Two-variable Decoupling Control and Simulation of Bag Filter

Yu Wang, Libing Liu*, Yanan Liu, Xuefeng Qin
School of Mechanical Engineering, Hebei University of Technology,Tianjin,China
Corresponding author: Libing Liu, Email: 763753296@qq.com

***Abstract*—Aiming at the problem of strong coupling between many control parameters caused by the complex structure of the large bag filter and the unstable operating conditions, the representative wind pressure and wind pressure are selected for decoupling control research. By analyzing the model of air pressure control system of bag filter, the decoupling compensator of wind pressure control loop is designed by feedforward compensation decoupling method and diagonal array decoupling method, and the control parameters are adjusted and analyzed. The simulation results show that the decoupling control makes the system have good dynamic and static performance, which lays a foundation for reducing the energy consumption of the bag filter.**

***Index Terms*—bag filter, air volume wind pressure, decoupling control, simulation**

I. INTRODUCTION

The large bag type dust collector has the characteristics of high dust removal efficiency and stable operation, and is currently the key technology and equipment for solving industrial dust emission[1]. As a typical industrial process equipment, bag filter has a direct impact on the quality of the operating system and the amount of flue gas. Since the bag filter is essentially a complex multivariable control system, the key and difficult point affecting its operation is the complex coupling relationship between input and output variables. Therefore, the optimization method of the general and effective multivariable control system is improved. The safety and economy of the bag filter are of great significance. In this paper, we mainly design the decoupling controller by adjusting the opening degree of the induced draft fan inverter and the electric regulating valve to adjust the air volume and wind pressure so that the operating condition meets the required control process.

At present, many scholars at home and abroad have conducted research on the control of bag filter. Shuyun Li et al[2] proposed the application of fluid-solid coupling analysis method to the vibration analysis between the gas flow field inside the filter bag and the filter bag and the bag cage, and obtained a good application effect; Hongjie Chong et al[3] From the theoretical analysis of the cleaning process and its influencing factors, in view of the defects of the traditional control method and the new problems brought about by the frequency conversion speed regulation, the dust control fuzzy control strategy of the dust collector is proposed; Yanling Gu et al[4] on the dust temperature of the dust collector The coupling mechanism between the resistances is briefly introduced.The fuzzy control technology is applied to the resistance control of the dust collector, and some application results are obtained. Therefore, the research on the control of bag filter is mainly focused on the cleaning and resistance control. The research on the decoupling control of the wind pressure is relatively rare.

Feedforward compensation decoupling is one of the earliest applications of multivariable decoupling systems[5].This method is simple in structure, easy to implement and has a remarkable control effect.It is designed to decouple the controller according to the invariance principle of the coupled system, thereby eliminating the interconnection of the system. In the design process, the diagonal matrix decoupling method requires that the product of the characteristic matrix of the controlled object and the decoupling link matrix is equal to the diagonal matrix, and its application is also extensive.

II. DESCRIPTION OF AIR VOLUME CONTROL SYSTEM

A. Bag filter working process

During the operation of the bag filter, under the negative pressure environment extracted by the induced draft fan, the dust gas to be treated enters the filter chamber from the inlet, and the dust particles and the filter bag are sieved and intercepted to settle on the surface of the filter bag. The exhaust port is exhausted. After a long period of filtration, the dust adhering to the surface of the filter bag is continuously increased, resulting in a gradual increase in the wind pressure and resistance in the filter bag, and the air volume of the dust collector is significantly reduced[6]. When the filter bag resistance is too high, the filter bag needs to be sprayed and cleaned, so that the dust layer on the filter bag falls into the ash hopper, the filter bag resistance is reduced, and the treatment air volume is restored to the design value. Complete a complete work process. The schematic diagram of the working process of the bag filter is shown in Figure 1.

© ACADEMIC PUBLISHING HOUSE

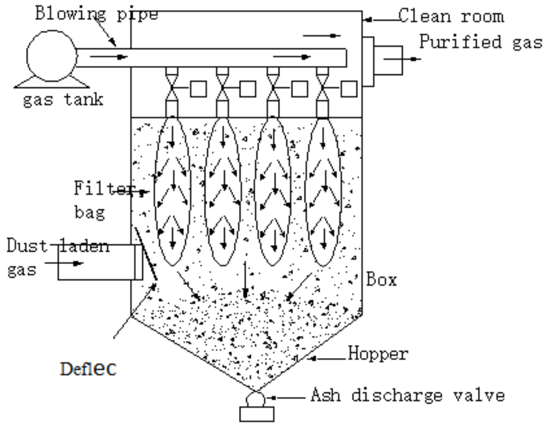

Figure 1. Brief description of the working process of the bag filter.

B. Air volume wind pressure control system structure

It can be seen from the above working process that the premise of good operation of the bag filter is to maintain the wind pressure and wind pressure within a suitable threshold range. However, due to the large mechanical structure of the dust collector and the unstable flow field, it exhibits strong coupling characteristics under wide working conditions, resulting in difficult control and poor effect, which greatly reduces bag dust removal. The working efficiency of the device.

In this paper, based on the model construction and parameter identification requirements of wind pressure and wind pressure, a bag-type dust collector experimental device with core component of 1:1 is designed according to the principle of similarity. The bag air filter air pressure control system takes the PLC controller as the core, and adjusts the overall air volume and wind pressure in the precipitator pipe by adjusting the opening degree of the induced draft fan and the electric regulating valve. The effluent flow duct of the dust collector is equipped with a vortex flowmeter for detecting the change of the air volume of the pipeline; the pressure difference sensor is installed in the bag chamber to detect the pressure value of the bag chamber and the pipeline; the induced draft fan is installed at the end of the pipeline, and is a pipe and a bag. The chamber provides negative pressure; the electric control valve is installed in the system piping to adjust the air volume and wind pressure of the pipeline. The structure diagram of the air volume and wind pressure control system is shown in Figure 2.

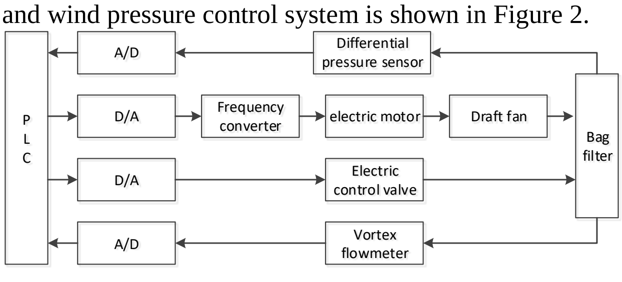

Figure 2. Schematic diagram of air pressure control system for bag filter.

C. Mathematical relationship between air volume and wind pressure system

The operating characteristics of the baghouse system are actually the intersection of the fan characteristic curve and the pipe characteristic curve[7], as shown in Figure 3. Among them, the fan characteristic equation is:

$$N = \frac{PQ}{\xi} \tag{1}$$

The gas pipeline characteristic equation is:

$$P = P_1 + SQ^2 \tag{2}$$

Where, N is the output power of the fan; P is the wind pressure at the end of the main pipe, that is, the total pressure provided by the fan; Q is the pipe flow; ξ is the fan efficiency; P_1 is the wind pressure at the beginning of the main pipe; S is the pipe resistance the coefficient, the impedance of the pipe.

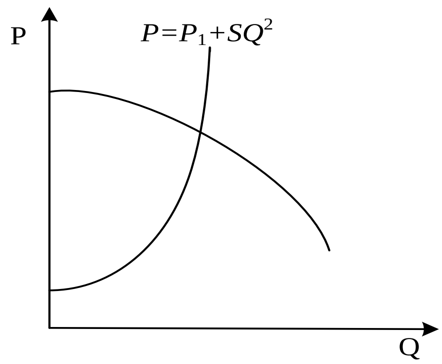

Figure 3. Fan characteristic curve and pipeline characteristic curve.

The transfer function matrix of the baghouse dust collector wind pressure is obtained by simplifying the physical model of the bag filter with a 1:1 core component and applying the approximate physical formula:

$$G(S) = \begin{bmatrix} G_{11}(S) & G_{12}(S) \\ G_{21}(S) & G_{22}(S) \end{bmatrix} = \begin{bmatrix} \dfrac{112.6}{10S+1} & \dfrac{91.8}{9.6S+1} \\ \dfrac{67.5}{9S+1} & \dfrac{78.7}{8.9S+1} \end{bmatrix} \tag{3}$$

Where: $G_{11}(S)$ ——the transfer function of the induced draft fan frequency converter on the wind pressure of the bag filter;

$G_{21}(S)$ ——The transfer function of the induced draft fan inverter on the air volume of the bag filter;

$G_{12}(S)$ ——the transfer function of the opening of the electric control valve to the wind pressure of the bag filter;

© ACADEMIC PUBLISHING HOUSE

$G_{22}(S)$ ——the transfer function of the influence of the opening of the electric regulating valve on the air volume of the bag filter.

III. DECOUPLING CONTROL OF AIR VOLUME AND WIND PRESSURE

The main task of decoupling control is to remove the coupling relationship between various variables of the system or between control loops. The decoupling requirement is that after the decoupling is realized, one-to-one independent control can be performed between the adjustment amount and the controlled quantity without affecting the controlled quantity of other control loops[8-10]. Among them, the design of the decoupling compensator is the core and key of decoupling control.

According to formula (3), the wind pressure and pressure transfer function matrix is established by Simulink software, and there is no coupling of wind pressure and wind pressure, and the simulation is simulated. The simulation curves are shown in Fig. 4 and 5.

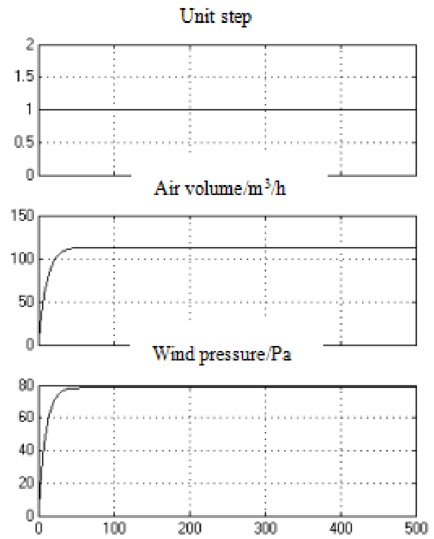

Figure 4. No coupling.

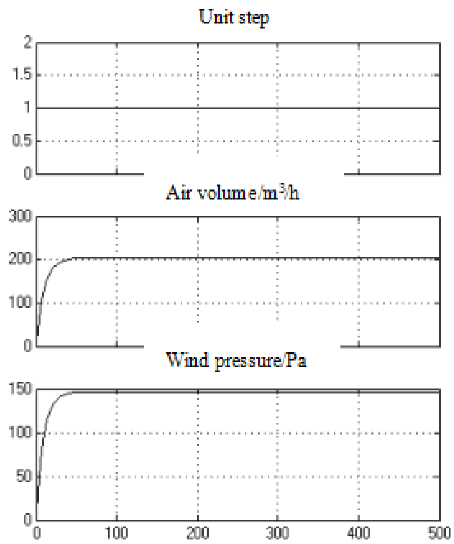

Figure 5. Existence coupling.

A. Feedforward compensation decoupling method

In this paper, the feedforward compensation decoupling method is first used to decoupling the wind pressure control system. Figure 6 is the wind pressure decoupling control structure after adding the feedforward compensator. Among them, is the added air volume decoupler, and is the wind pressure decoupler, which can respectively cancel the coupling relationship between the induced draft fan inverter and the regulating valve.

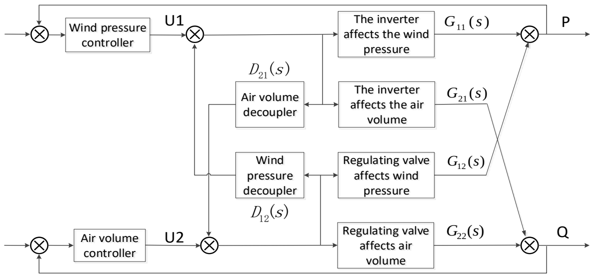

Figure 6. Structure diagram of air volume wind pressure feedforward compensation decoupling control.

According to the invariance principle of the feedforward compensation decoupling method, the feedforward compensator that can obtain the wind pressure and wind pressure is:

$$D_{21}(S) = -\frac{G_{21}(S)}{G_{22}(S)} = -\frac{600.75S + 67.5}{708.3S + 78.7} \quad (4)$$

$$D_{12}(S) = -\frac{G_{12}(S)}{G_{11}(S)} = -\frac{918S + 91.8}{1080.96S + 112.6} \quad (5)$$

The step response diagram obtained by adding the feedforward compensator to the wind pressure control system using the feedforward compensation decoupling method is shown in Fig. 7.

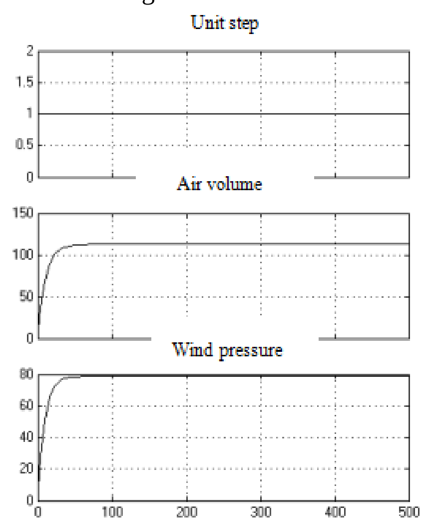

Figure 7. Feedforward compensation decoupling response curve.

Comparing Fig. 7 with Fig. 4, the adjustment time, response speed and steady state value of the wind pressure response curve obtained by the feedforward compensation decoupling method are close to the

© ACADEMIC PUBLISHING HOUSE

response curve when there is no coupling. After the feedforward decoupler is added, the coupling relationship between the air volume and the wind pressure is basically eliminated, and the decoupling effect is good.

B. Diagonal array decoupling method

The diagonal array decoupling method is used to decouple the wind pressure control system. Figure 8 is the block diagram of the control system after adding the diagonal array decoupler. is the wind pressure decoupler and is the air volume decoupler.

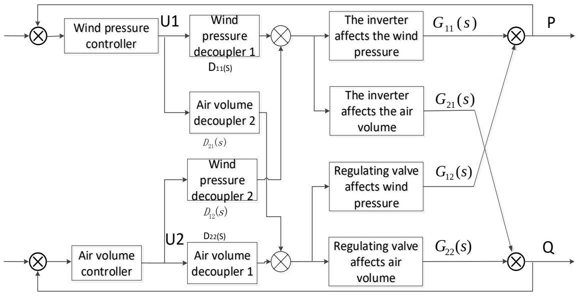

Figure 8. Structure diagram of air volume wind pressure diagonal array decoupling control.

According to the diagonal matrix decoupling method, the product of the characteristic matrix of the controlled object and the decoupling link matrix is equal to the principle of the diagonal matrix. The diagonal array decoupling compensator that can obtain the wind pressure and wind pressure is calculated as:

$$D(S)=\begin{bmatrix} D_{11}(S) & D_{12}(S) \\ D_{21}(S) & D_{22}(S) \end{bmatrix}= \begin{bmatrix} \dfrac{432s^2+93s+5}{120.8s^2+26.9s+1.5} & \dfrac{-(9s+1)(10s+1)(89s+10)}{296s^2+66s+3.7} \\ \dfrac{-427s^2-925s-50}{1408s^2+313.8s+17.5} & \dfrac{(9s+1)(48s+5)(89s+10)}{241.7s^2+53.8s+3} \end{bmatrix} \quad (26)$$

The step response diagram obtained by adding the compensator to the air volume wind pressure control system by the diagonal array decoupling method is shown in Fig. 8.

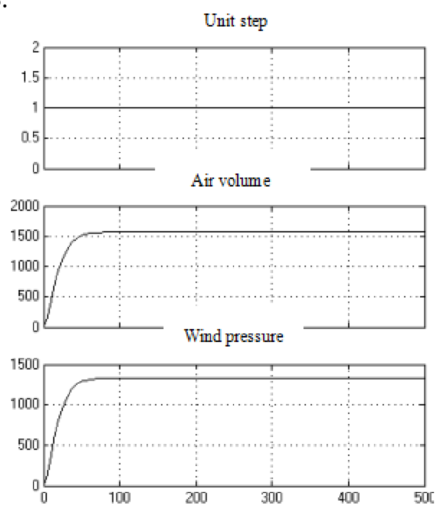

Figure 9. Windshield wind pressure diagonal array decoupling response curve.

Comparing Fig. 8 with Fig. 4, the steady state values of the wind pressure response curves obtained by decoupling by the diagonal array decoupling method are very different from the response curves when there is no coupling, which proves that the diagonal array is added. The decoupling control system is not decoupled and its decoupling effect is poor. According to the simulation experiment, the decoupling control effect of the feedforward compensation decoupling method is obviously better than the diagonal array decoupling method for the air filter pressure control system of the bag filter.

IV. AIR VOLUME CONTROL SYSTEM PARAMETER SETTING

For a complex process equipment, the design of the controller is essentially to modify the characteristics of the controlled process to meet the control objectives that need to be achieved. Since the bag filter has its own unique control requirements, although the expression and dynamic characteristics of the controller are different according to different decoupling methods, the core purpose is to make the bag filter operate under optimal working conditions. under.

According to the actual working conditions and operating experience of the bag filter, when the dust collector is operating normally and the dust removal effect is the best, the pipe air volume is required to be 3000m3/h, and the static pressure value of the outlet pipe is -3000Pa. Using the feedforward compensation decoupling method and field experimental parameters, it can be known that when the induced draft fan frequency is between 20-30Hz and the regulating valve opening is between 30-40%, the air volume and wind pressure have the conditions that meet the working conditions. After further experimental adjustment, when the induced draft fan frequency is 26.6Hz and the regulating valve opening is 38.2%, the air volume is 3000m3/h and the wind pressure is -3000Pa. The simulation curve is shown in Figure 10.

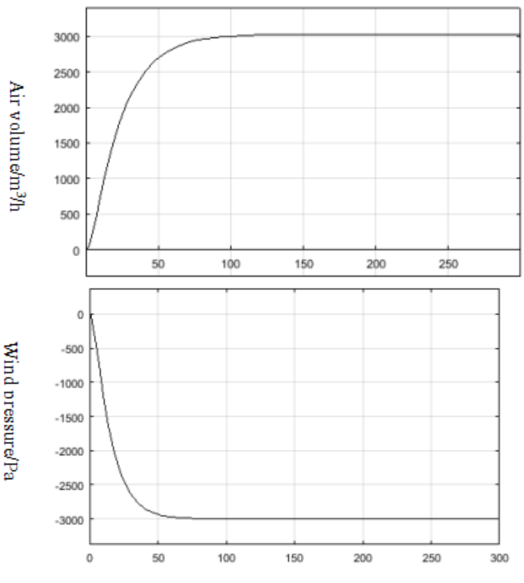

Figure 10. Optimal operating conditions of air volume and wind pressure after decoupling.

© ACADEMIC PUBLISHING HOUSE

V. CONCLUSION

(1) In this paper, the typical two-variable control parameters of the bag filter - the decoupling control problem of air volume and wind pressure, and the experimental device with the core component of 1:1 as an example, by analyzing the wind pressure and pressure control system and mathematics Relational expression, the transfer function of wind pressure and wind pressure is obtained.

(2) The feedforward compensation method and the diagonal array decoupling method are applied to the wind pressure decoupling control of the bag filter, and the simulation results are verified. The results show that the feedforward compensation decoupling method is decoupled. The effect is better than the diagonal array decoupling method, which can make the system have good dynamic and static performance.

(3) The feedforward compensation decoupling method and experimental operation method are used to find the optimal operating parameters of the dust collector, which lays a foundation for reducing the energy consumption of the bag filter.

REFERENCES

[1] Chen Guozhong, Xiao Weifang, et al, "Development of manufacturing technology of bag filter in China", *China Environmental Protection Industry*, 2015, (1): 22-26.

[2] Li Shuyun, Tan Zhihong, Jiang Yang, Liu Libing, Wang Zuojie, "Numerical simulation of filter bag vibration based on fluid-solid coupling", *Journal of Environmental Engineering*, 2016.12(10).

[3] Chang Hongjie, Zhang Xinju, Wang Huizhen, "Study on cleaning control strategy of low pressure pulse bag type dustcollector", *Environmental Engineering*, 2007, 25(3):48-50.K. Elissa, "Title of paper if known," unpublished.

[4] Gu Yanling, "Research on key technologies of high temperature flue gas bag dust removal system". Shenyang University of Technology, 2015.

[5] Yan Juan, Huang Zhichu, "*Multivariable Decoupling Control Method. Control Engineering"*, 2005, 12(5): 342-349.

[6] Fang Xin, "Numerical simulation of filter dust removal by bag filter", Changsha: Hunan University, 2012.

[7] Yan C, Liu G, Chen H, "Effect of induced airflow on the surface static pressure of pleated fabric filter cartridges during pulse jet cleaning", *Powder Technology*, 2013, 249(11):424-430.

[8] Comanescu M, "A double-manifold sliding mode observer for the speed and flux of the induction motor using an alternative state-space model", *Industrial Electronics Society*, 2015: 318-322.

[9] Xue Yali, "Optimization design of multivariable control system for thermal process", Tsinghua University. 2005.

[10] Li Xu, Xiong Zhonghui, Gao Sheng et al, "Decoupling control of a class of multivariable control systems", *Power Engineering*, 2003, 4(10): 35-41.

Yu Wang, Baoding City, Hebei Province, born in January 1992, studied in Tianjin, China - School of Mechanical Engineering, Hebei University of Technology, master's degree, the main research direction is industrial measurement and control technology.

He has received several academic scholarships from Hebei University of Technology and a national postgraduate academic competition.

Libing Liu, a native of Beijing, was born in November 1961. He graduated from the School of Mechanical Engineering of Tianjin University, China. His main research direction is complex electromechanical systems research.

She is currently working at Hebei University of Technology, a doctoral tutor, and has published several high-level academic papers.Firstname A.

Yanan Liu, born in Hengshui City, Hebei Province, was born in April 1992. He studied at the School of Mechanical Engineering of Hebei University of Technology, and his master's degree is computer measurement and control technology.

Xuefeng Qin, born in Ningxia City, was born in March 1995. He studied at the School of Mechanical Engineering of Hebei University of Technology, and his master's degree is mainly in industrial measurement and control technology.

© ACADEMIC PUBLISHING HOUSE