Program Design and Calculation Example of Direct Fired Pulverizing System with Medium Speed Mill

Yuanyuan Li*, Zhenning Zhao and Qingfeng Zhang
North China Electric Power Science Research Institute Co. Ltd, Beijing, China

*Corresponding author e-mail: 285983963@qq.com

Abstract. The large amount of calculation and iteration for manual thermal calculation are easily lead to errors. In this paper, based on the direct fired systems with medium speed mill, a common computing program of coal pulverizing system is written by Visual C++ 6.0. The program can automatically gain physical parameter of air, vapour, gas and coal and solve some problem of cyclic iteration. It implements the organic combination of manual intervention and computer, enhances the accuracy and speed and save the cost of calculation.

1. Introduction
With the development of the electric power industry in China, the installed capacity is increasing, the power structure will not change for a long time. The thermal power unit is gradually developing towards the direction of large-scale and clean production. In recent years, China impels the electric power reform. Improve power generation efficiency and power management and reduce the cost of power generation have become the primary task of thermal power enterprises. Now, coal-fired power generation is still the main way of generating electricity. The coal pulverizing system is one of the most important accessory equipment of coal-fired power plant. The electricity consumption is large, which makes up approximately 15%-25% of total electricity consumption [1]. The performance and operation of coal pulverizing system is directly affect the economy and safety of the coal-fired power plant.

The coal pulverizing system includes low speed ball mill, medium speed mill and high-speed mill. Judging from extant units in our country, the single in-out ball mills are usually equipped with intermediate storage pulverizing system. The double in-out ball mills and the medium speed mill are usually equipped with direct fired pulverizing systems. The past three decades, some new-type coal, such as Shenhua coal, has been mined. These new-type coal have breeziness thermodynamic property and more suited to medium speed mill. So medium speed mills are extensively used owing to its characteristic of high adaptability and safety [2, 3].

Usually, thermal calculation is required when the pulverizing system is designed or the coal type and conditions is changed. The large amount of calculation and iteration for manual thermal calculation are easily lead to errors [4]. In this paper, based on DL/T5145- 2012 Technical code for design and calculations of coal pulverizing system of fossil-fired power plant, a common computing program of the direct fired systems with medium speed mill is written by Visual C++ 6.0. Some physical parameter of air, vapor, gas and coal can get and some problem of cyclic iteration can be solve through the program. The program enhances the accuracy and speed and save the cost of calculation.
2. Mathematical model and the function of program

2.1. Fuel characteristic judgment
Coal is the main fuel of coal-fired power plant. There are many classification methods of coal in China. The content of components is different for different coal. The sum for each content of component should be equal to 100, such as formula (1).

\[ C_c + H_c + O_c + N_c + S_c + M_c + A_c = 100 \]  

The main function of the fuel class as follow: judge whether the sum equal to 100. If the sum equal to 100, the program continue to calculate and output “The sum of content is right and continue to calculate”; otherwise output “The sum of content is wrong and stop calculate”; Judge the type of coal according to the component content.

2.2. Milling force calculation
The milling force is related to moisture, grindability index, and ash and coal fineness. It is equal to basic force time’s correction coefficient. The correction coefficient includes grindability index, coal fineness correction coefficient, moisture correction coefficient, ash correction coefficient, coal particle size correction coefficient and so on. The relevant charts are fitted to mathematical formula in order to help programming. The milling force changes when coal type changes. The main function of the milling force class as follow: Set the type of mill; Calculate correction coefficient according to the type of mill; Calculate the milling force.

2.3. Heat balance calculation of pulverizing system
The study goal of heat balance calculation of pulverizing system is determine the temperature and mass of desiccant under safe and economic operation. The starting position of pulverizing system calculation is inlet of raw coal. The starting position of desiccant is the pipe cross section of desiccant enter mill. The terminal position of pulverizing system calculation is the entrance of the mill exhauster. In the thermal calculation, the pulverizing system is regarded as a whole system. The thermal calculation of pulverizing system should follow the conservation of heat and mass. That is to say, the heat and mass entering the system is equal to leaving the system. The calculation methods are as follow:

\[ q_{agl} + q_{le} + q_s + q_{mac} + q_{rc} = q_{ev} + q_{ag2} + q_f + q_5 \]

\[ g_1 + m_{le} + m_s + \Delta M = g_2 \]

\( q_{agl} \): physical heat of the desiccant, kJ/kg; \( q_{le} \): physical heat of leaking cold air, kJ/kg; \( q_s \): physical heat of the seal air, kJ/kg; \( q_{mac} \): milling mechanical heat, kJ/kg; \( q_{rc} \): physical heat of raw coal, kJ/kg; \( q_{ev} \): The heat consumed by raw coal water evaporation, kJ/kg; \( q_{ag2} \): exhaust air heat; kJ/kg; \( q_f \): heat of heating fuel, kJ/kg; \( q_5 \): loss of heat dissipation of equipment, kJ/kg.

The mass conservation of desiccant:

\[ g_1 + m_{le} + m_s + \Delta M = g_2 \]

\( g_1 \): Initial desiccant mass, kg/kg; \( m_{le} \): leaking cold air mass, kg/kg; \( m_s \): the seal air mass, kg/kg;
\( \Delta M \): the evaporated moisture mass of raw coal, kg/kg; \( g_2 \): terminal desiccant mass, kg/kg.

In the actual operation of power plant units, the temperature of cold air, hot air and mixed air can get from the DCS dial. But the ratio of cold air, hot air is not get. So the ratio of cold air, hot air need to be calculated by program. The temperature of cold air is \( t_c \), the temperature of hot air is \( t_h \), the ratio of cold
air is \( r_c \), the ratio of hot air is \( r_h \). The temperature of hot air rise and the temperature of cold air drop after hot air and cold air mix. The heat release by the hot air is equal to the heat absorb by the cold wind. According to the conservation of heat, it can be obtained:

\[
r_c \times (t_h - t_c) = r_h \times (t_h - t_i)
\]

(4)

The ratio of hot air:

\[
r_h = \frac{t_i - t_c}{t_h - t_c}
\]

(5)

The ratio of cold air:

\[
r_c = 1 - r_h = \frac{t_h - t_i}{t_h - t_c}
\]

(6)

Ideally, the heat entering the system is equal to leaving the system. But there are much loss during the combustion process, so thermal deviation rate need to be calculated:

\[
\frac{|q_{in} - q_{out}|}{q_{in}}
\]

(7)

The main function of heat balance calculation class as follow: calculate entering heat, leaving heat and thermal deviation rate. If the thermal deviation rate is greater than or equal to 0.1, the program output” The result of heat balance calculation is wrong”, otherwise output” The result of heat balance calculation is right”.

During the operation process of direct fired pulverizing systems with medium speed mill, security and economy should be considered. The overtop temperature of primary air in mill outlet can easily lead to blast and the low temperature can easily lead to insufficient drying capacity. So reasonable and safe temperature of air in mill outlet and inlet are need to set.

2.4. **Using air coal ratio to check output**

The output of the pulverizing system is directly related to the stability of combustion and the output of the boiler unit. During the operation process of direct fired pulverizing systems with medium speed mill, air coal ratio can get from the DCS dial and the output of the pulverizing system should be checked. Suppose output is 35t/h, calculate air coal ratio and compare with actual air coal ratio. If the result is greater than or equal to 0.1, continue to calculate, otherwise stop to calculate.

2.5. **Using initial desiccant mass to calculate initial desiccant temperature**

The initial desiccant temperature is the temperature of starting position of heat balance calculation. Suppose primary air temperature is 220℃, calculate entering heat, leaving heat. Calculate primary air temperature and compare with hypothetical primary air temperature. If thermal deviation is greater than or equal to 0.1, the program output” The result of heat balance calculation is wrong”, reorganize the primary air temperature and calculate, otherwise output” The result of heat balance calculation is right”, stop calculate and output primary air temperature value.

2.6. **Using initial desiccant mass to calculate initial desiccant mass**

Suppose primary air mass is 1.5 times as much as coal feed, primary air temperature is known. Calculate primary air mass and entering heat, leaving heat. If thermal deviation is greater than or equal to 0.1, the program output” The result of heat balance calculation is wrong”, reorganize the hypothetical primary air mass and calculate, otherwise output” The result of heat balance calculation is right”, stop calculate and output hypothetical primary air temperature mass.
2.7. Using initial desiccant mass to calculate initial desiccant temperature

The main function of state parameter calculation of terminal desiccant class as follow: calculate density, actual volume, humidity ratio, dew point, oxygen content of desiccant and check the drying capacity of desiccant. The drying capacity of desiccant should be equal to coal feed. If drying capacity is greater than coal feed, the program output" excessive drying capacity”, otherwise output” insufficient output”. The excessive drying capacity will lead to excessive outlet temperature of mill and unsafe transportation and storage of pulverized coal. So initial temperature of desiccant should be reduced. The insufficient output will lead to lower milling force and need to rise initial temperature of desiccant.

3. Example of calculation

In this study, the A mill of NO.1 unit of a power plant is selected as an example. The unit is 350MW supercritical coal-fired heating unit, and the pulverizing system is a positive pressure direct fired pulverizing systems with medium speed mill, and the mill is MPS180HP-II mill, which is made by Changchun generating equipment plant.

Input coal composition contents to the program, main page shows” The sum of content is right and continue to calculate”. Through program judge, the coal is low ash, low moisture and low sulfur bituminous coal, and the result is shown in Fig.1.

![Figure 1. Main page shows](image1)

The mill is MPS180HP-II mill and basic force is 59.78t/h. Input mill type, basic force, grindability index and coal fineness to the program, the result of main page shows” milling force is 58.15t/h”.

The dynamic monitoring screen is shown in Fig.2. The hot air temperature of mill inlet is 321.34°C and the cold air temperature is 226.90°C. The result of main page shows” the ratio of hot air is 67.42% and the ratio of hot air is 32.58%”.

![Figure 2. Dynamic monitoring screen](image2)
The calculation results of program are shown in Table 1 and Fig.1. From the results of computation, entering total heat to pulverizing system is 21407841kJ/h, leaving total heat is 17124046kJ/h. The entering total heat is larger than leaving total heat and thermal deviation rate is 0.2, the program output” The result of heat balance calculation is wrong”. So cold air door and hot air door should be adjusted in order to optimal operation under the condition of reasonable outlet temperature and drying capacity. The result of main page shows “the drying capacity is 52.06t/h”. The drying capacity is less than milling force, the program output” insufficient output”.

4. Conclusion
In this paper, based on DL/T5145- 2012 Technical code for design and calculations of coal pulverizing system of fossil-fired power plant, a common computing program of the direct fired systems with medium speed mill is written. The main conclusions are as follows:

a) Through the program, some physical parameter of air, vapor, gas and coal can get and some problem of cyclic iteration can be solve .The program is convenient and practical, and enhances the accuracy and speed and save the cost of calculation.

b) Select the A mill of NO.1 unit of a power plan as an example. Input coal composition contents, environmental parameters and dial data to the program, the results show that, the coal is low ash, low moisture and low sulfur bituminous coal.

c) The results show that, calculated initial and terminal desiccant temperature are basically as same as the actual values.

d) Air coal ratio check results show that, the actual air coal ratio is larger than the calculated value. The result of heat balance calculation results show that, the entering total heat is larger than leaving total heat and thermal deviation rate is 0.2, the program output” The result of heat balance calculation is wrong”. The result of output calculation results show that, the calculated output is larger than actual feed coal. The result of drying capacity show that, the drying capacity is 52.06t/h and less than milling force, the program output” insufficient output”. In view of the above conditions, it is suggested that the

| Name                                      | Symbol | Unit   | Value      |
|-------------------------------------------|--------|--------|------------|
| Physical heat of desiccant                | $q_{ag1}$ | kJ/h   | 20306094   |
| Physical heat of row coal                 | $q_{rc}$  | kJ/h   | 0          |
| Physical heat of seal air                 | $q_{s}$   | kJ/h   | 97898      |
| Milling mechanical heat                   | $q_{mac}$ | kJ/h   | 596400     |
| Physical heat of leaking cold air         | $q_{le}$  | kJ/h   | 407449     |
| Total entering heat                      | $q_{in}$  | kJ/h   | 21407841   |
| The evaporated moisture mass of raw coal  | $\Delta M$ | kg/kg | 0.059      |
| The heat consumed by raw coal water evaporation | $q_{ev}$ | kJ/h | 6011058    |
| Exhaust air heat                          | $q_{ag2}$ | kJ/h   | 7899469    |
| The heat of heating fuel                  | $q_{t}$   | kJ/h   | 2785363    |
| Loss of heat dissipation of equipment     | $q_{out}$ | kJ/h   | 17124046   |
| Milling force                             | $B_M$    | t/h    | 33.218     |
| Initial desiccant temperature             | $t_1$    | °C     | 219.31     |
| Initial desiccant mass                    | -        | t/h    | 68.35      |
| Terminal desiccant mass                   | $g_2$    | kg/kg  | 2.68       |
| Terminal desiccant volume                 | $V_2$    | m³/kg  | 1.47       |
| Terminal desiccant density                | -        | kg/m³ | 1.81       |
| Humidity ratio of terminal desiccant       | $d_2$    | g/kg   | 32.80      |
| Oxygen content of terminal desiccant       | -        | m³/kg | 0.42       |
operating parameters of mill should be optimized under the condition of reasonable outlet temperature and enough drying capacity.

References
[1] Sida Tian, Yaqin Wang. Development and Research of Calculation Software for Pulverizing System of Power Plant Boiler. Modern Electric Power. 2000, 11, 17 (4): 1-5.
[2] Zhengwei Lu, Jianfei Chen. Development Direction Analysis of Medium Speed Pulverizer. Industrial Technology. 2015, 36: 130.
[3] Lifeng Dong. Development and Analysis of Medium Speed Pulverizer. Private Science and Technology. 2011, 10: 147.
[4] Changgui Nie, Xiaomin Mou, Linhua Huo. Analysis and Prevention of Explosion Cause in Pulverizing System of Coal-fired Boiler. Power Safety Technology. 2013 (1): 19-22.