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Absorption cleaning of flue gas with special focus on SO_2 elimination

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Current interest in environmental issues is closely linked to issues of waste treatment. Waste which is not suitable for material utilization may be processed in several other ways; it may be landfilled, thermally processed, etc. These processes are necessary for detoxication, decrease of negative impact on environment as well as for secondary energy production from waste.

However, thermal processing also has its positive and negative side. Some of the disadvantages include air pollution from emissions, formation of residual waste and water pollution. Air pollution is caused by hazardous polluting substances in flue gases which are formed during incineration. Residual waste includes products formed during incineration process, such as ashes. Flue gas cleaning equipment may produce secondary waste in the form of waste water which contains wide range of dissolved polluting substances.

Tests for SO_2 elimination using various pH absorbents were carried out at experimental unit with two levels for flue gas cleaning. Calculation studies in ChemCad commercial programme were conducted under the same conditions. Comparison of individual results will be presented in the article. Calculation of pressure losses at the experimental unit will be given as well as detailed description of the equipment and conducted experiments.1

1. Introduction

Pilot plant of flue gas wet scrubber was put into service at the Institute of Process and Environmental Engineering (IPEE) (Figure 1). Experimental equipment of two-stage flue gas cleaning consists of “O-element” first stage (Filip, 2002) and second stage of packed column (Jecha, 2006). O-element device developed at IPEE substitutes Venturi scrubber device which is commonly used as a first stage of absorption in practice. Design of packed column consists of two theoretical stages and is packed with structured packing. Experimental unit of flue gas cleaning is connected to unit of thermal processing of waste gas (Štulíř, 1998). This unit generates flue gas containing SO_2.

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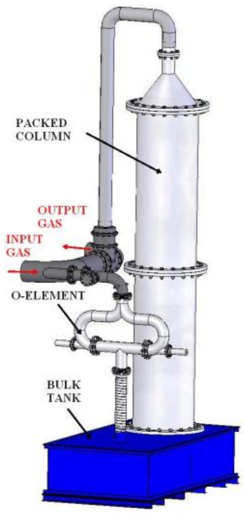

Figure 1: Overall view of experimental unit for flue gas cleaning.

Measurement of hydraulic resistance at first and second stage of wet scrubber was conducted at experimental unit. These results were compared to results obtained in calculation modeling. Concentration of SO_2 in outlet flue gas with varying pH of absorbent was measured as well. Experimental data were compared to data obtained in ChemCad program.

2. Experimental Unit

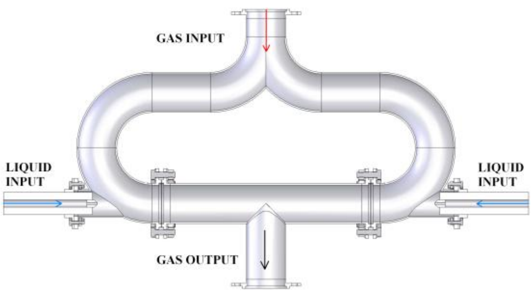

Figure 2: Description of flowing in 2P O-element.

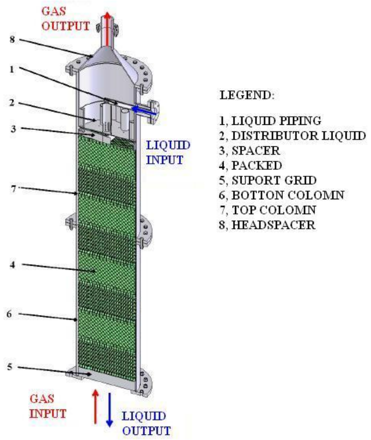

Figure 3: Description of second stage of flue gas cleaning.

Chapter 1 First stage of wet flue gas cleaning is designed as O-element which substitutes device for intensive contact between gas and fluid which is called Venturi scrubber. Homogenizer called O-element is a piece of device which serves for homogenization of gaseous-liquid mixture and was already used for similar purposes (Bébar et al., 1975).

Chapter 2 Main objective of the O-element (Figure 2) is a perfect mixing of individual flows and formation of large mid-phase area which is secured by formation of dispersed flow. This further enables increase of mass transfer intensity during absorption. Other objectives include minimization of hydraulic resistance. Second stage of experimental unit is made up by packed column (Figure 3) which is designed as a countercurrent absorber with structured packing (Jecha, 2006).

3. Measurements and Simulations

Experimental measurements carried out at two-stage absorption equipment were to verify calculation modeling of hydraulic resistance of individual devices and results of simulations of elimination of SO_2 from flue gas at wet scrubber.

3.1 First stage of absorption flue gas cleaning

O-element pressure drop is made up by several components of pressure drop. Particular sections contribute to pressure drop with local resistances, direct pipes, two-stage flowing and flow shrinking-in. These sections are presented and described in Figure 4. Calculation was applied for four-pipeline O-element type (O-element 4P) and for two-pipeline O-element type (O-element 2P).

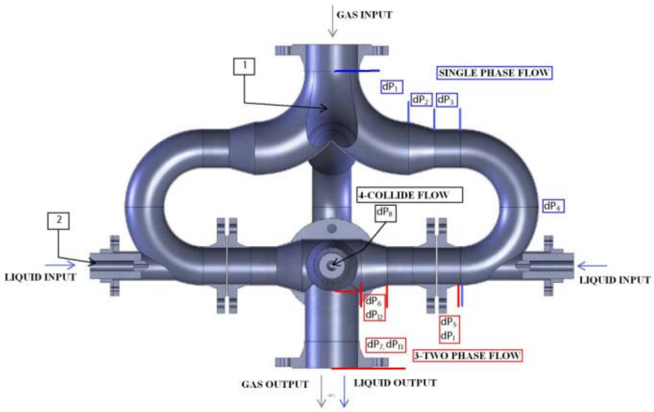

Figure 4: Description of flowing in 4P O-element.

Pressure drop was measured at 2P O-element for various operational absorption conditions. Measured values are available in (Jecha, 2006). Pressure drop in identical operational conditions was measured in Venturi scrubber, which is available in (Filip, 2009). Based on calculations of hydraulic resistance of O-element which is presented in (Jecha, 2010), hydraulic resistance results of 2P, 4P O-element were obtained. Comparison of hydraulic resistances measured in experiments at 2P O-element and Venturi scrubber and calculated results for 2P, 4P O-element are presented in Figure 5.

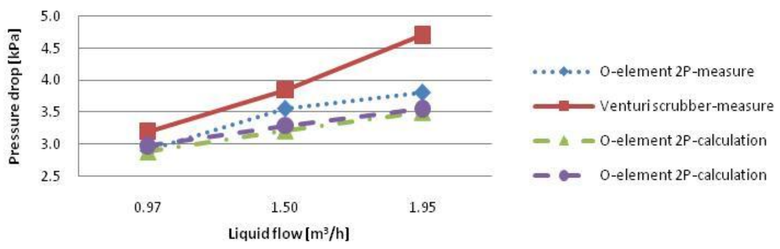

Figure 5: Comparison of pressure drop in O-element and Ventura scrubber obtained in measurements and mathematical calculations for flue gas flow rate of 1000 m^3_N/h.

Results in Figure 5 clearly show reduction of pressure drop at O-element, as opposed to Venturi scrubber, which in average amounts to 15 %.

3.2 Second stage of flue gas absorption cleaning

Calculation of pressure drop of structured packing (Flexipack 2Y HC) of absorption column (0.6 m in diameter and 2.5m height) was carried out in a standard way using method stated in (Chopey, 2004).

Flue gas flow rate ranging from 500 to 1100 m^3_N/h, 1.24 kg/m^3 density and absorbent constant flow rate of 3.8 m^3/h were entered for calculation of pressure drop in experimental unit. Load of fluid packing amounted to 13. $[m^3/(m^2.h)]$ in this particular case. Pressure drop was of unit height of structured packing was determined using diagrams from (Chopey, 2004) and (Koch-Glitsch, 2010). Hydraulic loss caused by column input flue gas flow, fluid distributor and aperture in top of column were neglected in calculations. Comparison of measurement results and calculations (Figure 6) gives significant correlation of measured values with calculations in (Chopey, 2004) with calculation inaccuracy significantly deviating at value of 1100 m^3/h.

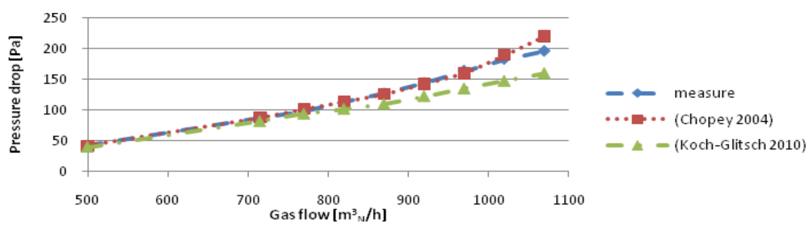

Figure 6: Comparison of measured and calculate data of hydraulic resistance of experimental absorption column.

3.3 Simulation of wet flue gas cleaning in ChemCad program

Research of absorption in simulation software was conducted simultaneously with experimental research (Jecha et al., 2007). Simulation model was created which corresponded with experimental equipment and thus the experimental data can be compared with data obtained in this model (Figure 7).

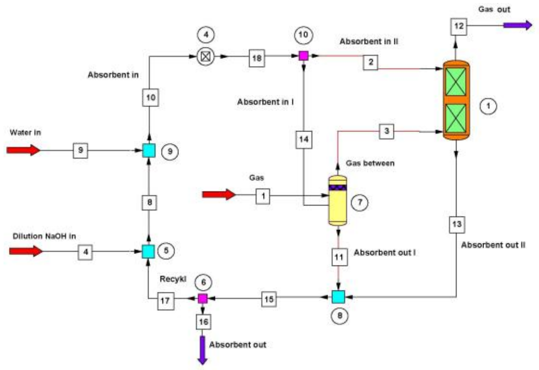

Figure 7: Simulation model of wet flue gas cleaning.

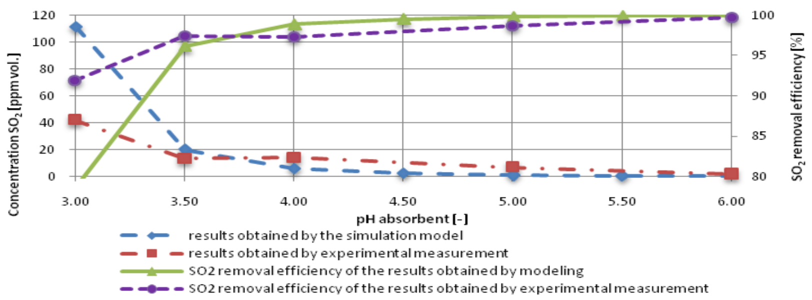

Figure 8: Comparison of measured and calculated data of packing hydraulic resistance

Figure 8 presents comparison of results from experimental measurements and simulation program showing SO_2 concentrations in output flue gas in dependence with pH absorbent modifications. Measurements and simulations were conducted under following conditions:

- Of Flue gas flow rate 600 m^3_N/h and of fluid flow rate 2.5 m^3/h into first stage, of fluid flow rate 3.78 m^3/h into absorption column
- Of SO_2 concentration in input flue gas 520 ppm vol.

4. Conclusions

Pressure drop was observed at first stage of absorption flue gas cleaning. Measured values of pressure drop of 2P O-element device were compared with calculated values of pressure drop of 2P and 4P O-element devices along with measured data from Venturi scrubber pressure drop. Results presented in Figure 5 show pressure drop reaches the highest values in Venturi scrubber under particular conditions. Based on comparison of measured and calculated values of 2P O-element, calculation model is corresponds well with a given hydraulic resistance of 2P O-element. Comparison of pressure drop was also done for absorption column with structured packing. These results allow to apply the calculation on a given type of packing since measured data of pressure drop fall into assumed calculated limits of packing pressure drop. Dependence of SO_2 concentration in output flue gas upon pH absorbent was observed in two stage flue gas cleaning device as well. Results were obtained both by experimental measurements and in ChemCad simulation program. Value of 3 pH gives highest deviation between measured and calculated SO_2 concentrations beyond second stage. This difference was assigned to experimental measurements as absorbent pH regulation was failing for values of 3 absorbent pH.

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