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Human-Simulated Intelligent Control Technique for Incineration Treatment of Municipal Solid Waste

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Abstract: The municipal solid waste Incineration has been popularly applied as a full-blown technology in most large or middle sized cities of our country. A lot of nocuous secondary pollutants will be induced in the combustion process. To control the secondary atmosphere pollution, the study presents a Human-Simulated Intelligent Control strategy for the incineration process controlling. Both the control rules and the structure of control system are presented and the simulation results showed that it is better not only in dynamic and steady quality of system, but also obvious in energy saving effect, feasible and effective in control strategy.

Key words: Municipal solid waste, combustion stability, human-simulated intelligent control, human simulated intelligent controller, incineration treatment, secondary pollution

INTRODUCTION

With the improvement of civil life and the development of economy, our country is undergoing extremely astonished yield of Municipal Solid Waste (MSW) every year. Of all disposal ways, the MSW Incineration with its perfectly integrated competence and social economic benefits in waste volume reduction, innocuous and comprehensive utilization, has been popularly applied as a full-blown technology in most large or middle sized cities of our country. Incineration of MSW is a synthetic process of several different combustion forms (Fang, 2004). It is a close coupling non-linearity, multi in-out process. So, the traditional control is difficult to s tabilize the MSW Incineration process. Combined the operation of MSW incinerator with the analysis of the combustion mechanism and pollutants inducing-mechanism, combustion stability is verified to be a guarantee of effective MSW combustion and of holding down the production of pollutants, features of MSW directly impacting the combustion stability is also convinced. Traditional controlling is difficult to stabilize the combustion of MSW, for it is a close coupling non-linear complex process. The study took the secondary pollution control of exhaust gas in MSW incineration process as an example to research the related.

GARBAGE INCINERATION AND POLLUTION CONTROL

MSW incineration and pollution control: The following secondary pollution source lurks in the process of the MSW incineration treatment: the gas pollution source formed by the exhaust gas in incineration process, the dust collected by the incineration residues and the exhaust gas purification system and the solid pollution source formed by the resultant of reaction, the liquid pollution sources formed by percolating water treatment during garbage storage (Puri *et al*., 2008), the gas pollution sources with special odor emanating from the garbage and the source of noise pollution from the garbage incineration plant. The nocuous pollutants such as carbon monoxide (CO), microscale organic chlorides (such as PCDDs and PCDFs), nitrogen oxide (such as NOx), trace elements and fly ash will be induced in the incineration process. Therefore, the key factor of the prevention and control for secondary pollution is how to deal with the exhaust gas in the incineration process. The organic chlorides are the toxic gases(Jafari *et al*., 2008). Especially, dioxin is special toxic gases.

In order to control the special toxic gases such as dioxin and so on in the Garbage incineration process, the incineration furnace must keep higher temperature field and the temperature of incinerator must be controlled over

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850°C and the residence time of exhaust gas in the incinerator has to be greater than 2 sec so as to ensure that the dioxin about 99.9% can be decomposed. In a word, the factors of determining the combustion quality mainly are the garbage combustion temperature, residence time of garbage and the high temperature exhaust gas in the incinerator and so on.

Control requirement of optimization incineration: The incineration process consists of 4 stages that they are respectively the drying stage, thermal decomposition stage, incineration treatment main stage that is a real combustion stage and the burnout stage that is the final stage of combustible matter combustion generating a solid residue. The four control parameters of the combustion control system for the incinerator are the incineration temperature, mixing degree of stir, residence time of exhaust gas and the excess air ratio. The control objectives of incinerator combustion are those (1) It makes the furnace temperature reach a predetermined temperature value and reduce the fluctuation, (2) It maintains a stable combustion and reduces the formation of dioxin-like organic chlorides, (3) It must reach a predetermined treatment capacity for the garbage, (4) It makes the particulate matter, nitrogen oxide and carbon monoxide less in exhaust gas, (5) The incineration residue of ignition reduction reaches the design value, (6) To maintain the stability of steam flow and (7) To reduce the operation error artificially.

The control factors of the incinerator combustion include that (1) The temperature, pressure of superheated steam and the water level of steam drum, (2) Feeder and the speed of the fire grate, (3) Control of exhaust gas at 850¡æ and 2 seconds time stayed, (4) Negative pressure control of combustion chamber, (5) Control of the coal economizer outlet temperature and (6) Control of the oxygen content in exhaust gas. The temperature fluctuation would cause changes in burn rate and the clinker ignition loss would exceed the standard. At the same time, it would influence the production of steam and reduce the operation economy of incinerator. The engineering practice shows that the temperature of incinerator should be controlled within the range from 850¡æ to 950¡æ and at this time, the pollutants of exhaust gas emission in online monitoring is smaller, the steam output is more stable and the clinker ignition loss is also minimal and stable.

CONTROLLED OBJECT CHARACTERISTIC AND CONTROL STRATEGY

Cybernetics characteristics: The controlled variables needed to be controlled of the incinerator combustion are as the following, such as temperature and pressure of superheated steam, water level of steam drum, speed of the fire grate, exhaust gas temperature and stayed time stayed, negative pressure in combustion chamber, outlet temperature and oxygen content in exhaust gas and so on and the features of the control and the controlled process mentioned above are closely related to the cybernetics characteristic (Dong *et al*., 2010). The combustion process is a very complex process of physics and chemistry, due to the characteristics of combustion process owns uncertainty, nonlinearity and feature of time-varying and so on, therefore there exists the following puzzles in the specific control implementation. They are respectively the uncertainty, high nonlinearity, semi-structured and unstructured, system complexity and the reliability problem. From the analysis of cybernetics characteristic, because it belongs to the control problem of the complex process of uncertainty, it is difficult effectively to optimize the combustion process control by conventional control strategy and algorithm. Therefore it must explore the more effective control strategy.

Control strategy selection: Although, the optional control strategy is quite a bit, for example, the conventional PID control, fuzzy control and human-simulated intelligent control etc. (Xu *et al*., 2013), but each has its limitations in application. In the control process of incinerator combustion, the fusion control strategy is a more wise choice that is based on Human Simulated Intelligent Controller (HSIC) and then fused the expert knowledge (Gao *et al*., 2013). Because the fundamental feature of the control strategy of HSIC is to imitate the control behavior of control expert, its control algorithm is a control method of multimodal and is alternatively a control model using the multiple mode control (Xia, 2012). The expert knowledge can be expressed by means of the production rule representation and so long as it increases the number of if condition then action conditional statements, then it can easily construct fusion control algorithm, therefore the control strategy is more close to the actual needs of the project.

Control model and algorithm: The control model of combustion process is shown as in Fig. 1 and it is a solving model of control problem constituted by the system error e(t), the change rate of error $\dot{e}(t)$ and a time t (Zhang *et al*., 2012). The control system of incineration combustion consists of controlled incineration process

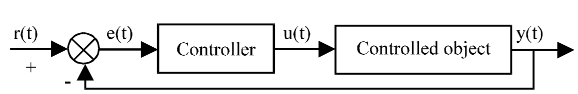

Fig. 1: General control model structure

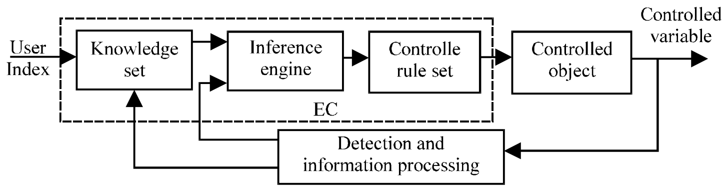

Fig. 2: HSIC control model structure

and controller. In which, the error $e(t) = r(t)-y(t)$, $r(t)$ is the system input and $y(t)$ is the system output. The control objective is that when $t\rightarrow\infty$ it makes $e(t) = \dot{e}(t) = 0$. In order to achieve better control effect, it is necessary to sum up the field experience of engineering and technical personnel as well as the wisdom of operator and after fusing the knowledge of expert system, the structure of control model is shown as in Fig. 2.

In the incinerator control system, the system of the highest control demand is the sub-system of exhaust gas and pollution water treatment control. Aimed at this two sorts of sub-system, its concrete fusion control algorithm can be achieved by means of improving the prototype algorithm of HSIC and then after fused the knowledge of expert system, it could form the fusion control algorithm based on human simulated intelligence (Yu *et al*., 2009). The algorithm can be expressed as the following.

- If $e>\beta R$ then $u_n = u_m$
- If $e<-\beta R$ then $u_n = -u_m$
- If $|e|<\delta_1$ and $|\dot{e}|<\delta_2$ then $u_n = u_{n-1}$
- If $|e|>m\bullet R$ and $e\bullet\dot{e}>0$ then $u_n = u_p$
- If $e\bullet\dot{e}<0$ and $|e/\dot{e}|>a$ THEN $u_n = op_1$
- If $e\bullet\dot{e}<0$ and $|e/\dot{e}|>b$ then $u_n = p_1+K_d\dot{e}$
- If $e\bullet\dot{e}<0$ and $b\leq|e/\dot{e}|\leq a$ then $u_n = p_1$
- If $e\bullet\dot{e}\geq 0$ and $|e|\epsilon(\delta_1, \theta_1)$, $|\dot{e}|\epsilon(\delta_2, \theta_2)$
- Then $u_n = P_1+K_{p2}e+K_{i2}\Sigma e_j$
- If $e.\dot{e}<0$ and $|e|\epsilon(\delta_1, \theta_1)$, $|\dot{e}|\epsilon(\delta_2, \theta_2)$
- Then $u_n = P_1+K_{p2}e$
- If $e.\dot{e}\geq 0$ and $|e|>\theta_2$
- Then $u_n = P_1+K_{p1}e+K_{i1}\Sigma e_j-K_d\dot{y}$

In which, u_n is the nth output value of controller, u_m is a output retention value related to Input change ΔR, up is a forced retention value, e, $\dot{e}$ is respectively the system deviation and its change rate, $\dot{y}$ is the output change rate of system, $P_1 = r\Sigma e_{m,i}$ $(i = 1,2,\ldots 1)$ is the latest retention value of controller output and in which, $e_{m,i}$ is the jth extremum of deviation, r is a weighted factor of extremum and it can be modified on line. K_{p1}, K_{p2}, K_{i1}, K_{i2}, K_d is respectively the proportional, integral and differential gain. Σe_j is the accumulated deviation during $e.\dot{e}\geq 0$. β is a switching factor, α, a, b is respectively the different constant and it can be determined by the experience rule in knowledge set. R is a set value and δ_1, δ_2, θ_1, θ_2 is respectively the error and error rate of the permissible range.

SIMULATION EXPERIMENT AND ITS ANALYSIS

In the simulation experiment, it takes a familiar two order with lag link in industrial control object as an example and makes the simulation respectively by PID plus Smith predictor (optimal PID) control algorithm and fusion control algorithm based on Human-Simulated Intelligent Controller (HSIC). Assume the controlled process control model is below.

$$W(s) = 4.13e^{-\tau s}/(s+1)(2s+1) \quad (1)$$

When the delay time $\tau = 10$ sec, its response curve is shown as in Fig. 3. Figure 4 shows the response curve when the disturbance is joined at time t = 15 sec and the width and amplitude of joined disturbance pulse signal is respectively 0.2s, 0.5.

From the analysis of Fig. 3 and 4, it can be seen that no matter what the speediness, stability and overshoot of system response, or the anti-interference ability of the system, all the performance of fusion control algorithm (HSIC) excels the optimal control algorithm of PID plus Smith predictor. Figure 4 further explains that the fusion control algorithm is very strong in robustness of anti-jamming performance and under the strong interference, it still keeps better control quality.

Furthermore the output response is almost influenced under the following conditions (1) When the external disturbance changes, if the air is constant, the main steam pressure is constant and the garbage amount increased 5% disturbance, (2) The amount of air is constant, the main steam pressure is constant and garbage 5% reduction in the amount of perturbation, (3) The amount of garbage is constant, air volume decreased 5% disturbance, (4) The amount of garbage is constant, air volume reduced 5% disturbance, (5) Main steam pressure is constant and the garbage water content increased 10% disturbance and (6) Main steam pressure is constant and

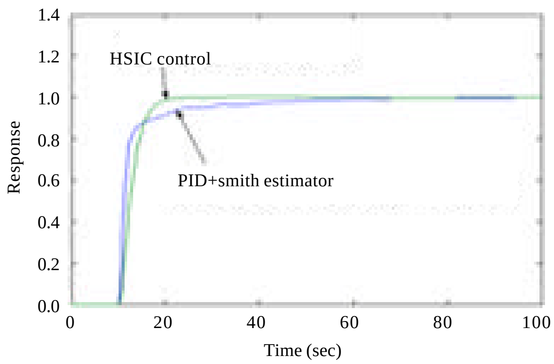

Fig. 3: Response curve of HSIC and optimal PID

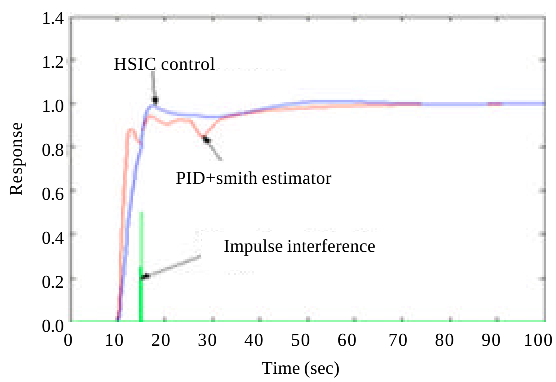

Fig. 4: Response curve under disturbance

the garbage water content reduced 10% disturbance and so on. It shows that the intelligent fusion control strategy is effective and it owns very strong robustness.

CONCLUSION

Incineration, as an essential way of clearly and economically dealing with MSW, is the main objective of MSW disposal. The combustion of MSW is a close coupling non-linearity, multi in-out process. Temperature of incinerator is a key parameter of incineration efficiency and generation of pollutants controlling. Keeping it in an appropriate scale is an indication of complete incineration and less production of Secondary Pollution. Actualizing the control strategy proposed in the study can achieve the control objectives. The experiment results show that the control strategy is reasonable, feasible and effective for complete incineration and secondary pollution control and it is high in control precision, better in dynamical and steady quality and very strong in robustness.

REFERENCES

Dong, X.M., Z.S. Li, M. Yu, C.R. Liao and W.M. Chen, 2010. Human simulated intelligent control and its application in magneto-rheological suspension. Control Theory Appl., 27: 249-256.

Fang, J.H., 2004. Exploration of development of municipal solid waste incineration in Beijing. City Manage. Technol., 6: 34-41.

Gao, G.Q., H.Y. Zhou, X.M. Niu and Z.M. Fang, 2013. Research on intelligent decision-making system of variable spraying for mobile robot in greenhouse. Applied Mech. Mater., 241: 1835-1838.

Jafari, M.J., A. Karimi and M.R. Azari, 2008. The role of exhaust ventilation systems in reducing occupational exposure to organic solvents in a paint manufacturing factory. Indian J. Occupational Environ. Med., 12: 82-87.

Puri, A., M. Kumar and E. Johal, 2008. Solid-waste management in Jalandhar city and its impact on community health. Indian J. Occup. Environ. Med., 12: 76-81.

Xia, Z.L., 2012. The research of humanization design for coal mine machine. Applied Mech. Mater., 130: 179-182.

Xu, P., J. Xiao, S. Li and Y. Yang, 2013. Human simulated intelligent control for permanent magnet synchronous motor. Applied Mech. Mater., 241: 1821-1827.

Yu, M., X.M. Dong, S.B. Choi and C.R. Liao, 2009. Human simulated intelligent control of vehicle suspension system with MR dampers. J. Sound Vibration, 319: 753-767.

Zhang, X.L., Y.H. Hu and S.F. Chai, 2012. Modeling method for complex structure system in finite element simulating analysis. Applied Mech. Mater., 130: 195-199.