ABSTRACT

Main emissions from the industrial flue gases are carbon monoxide (CO), nitrogen oxide (NO_X), sulphur oxide (SO_X), chlorofluorocarbons (CFC) and air- borne inorganic particles such as fly ash, soot and other trace gas species. These gases are considered to be responsible for heating up the atmosphere, producing a harmful global environment. Among these gases, sulphur dioxide (SO_2) play a predominant role in atmospheric chemistry and contributes to acid rain as it dissolves in water to form sulphuric acid. Excessive exposure to sulphur dioxide severely affects eyes, lung and throat. Also, sulphur dioxide is toxic to a variety of plant life and may produce visible signs of injury and reduces crop yields. In accordance with the environmental conservation act and environmental rules, it is mandatory to install Flue Gas Desulphurization (FGD) plants to absorb SO_2 from the flue gas, before it is exposed into the open atmosphere. Efficient removal of SO_2 can be achieved by using wet FGD techniques. There has been a rise in interest in using various reactants for Wet Flue Gas Desulphurization (WFGD) techniques. Among all, a treatment process using recycled sulphuric acid (H_2SO_4) with externally added hydrogen peroxide (H_2O_2) absorbents are materialized to be effective and it used in the present research. Based on the concentration of SO_2, the flow rate of externally added hydrogen peroxide is regulated to achieve the maximum SO_2 removal

efficiency. For this, Fractional Order based CDM-PID (FOCDM-$PI^{\lambda}D^{\mu}$) controller is proposed and implemented in the lab scale SO_2 emission control setup.

The first stage of the research work focuses on physical modelling of the packed column. Based on physical modelling, the parameters of the packed column such as diameter, total height, packed height and Liquid/Gas ratio are determined by two-film gas-liquid absorption theory. These packed column parameters are used for CFD model development to ensure for obtaining maximum SO_2 removal efficiency. From the outcome of the above modelling, the lab scale SO_2 emission control set up is developed which is suitable for kinetic studies as its specific surface is quite insensitive to the liquid flow rate. The preliminary experimental investigations are carried out with this setup to confirm the type and concentration of the absorbent used for controller studies. For this investigation, different absorbents such as, water, sodium hydroxide (NaOH), H_2O_2 and H_2SO_4 with different combinations and concentrations are considered. Based on the investigation, H_2SO_4 with externally added H_2O_2 are chosen as an absorbent for further analysis.

The second stage of the research work describes the design and implementation of proposed Fractional Order based CDM- $PI^{\lambda}D^{\mu}$ (FOCDM-$PI^{\lambda}D^{\mu}$) controller by incorporating the concept of Coefficient Diagram Method (CDM) and fractional calculus in the laboratory scale SO_2 emission control setup. For controller design, SO_2 emission control system is approximated as First Order Plus Time Delay (FOPTD) transfer function by using an experimental step test method. Based on the FOPTD model, the tuning parameters such as Kp, T_i, and T_d are determined based on CDM design strategy and the additional tuning parameters such as fractional integral order (λ) and fractional differentiation order (μ) are computed based on the simple and robust Paricle Swarm Optimization (PSO) algorithm.

In the third stage, the performance, robustness and disturbance rejection property of the proposed FOCDM- $PI^{\lambda}D^{\mu}$ controller is analysed at the operating points of 50 ppm and 500 ppm. The results of the proposed FOCDM- $PI^{\lambda}D^{\mu}$ controller is compared with the classical controllers such as Coefficient Diagram Method (CDM) based PID (CDM-PID) controller and Ziglar-Nichols PID (ZN-PID) controller in terms of performance measures (Integral Squared Error (ISE), Integral Absolute Error (IAE), Settling time (t_s)) of the output signal. In addition, the performance of the proposed FOCDM-$PI^{\lambda}D^{\mu}$ controller is also tested with the mixed (SO_2+NO_2) gases. The experimental results reveal that the proposed FOCDM-$PI^{\lambda}D^{\mu}$ controller enhances the performance in all aspects when compared to the classical control techniques. The robustness and load rejection characteristic of the controllers have also been tested and the results favour FOCDM-$PI^{\lambda}D^{\mu}$ controllers. It concludes that the proposed FOCDM-$PI^{\lambda}D^{\mu}$ controller work well in spite of the nonlinearity in the system. More importantly, the proposed control strategy can be used effectively in industrial applications to control the class of processes.