T_{Ec,e}) + a_{10} \Delta M_{wi}$$

a_9=1.7249
a_{10}=0.0698

5. $$\Delta h_{Ec,i} = a_{11} \Delta T_{Ec,i}$$

a_{11}=1.14

6. $$\Delta h_{Ec,e} = a_{12} \Delta T_{Ec,e}$$

a_{12}=1.77

$$\Delta\rho = -a_{13} \Delta T_{Ec,e}$$

a_{13}=3.54
We eliminate the insignificant size and we choose for state size:
$x_1=T_m$
$x_2=T_{Ec,e}$
entry size:
$Q_{Ec,g}$
M_{wi}
$T_{Ec,i}$
exit size:
$T_{Ec,e}$
M_{we}

$$\dot{x} = A_{Ec} x + B_{Ec} u$$
$$y = C_{Ec} x + D_{Ec} u$$

$$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} T_m \\ T_{Ec,e} \end{bmatrix}$$

$$u = \begin{bmatrix} Q_{Ec,g} \\ M_{wi} \\ T_{Ec,i} \end{bmatrix}$$

$$y = \begin{bmatrix} T_{Ec,e} \\ M_{we} \end{bmatrix}$$

$$A_{Ec} = \begin{bmatrix} -0.017734 & 0.0177340 \\ 0.011279 & 0.0161403 \end{bmatrix}$$

$$B_{Ec} = \begin{bmatrix} 0.0102812 & -7.17627 \cdot 10^{-4} & 0 \\ 0 & -0.9155 \cdot 10^{-4} & 0.00313 \end{bmatrix}$$

$$C_{Ec} = \begin{bmatrix} 0 & 1 \\ 4.7434 & -6.7878 \end{bmatrix}$$

$$D_{Ec} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0.961 & -0.0877 \end{bmatrix}$$

3.THE EXPERIMENTAL RESULTS

I implemented the simulation structure, using Matlab programs, in conformity with the structure of economizer. Also, I simulated the control system of the temperature T_{Ec} at the output of the economizer. The modeling results are presented in fig.2, fig.3, fig.4., fig.5., fig.6 and fig.7.

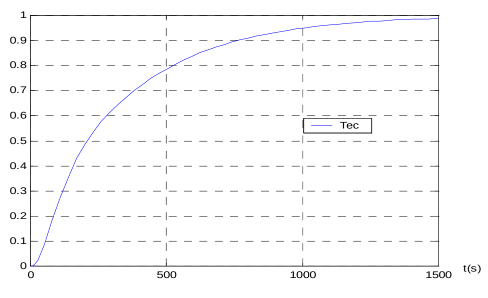

Fig.2 Feed back by M_W

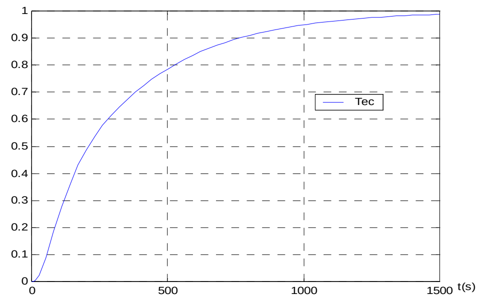

Fig.3 Feed back by $Q_{Ec,g}$

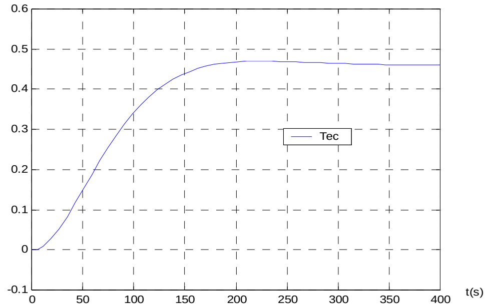

Fig.4 Entry step by $Q_{Ec,g}$

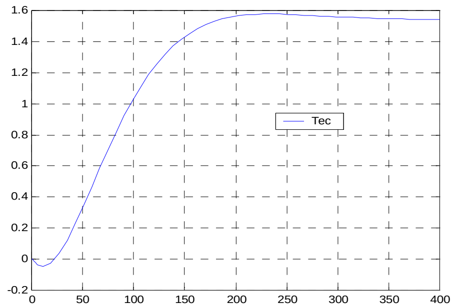

Fig.5 Entry step by M_W

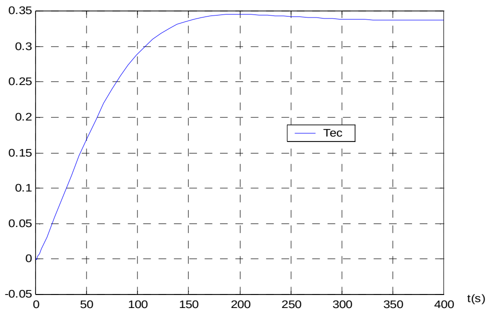

Fig.6 Entry step by T_{Ec}

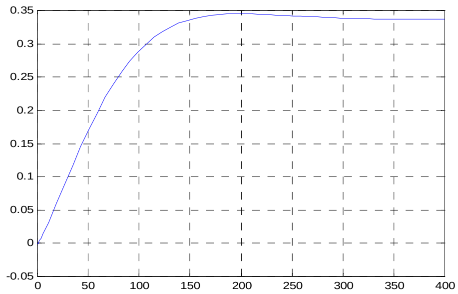

Fig.7 Feed back by T_{Ec}

4. CONCLUSION

In the practical implementation of control systems for power plant, it is necessary to realize a lot of simulation experiments, to validate the synthesis programs.

This paper offer a solution for study the industrial control systems for boiler components, with application in modeling and process.

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