# An Improved Mixed Gas Pipeline Multivariable Decoupling Control Method Based on ADRC Technology

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***Abstract*—According to the serious decoupling, uncertainty, easily disturbed and nonlinear characters of the gas mixture of butterfly valve string couplets system, an ADRC static decoupling technology and the dynamic decoupling method based on extended state observer (ESO) were proposed. In this method, coupling from other input, parameters time-varying and external disturbances are all regarded as a total disturbance. The total disturbance can be estimated by ESO and feedback to controller, and coupling is achieved. In order to improve response speed of the system, and reduce the computation, this control system use nonlinear tracking-differentiator(TD), ESO and the nonlinear state error feedback control law (NLSEF) uses nonlinear function.Simulation results shows that, in this method, the decoupling is simplified, and the requirement of the model is reduced. The novel method can also ask for less calculation with faster response and better robustness, still with good tracking performance and disturbance rejection capability, the decoupling effect is fine.**

***Index Terms*—gas mixing; active disturbance rejection control (ADRC); extended state observer (ESO); decoupling**

## I. INTRODUCTION

For the steel industries, gas compressor stations is a very important units, it is responsible for the iron and steel group and the surrounding cities with mixed gas calorific value and pressure. If the gas compression station stops, all units of the iron and steel group have to stop manufacturing.As the iron and steel production processes and the geographical layout of the business characteristics and complex situation of the production statement, it requires the mixed gas pressure station control system to adapt to the following features:

(1) The variability of the in-put and out-put pressure that under the effect of the upstream user and downstream user change in the amount.

(2) Medium is the gas, and change-process in a long term.

(3) Volatility characteristics of the pipe network.

Obviously, we are facing with a mathematical model which is difficult to determine with great delay and nonlinear parts of the complex controlled object.

With the more and more complex, characters as uncertainty, interference, nonlinearity, non-minimum phase, etc, more than one variable is needed to be regulated. And there are several interrelated variables. Traditional single-variable control system designed approach is clearly unable to meet the requirements. In engineering area, bring in the multi-variable decoupling is common. There are two butterfly valves in pipeline blast, coke pipe also have two butterfly valves, by adjusting this four valve, regulation of coke oven gas and blast furnace gas flow ratio, to achieve the ratio of calorific value and pressure regulation.There is serious coupled between the flow control and pressure regulator [1], at the same time the regulation of the four butterfly valves are also interaction, this implies that there is a relative strong coupling in this system. In recent years, along with the development of control theory, a variety of decoupling control method adapt to the times require.

At present, most of the major domestic pressure station by artificial control. There are three common methods of gas mixture pressure control in automatic control of the compression stations: pressure and calorific value dual-loop controller, feed-forward compensation decoupling and intelligent decoupling. Pressure and calorific value of the dual-loop adjustment method using the variable matching circuit, by matching the appropriate of regulating variables, this method is not accurate, the ability to inhibit the disturbance is not strong. Since the feed-forward compensation decoupling method due to the limitations of control methods, control effect is poor [1 4]. Along with the development of intelligent control, intelligent decoupling control strategy is proposed by Ren Hailong [5]. By analysis the disciplines and the physical structure of the gas mixture pressure process, they divided the control loop into two: the calorific value


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pressure decoupling control loop and the pressure control loop. However, because the two valves series on the blast furnace gas pipes and the two valves series on the coke oven gas pipes are very close, the literature one pointed that: this is a typical strong coupling system.

Because of this,we explore a new control method—— Active Disturbance Rejection Control (ADRC),use this technology in mixed gas pipeline multi-variable system, in order to achieve better control results. ADRC have 3 parts: the tracking differentiator (TD),extended state observer (ESO) and nonlinear state error feedback control law (NLSEF).It is a kind of nonlinear controller that not dependent on the model, it attributed the model uncertainty and unknown external disturbance effects (including the coupling term) to the general disturbance of the system, by the extended state observer (ESO) to real-time estimation and dynamic compensation, there are many advantages, such as high precision, fast response, robustness, usability, etc. Active disturbance rejection control is to adapt the trend of digital control, absorb the results of modern control theory, development and application of nonlinear effects to develop new practical technologies.Therefore, in this paper, used ADRC static decoupling technology and ESO dynamic decoupling techniques, established multi-variable control system of gas mixed, realize the decoupling control of two butterfly valves.

## II. Process Introduction

According to the law of energy conservation, the heat value of mixed gas, such as (1) below.

$$R_3Q_3 = R_1Q_1 + R_2Q_2 \tag{1}$$

Symbol subscript l, 2, and 3 were side coke oven gas, blast furnace gas and mixed gas.

Among, R-gas calorific value ($KJ / m^3$), Q—gas flow ($m^3/s$)

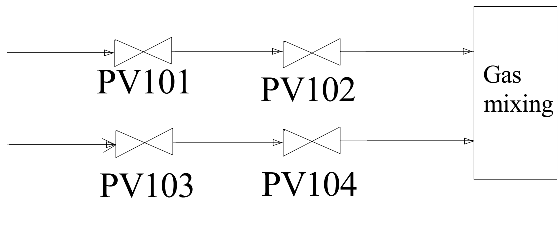



Fig 1. Process mixed gas compressor stations

Simplify process of gas mixing compression station shows in figure 1.There are two butterfly valves in blast furnace gas pipeline,coke oven gas pipeline also have two butterfly valves, by adjusting this four valve, regulation of coke oven gas and blast furnace gas flow ratio, to achieve the ratio of calorific value and pressure regulation.The mixture of gas pressurized from the compression machine, compressor stations are generally installed in the inverter, by adjusting the frequency converter to change the speed of pressure machine to adjust the pressure purposes.

The design of four-valve regulating mixed-gas heating value was first proposed by the Japanese Nippon Steel Corporation, at present, the vast majority of gas pressure regulating stations have adopted such a program.

Why the butterfly in country has been developing rapidly, the reason is it has the following advantages:

(1) Simple structure, the installation length is short, easy layout, valve installation is far less than the length of DN, installation length and the nominal diameter ratio of only 0.2~0.1;

(2) Small size, light weight;

(3) Liquidity resistance is small. When the Low-pressure valve fully open, liquidity resistance coefficient <1;

(4) Switch is simple, just turn on a dish plate 90 °.

Butterfly valve has many advantages, but there is a drawback: most valve impatience high-pressure. In high-pressure environment, in order to solve the high pressure problem, general with double butterfly valve series pressure points. This is also the reasons why gas compressor stations using butterfly in series design.

Through the butterfly valve to regulate gas flow, gas pressure, gas heating value, the main principle is based on equation (2)

$$Q = \frac{A}{\sqrt{\xi}}\sqrt{2g\frac{\Delta P}{\gamma}} \tag{2}$$

In equation (2):

Q —volume flow ($m^3/s$), that is volume of gas flows through the pipe cross-sectional area in per second

A —pipe circulation sectional area ($m^2$)

$\xi$ —drag coefficient, dimensionless

g —acceleration of gravity ($m/s^2$)

△P—pressure differential is $(p_1 - p_2)(kgf / cm^2)$, $p_1$, $p_2$ respectively is before and after the pressure of valve.

$\gamma$ —medium severe ($kgf/m^3$)

For simplicity, excluding the impact of the density before and after mixing, obtain equation (3)

$$Q_3 = Q_1 + Q_2 \tag{3}$$

Symbol subscript l, 2, 3were side coke oven gas, blast furnace gas and mixed gas.

According to (3), because the total flow $Q_3$ of mixed gas is uncontrolled, decision by the users, when a gas flow rate changes, need to change another gas flow to reach the purpose of regulate the mixed gas calorific value.

## III. The Model of the Gas Mixing Butterfly Valve Group

In the blast furnace, coke oven gas pressure during the mixing,when the controller to calculate the control values of coke oven and blast furnace valve group, the butterfly valve controller according to the series gain matrix to decision that how to adjust the two valves of corresponding valve group in the end.

Due to the high valve and focal valve pressure distribution of the basic ideas are exactly the same, for example by coke oven butterfly group.

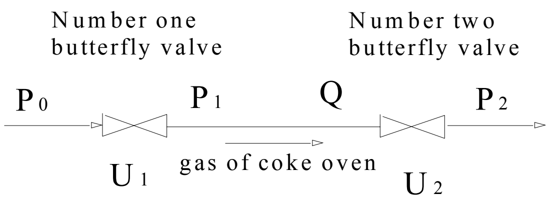



Fig.2. Pipe system of pressure-flow

In the fig 2, $P_0$ is coke oven gas pressure before the number one butterfly valve. $P_1$ is coke oven gas pressure before the number two butterfly valve. $P_2$ is coke oven gas pressure before the number two butterfly valve. $u_1$, $u_2$ are the opening of number one and number two butterfly valves. Q is the gas flow of coke oven pipeline.

According to the literature10, pressure-flow process can be described as

$$Q = u_1(P_0 - P_1) = u_2(P_1 - P_2) = \frac{u_1 u_2}{u_1 + u_2}(P_0 - P_2) \quad (4)$$

When two circuits are in the open loop, the first amplification factor is

$$\left.\frac{\partial Q}{\partial u_1}\right|_{u_2=\cos t} = \left(\frac{u_2}{u_1 + u_2}\right)^2 (P_0 - P_2) \quad (5)$$

Closed loop pressure, the first amplification factor is

$$\left.\frac{\partial Q}{\partial u_1}\right|_{p_1=\cos t} = P_0 - P_1 = \frac{u_2}{u_1 + u_2}(P_0 - P_2) \quad (6)$$

According to the definition of a relative gain

$$\lambda_{11} = \frac{\left.\frac{\partial Q}{\partial u_1}\right|_{u_2=\cos t}}{\left.\frac{\partial Q}{\partial u_1}\right|_{P_2=\cos t}} = \frac{u_2}{u_1 + u_2} \quad (7)$$

From equation (4) and solve for $u_1$ and $u_2$ into equation (7).can be used pressure to represent the gain

$$\lambda_{11} = \frac{P_0 - P_1}{P_0 - P_2} \quad (8)$$

can also find the relative gain of the $u_2$ and flow Q

$$\lambda_{12} = \frac{P_1 - P_2}{P_0 - P_2} \quad (9)$$

If use $P_1$ to describe the pressure-flow system, is

$$P_1 = P_0 - \frac{Q}{u_1} = P_2 + \frac{Q}{u_2} = \frac{u_1 P_0 + u_2 P_2}{u_1 + u_2} \quad (10)$$

Another gain can be determined, solve partial derivative for equation (10), can derived the relative gain of $u_1$, $u_2$ for two channels of the $P_1$.

Then, pressure-flow system of input-output relationship can be expressed by relative gain matrix as

$$\begin{bmatrix} Q \\ P_1 \end{bmatrix} = \Lambda \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \quad (11)$$

Among

$$\Lambda = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \end{bmatrix} = \begin{bmatrix} \frac{P_0 - P_1}{P_0 - P_2} & \frac{P_1 - P_2}{P_0 - P_2} \\ \frac{P_1 - P_2}{P_0 - P_2} & \frac{P_0 - P_1}{P_0 - P_2} \end{bmatrix} \quad (12)$$

If in the system $P_1$ close to $P_2$,$\Lambda$ is very close to the unit matrix, instructions to control the flow with a valve 1, with a valve 2 to control pressure $P_1$ is appropriate. If $P_1$ close to $P_0$, use valve 2 to control flow and with a valve 1 to control pressure $P_1$ is appropriate.if $P_1$ close to the midpoint of ($P_0$-$P_2$), adjusting the two valves are the best.

System of coke oven gas pipeline pressure is $P_0$=6.2kPa, $P_1$=5.5kPa, $P_2$=5.0kPa, the gain matrix is

$$\Lambda = \begin{bmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \end{bmatrix} = \begin{bmatrix} 0.58 & 0.42 \\ 0.42 & 0.58 \end{bmatrix}$$

$\lambda_{i,j}$ very close to 0.5 shows that there are serious coupling in this system. From equation (11), we could be find the mathematical model of this control system can be expressed as

$$\begin{bmatrix} y_1(s) \\ y_2(s) \end{bmatrix} = \overline{G}(s)\Lambda \begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix} \quad (13)$$

Among $y_1(s) = Q(s)$ and $y_2(s) = P(s)$

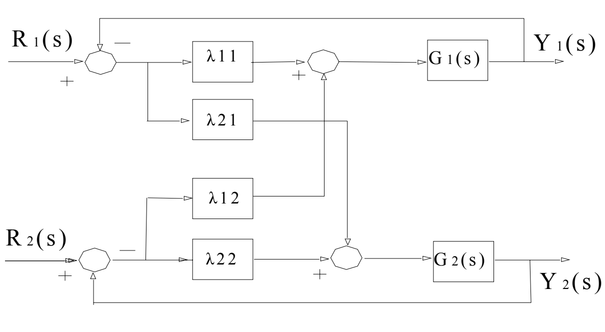



Fig 3. Gas mixing process control block diagram

$\overline{G}(s) = diag\{G(s), G(s)\}$is transfer function of controlled object.

In debugging the process of trial and error $G_1(s) = \dfrac{K}{T_0 s + 1}$, in the equation, $K = 2, T_0 = 1.5$

Gas mixing process control block diagram shown in figure 3.

## IV. ADRC Decoupling Controller Design For Butterfly valve series system

ADRC have 3 parts, the tracking differentiator (TD), extended state observer (ESO) and nonlinear state error feedback control law (NLSEF).Structure shown in the figure4.

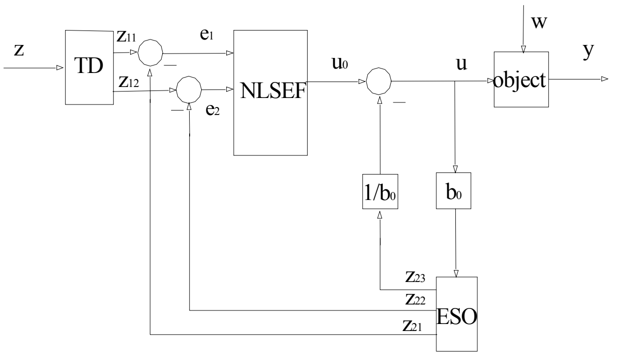



Fig.4. Structure of ADRC

Tracking differentiator (TD) is used to arrange the transition process, fast without overshoot to track the input signal, and has a better differential characteristic. Avoid when the set value mutations, control the amount of violent changes and output overshoot, largely solved the contradiction between of system response speed and overshoot. Precisely because of this the ADRC requirements in high speed applications are subject to certain restrictions.

Extended state observer (ESO) is the core part of ADRC, it can be attributed from the system internal or external factors to the disturbance of the system, through the extended state observer to estimate the system all state variables simultaneously estimate the system's internal and external disturbances and appropriate compensation, in order to achieve the dynamic feedback linearization.

Tracking differential output and extended state observer estimation to take error, and get the system the state variable error. The amount of error into the nonlinear state error feedback control law (NLSEF), after the operation, add from the compensation amount of the extended state observer, the final receive the control amount of charged with object.

Because disturbance rejection controller is based on the time scale of the system to divide objects, when design the controller, do not consider the linear or nonlinear, time-varying or time-invariant of the system, thus simplifying the controller design.

### A. ADRC Static Decoupling

ADRC static decoupling can use conventional controller to achieve. Due to the actual operation process, static coupling matrix $\Lambda$ is uncertain. Therefore, within the scope of its changes to take a rough estimate $\Lambda_0 \approx \Lambda$, approximation error can be attributed to disturbance.

Static decoupling compensator used in the decoupling controlled objects, command

$$\begin{bmatrix} v_1(s) \\ v_2(s) \end{bmatrix} = \Lambda \begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix} \tag{14}$$

In the formula (14), $v_i(s)$ is the virtual control amount of each channel, then

$$\begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix} = \Lambda^{-1} \begin{bmatrix} v_1(s) \\ v_2(s) \end{bmatrix} = N \begin{bmatrix} v_1(s) \\ v_2(s) \end{bmatrix} \tag{15}$$

So static decoupling compensator is

$$N = \Lambda^{-1} \tag{16}$$

After the static decoupling compensation, equation (13) can be described as

$$\begin{bmatrix} y_1(s) \\ y_2(s) \end{bmatrix} = \overline{G}(s) \begin{bmatrix} v_1(s) \\ v_2(s) \end{bmatrix} \tag{17}$$

Visible, ADRC static decoupling technology break through the limit of the conventional decoupled method of matrix inversion, it only need to know a rough estimate of $\Lambda$, that is $\Lambda_0$,and singularity of $\Lambda$ is not limited. For the reason of the uncertainty or singular to $\Lambda$ due to error of approximation, ADRC put it as a new disturbance, then automatically estimated and compensated. As long as the difference between them not very large, you can achieve a good decoupling objective. Therefore, ADRC static decoupling method adapt to wider range, better robustness.

### B. ADRC Decoupling Control Design

The ADRC is based on the idea that in order to formulate a robust control strategy. Although the linear model makes it feasible for us to use powerful classical control techniques such as frequency response based analysis and design methods, it also limits our options to linear algorithms and makes us overly dependent on the mathematical model of the plant. Instead of following the traditional design path of modeling and linearization and then designing a linear controller, the ADRC approach seeks to actively compensate for the unknown dynamics and disturbances in the time domain. Once the external disturbance is estimated, the control signal is then used to actively compensate for its effect, and then the system becomes a relatively simple control problem. More details of this novel control concept and associated algorithms can be found in [8]-[10].A brief introduction is given below.

In many practices, the performances of the controlled system are limited by how to pick out the differential signal of the non-continuous measured signal with stochastic noise. In practice, the differential signal (velocity) is usually obtained by the backward difference of given signal, which is very noisy and limits the overall performance. Han [8] developed a nonlinear tracking-differentiator (TD) to solve this problem effectively. It is described as

$$\begin{cases} e_0 = r_{1i} - r_i^* \\ \dot{r}_{1i} = -R \cdot fal(e_0, \alpha_0, \delta_0) \end{cases} \tag{18}$$

$R$——tracking parameter, $\delta_0$——control parameter, $\omega 1$ tracking $\omega^*$

The function of *fal* as following

$$fal(e,\alpha,\delta) = \begin{cases} |e|^{\alpha} \operatorname{sgn}(e) & |e| > \delta \\ \dfrac{e}{\delta^{1-\alpha}} & |e| \le \delta \end{cases} \tag{19}$$

The extended state observer (ESO) proposed by Prof. Han [8] is a unique nonlinear observer designed to estimate:

$$\varepsilon_i = z_{1i} - y_i \tag{20}$$

$$\begin{cases} \dot{z}_{1i} = z_{2i} - \beta_{1i} fal(e,\alpha,\delta) + b_{0i} v_i \\ \dot{z}_{2i} = -\beta_{2i} fal(e,\alpha,\delta) \end{cases} \tag{21}$$

$\beta_{01}$, $\beta_{02}$, $\beta_{03}$, $\beta_{04}$ are observer gains, $b_0$ is normal value of $b$.

Because performance of extended state observer has a direct impact on the performance of ADRC is good or bad,ESO parameter selection is critical.System speed links can be approximation reduced to first-order the object, only need to design a second-order extended state observer,then be able to estimate the system state variables, at the same time disturbance compensation,in equation(21),the parameters that need tuning only $\alpha$ ,$\delta$ and $\beta_1$ ,$\beta_2$ .

Among, parameter $\alpha$ in the range between 0 and 1,parameters of $\alpha$ smaller, non-linear is the better.ESO is stronger ability to adapt for the uncertainty and disturbance of system model, generally $\alpha$ often take 0.25, 0.5 or 0.75,here the first take $\alpha$ = 0.5,parameter $\delta$ is the linear interval width of nonlinear function, set the linear range is designed to avoid the error curve slope at the near zero large high-frequency pulse. If $\delta$ is too small easily lead to high-frequency pulse, $\delta$ is too large, nonlinear feedback will be some extent to degraded a linear feedback. Here take $\delta$ = 5.

$\alpha$ , $\delta$ determined, in the ESO, tuning parameters to be only $\beta_1$ and $\beta_2$ .Because the system dynamic performance by argument $\beta_1$ , $\beta_2$ a great impact, $\beta_1$ major impact on the estimated state variables, $\beta_2$ major influence on estimate of the disturbance, $\beta_1$ , $\beta_2$ ,the faster, the greater the estimate. For large inertial system, the greater the time constant, the corresponding value of $\beta_1$ , $\beta_2$ should be greater,additional,larger system disturbances, $\beta_1$ , $\beta_2$ are larger, however, if $\beta_1$ , $\beta_2$ is too large may cause the value of estimate oscillation, so we should be coordinated to adjust parameters $\beta_1$ and $\beta_2$ ,to ensure ESO can fast and accurate estimate, and when disturbance compensation, value of estimated will not oscillate at the same time. In this paper, ESO of the parameter selection is first in matlab simulation setting get a set of parameters and then into the actual system after many experiments, $\beta_1$ and $\beta_2$ are 90 and 2500.

Once the design of TD and ESO is accomplished, the general error and its change between the reference and the estimated states can be defined as $e_1$, $e2$ and $e_3$.The nonlinear proportional derivative (N-PD) law is used to synthesis the preliminary control action, which can be described as

$$\begin{cases} e_i = r_i - z_{1i} \\ \dot{z}_{3i} = r_i - z_{1i} \\ e_{0i} = z_{3i} \\ v_{0i} = k_{pi} fal(e_i, \alpha_i, \delta_1) + k_{di} fal(e_1, \alpha_1, \delta_1) \end{cases} \tag{22}$$

In the formula (22), $e_i$ is error term, $e_{0i}$ is error rate, $k_{pi}, k_{di}$ are the gains of PD controller.

Plus the control action to cancel out the external disturbance, then the total control action of ADRC can be determined as follows

$$v_i = (-z_{2i} + v_{0i}) / b_{0i} \tag{23}$$

The active disturbance rejection decoupling control system is given as figure 5.

## V. SIMULATION

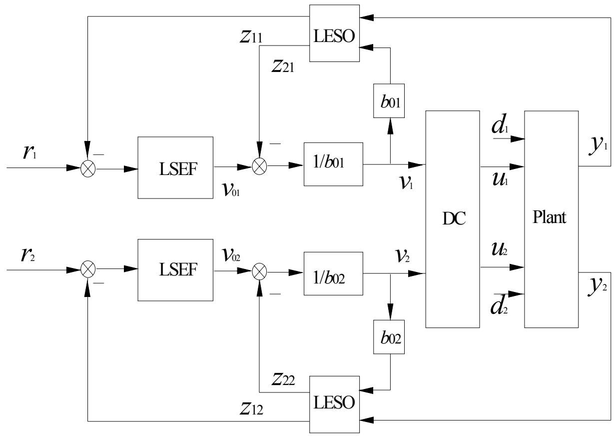
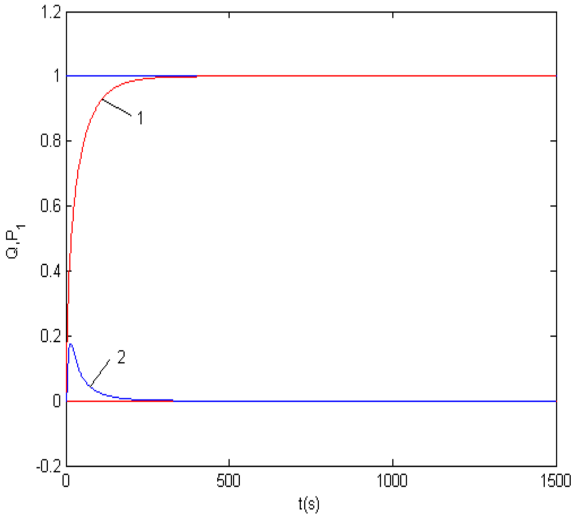



Fig.5 Architecture of ADRC for gas mixing butterfly valve group

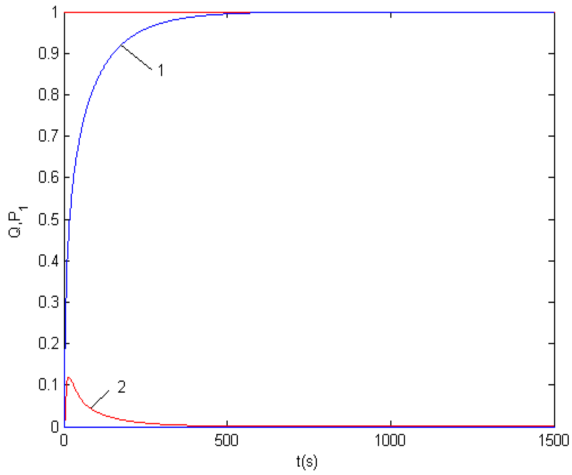
To verify the feasibility of the control program, figure 5 shows the block diagram of a simulation test. ADRC adjustable parameters using matlab nonlinear optimization toolbox optimized, two channels of ESO, NLSEF parameters is the same. ADRC controller parameters are: ESO parameters are: $\beta_{01} = 90$ , $\beta_{02} = 2500$ , $b_0 = 4/3$ .NLSEF parameters are: $k_p = 20, k_d = 10.5$ .

### A. Tracking Performance:

For the nominal state, two channels each with unit step value were given, the simulation results shown in figure 6. Figure (a) is the response curve of flow channel for a given value of the step change. Curve 1 is the flow curve, curve 2 is pressure curve. Figure (b) is response curve of pressure channel for a given value of the step change. Curve 1 is pressure curve, curve 2 is flow curve. Visible, although the coupling of two valve series system is more serious, but decoupling through decoupling method based on growth hormone two-way adjustment mechanism, when the flow rate Q changes, pressure remained almost unchanged, and the output is no static error, decoupling works well, and vice versa.




(a)Flow set point step change

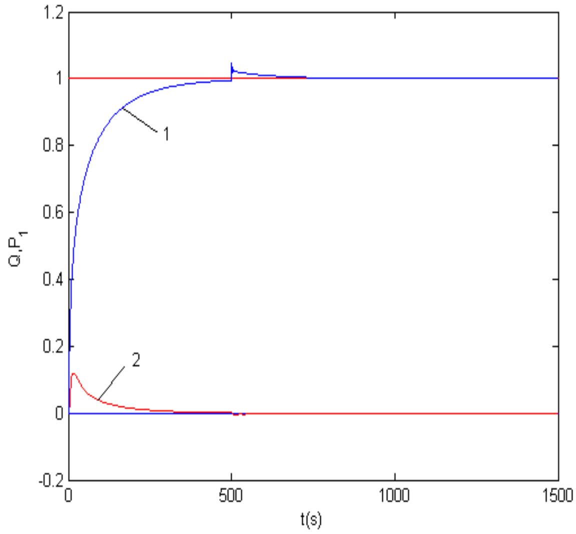



(b)Pressure set point step change

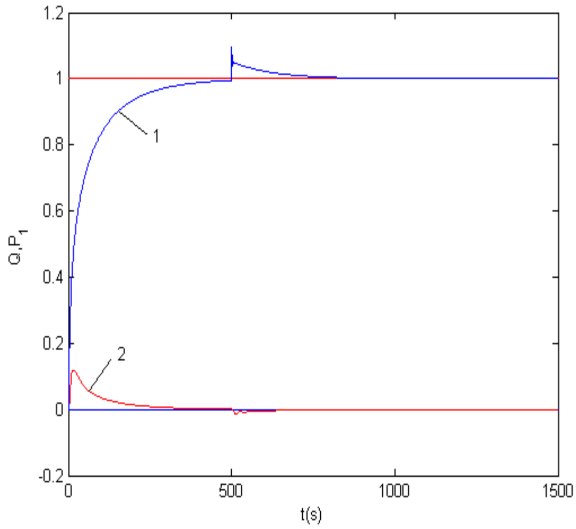
Fig.6. Responses of gas mixing butterfly valve group

### B. Disturbance Rejection Tests:

When t=500s, in the channel and amplitude of 0.5 load disturbance signal. The simulation results shown in figure 7.Figure(a)is response curve of the flow channel plus interference signal**,** curve 1 is the curves of flow, curve 2 is curves of the pressure, figure(b)is response curve of the pressure channel plus interference signal.




(a)Changes in flow channel




(b)Pressure channel change

Fig.7. Responses of disturbance rejection

Curve 1 is pressure curve, curve 2 is flow curve. Visible, butterfly valve series system has little effect of interference, so it is can negligible.

## VI. CONCLUSIONS

In summary, gas mixing is a nonlinear, large time-varying, uncertainty and complex multi-variable coupled production process. Mixed gas pressure calorific value fluctuations are determined by a variety of factors. Most of these factors are unpredictability, appeared frequently, resulting in pressure of mixed gas calorific value volatility, affects the production. Therefore, traditional decoupling method can not meeting the requirements, we can only use intelligent decoupling method.

Active disturbance rejection control rises in response to the proper time and conditions. It adapt the trend of digital control, absorbing the results of modern control theory, develop and enriching the classic control "to eliminate errors based on error" spirit and essence, development and application of nonlinear effects, with features as small overshoot, fast response, high control precision, strong anti-disturbance, the algorithm is simple and so on.

This paper use decoupling method based on ADRC to remove gas mixing system coupling. Simulation results shows that the control system is not only has better tracking performance, anti-disturbance ability, the decoupling works well, to solve the gas mixture system valve in series strong coupling, time-varying, confounding factors such as more adverse impact on the system.

## ACKNOWLEDGMENTS

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## REFERENCES

[1]. Qin lu. Decoupling and Smith compensator with a mixture of gas heating value control. Control Engineering, 73-75(2002).
[2]. Meng chun, Xia chen. SMAR intelligent regulator and control of mixed gas calorific value. Hebei Metallurgical, 53-55(2002).
[3]. Wu xiao feng, Sun han feng, Wei cheng yong.Automatic control of furnace gas pressure regulator. Metallurgical Automation, 64-65(2002).
[4]. Huang Jimin,Cao Jianmei. Computer-controlled system of gas mixing. Automation and Instrumentation, 28-30(2000).
[5]. Ren Hailong, Li Shengyu. Mixture gas pressure and calorific value of the fuzzy decoupling control. Automation Instrumentation, 65-67 (2004).
[6]. Shao li wei,Liao xiao zhong. ADRC in the voltage-type PWM Rectifier [J]. Beijing University of Technology. (2008).
[7]. Cao Weihua, Wu Min, Hou Shaoyun. Method and application of gas mixture pressurized process intelligent decoupling control. Zhongnan University News,780-785(2006).
[8]. Han Jingqing. ADRC control technology - an estimated uncertainty compensation control technology. Biejing National Defence Industry Press,(2008).
[9]. Wu meng, Zhu xi lin, E shiju,Sun ming ge, Tong shao wei. ADRC controller parameter tuning Method [J]. Beijing University of Technology.(2009).
[10]. Jin yi hui, Fang chong zhi. Process Control [M]. Beijing: Tsinghua University Press, 1995.
[11]. Guo jiang.Intelligent control of blast furnace, coke oven gas pressure and calorific value of mixture. Xinjiang University News: Engineering Edition, 231-235, 2001.
[12]. Li SL,Yang X,Yang D. Active disturbance rejection control for high pointing accuracy and rotation speed. Automatica, 1854-1860, 2009.
[13]. Qing zhang. On active disturbance rejection control: stability analysis and applications in disturbance decoupling control. National University of Singapore, 2003.
[14]. Qiu xiao bo,Dou li hua, Han jing qing, Zhou qi huang. Application of ADRC control used in tanks maneuvering target state estimation [J]; Ordnance Technology, 2009.
[15]. Xu xiang bo,Fang jian cheng. Angular acceleration of the gyro frame-based servo system disturbance observer [J]. Journal of Beijing University of Aeronautics. (2009).
[16]. Wu meng,Zhu xi lin,E shi ju,Sun ming ge,Tong shao wei. ADRC controller parameter tuning Method [J].Beijing University of Technology.(2009).
[17]. J. Timmis and M. Neal. Artificial homeostasis: integrating biologically inspired Computing [EB/OL], www.cs.kent.ac.ulc/pubs/2003/1586Zcontent.pall, Apr.15, 2006.
[18]. B. Liu, K. R. Hao and Y S. Ding . A nonlinear optimized controller based on modulation of testosterone [A]. Proceeding of The Third International Conference on Computational Intelligence, Robotics and Autonomous Systems (CIRAS2005) [C], Singapore, Dec.14-16, 2005.
[19]. B.Liu and Y S.Ding.A decoupling control based on the bi—regulmion principle of growth hormone[A].Proceeding of 2005 ICSC Congress on Computational Intelligence: Methods & Application 2005 (ClMA'05)[C], Istanbul, Turkey, Dec.15-17.2005.
[20]. Bliu, YS. Ding and J. H. Wang. An intelligent controller inspired from neuroendocrine-immune system [A]. Proceeding of 2006 International Conference on Intelligent Systems & Knowledge Engineering (ISKE2006) [C], Shanghai, China, Apr.6-7, 2006.
[21]. WU M,CAO W H,HE C Y.I ntegrated intelligent control of gas mixing-and-pressurization process[J]. IEEE Transactions on Control Systems Technolopogy, 2009, 17(1) :68-77.
[22]. Xia wei xing, Yang xiao tong. Filtering characteristics of the steepest tracking-differentiator based on robust filtering theory. 2010, 17(2).
[23]. D. M. Keenan, J. Licinio and J. D. Veldhuis. A feedback-controlled ensemble model of the stress-responsive hypothalarno-pituitary-adrenal axis [J]. PNAS, 2001, 98(7): 4028—4033.

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