DESIGN AND OPTIMIZATION OF EXHAUST GAS CLEANING SYSTEMS WITH CHLORITE-BASED WET OXIDATIVE SCRUBBING (WOS)

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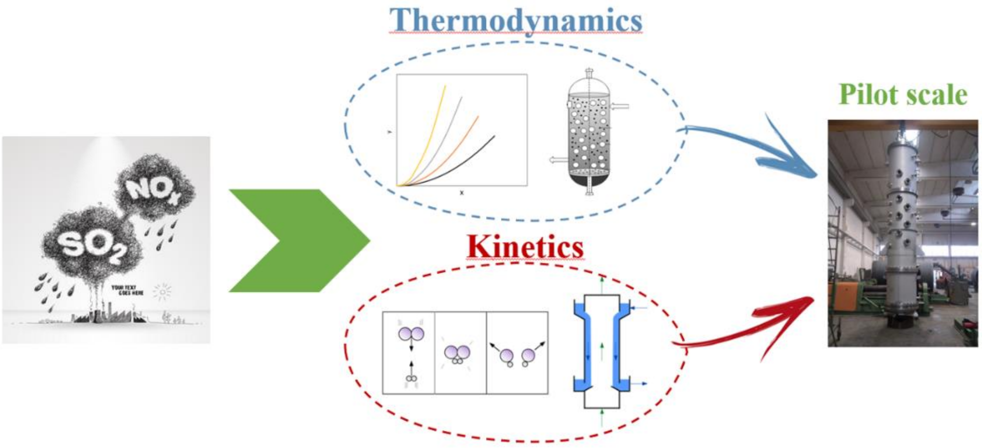

Despite the successful implementation of legislation over several decades and the success in dealing with the emission of certain pollutants into the atmosphere, much of the European - and global - population still breathes air with air pollution levels that exceed EU standards and World Health Organisation (WHO) air quality guidelines for health protection. Current levels of air pollution continue to cause significant impacts on human health and ecosystems. The main pollutants (CO_2, SO_2, NO_x, VOCs, and PM) are released into the atmosphere through both natural and anthropogenic sources of pollution, and it is on the latter that the regulations focus. Indeed, it is human activities that have led to the release of large quantities of pollutants into the atmosphere. Focusing our attention on SO_2 and NO_x as part of its long-term strategy to reduce SO_2 and NO_x emissions, the European Union ratified the 2016/2284/UE Directive, which defines new and more severe targets for SO_2 emissions in its countries. This new directive amends the 2003/35/UE Directive and repeals the 2001/81/ UE, which forces to reduce the anthropogenic atmospheric emissions of SO_2 and NO_x for the Member States until 2029 and for the subsequent years. According to this Directive, most of the European countries will be forced to reduce more than 70% of their actual SO_2 and NO_x emissions starting from 2030. Consequently, substantial research work is focused on developing sustainable processes that enable efficient management of the pollutants produced.

Currently, it is widely known that SO_2 emissions can be limited and almost eliminated by using fuels with low-sulphur content, more expensive. Differently, NO_x emissions can be partially controlled by improving the combustion technologies, but for several applications, after-treatment processes are the only available options to comply with regulations. These technologies include dry and semi-dry (dry-scrubbers and spray dryer) or wet scrubbing columns (wet-scrubbers) for SO_2 capture, while Selective Catalytic Reduction (SCR) or Selective Non-Catalytic Reduction (SNCR) units can be implemented for NOx control. The mutual integration of these technologies in the exhaust gas cleaning field needs several efforts to contain CAPEX and O&M costs and to reduce the plant footprints. These constraints are even more relevant in the case of retrofitting of existing systems or in the case of non-stationary installations such as ships and trains. As an alternative to traditional after-treatment processes, Wet Oxidative Scrubbers (WOS) aim to improve the performance of conventional scrubbers for flue-gas treatment by adding oxidizing reagents to the liquid. This process can be used to design absorption towers in which de-SO_2 and de-NO_x operation are combined in one device, potentially allowing the compliance with the more stringent emissions regulations in force so far and simultaneously reducing CAPEX and O&M costs, and footprints, as compared to traditional after-treatment systems.

The optimal operation of reactive absorption processes depends primarily on the correct design of the equipment and a sufficient understanding of the phenomenology of the process. To adequately describe these phenomena, specially developed mathematical models capable of simultaneously considering the thermodynamic of the process, column hydrodynamics, mass and heat transfer resistances and reaction kinetics are required. Currently, there are reliable predictive models for mass and heat transfer and hydrodynamics which are able to properly describe the phenomena depending on the type of contact taken into consideration, while the thermodynamic and kinetic contributions given by the reaction in the liquid phase are specific data that depend on the type of gas absorbed and the reactant selected for the absorption operation: in this sense, a dedicated experimental activity is required to estimate equilibrium dataset and kinetic reaction data.

This project aims to study the simultaneous reactive absorption process of SO_2 and NO_x in absorbing solutions containing sodium chlorite ($NaClO_2$) which is selected based on its interesting oxidative properties toward NO_x on top of SO_2 even under acidic conditions, where this chlorine-based oxidizer exhibits its full potential with a very fast chemical reaction.

Focus will be on these two fundamental aspects needed to design of reactive absorption columns, with the following experimental activity:

- a thermodynamic study of the reactive absorption process with oxidative reactions and experimental estimation of the equilibrium dataset, i.e., the chemical solubilization data of the gas absorbed. The thermodynamic experiments are performed in a bubble column working in fed-batch mode, this means that the gas flow is fed in continuous, and liquid is a batch to exploit the absorption capacity of liquid until its saturation, which corresponds to the equilibrium conditions that could be reached in a single equilibrium stage. A Thermodynamic model will be developed in ASPEN PLUS using the phase and chemical equilibria equations.
- a study of liquid-phase reaction kinetics between the gas absorbed and the oxidant to determine the experimental values of the Enhancement factor representing the contribution given by chemical reactions. The kinetic experiments were performed in a falling-film absorber working in continuous mode, in this case we can see the concentration of the gas at steady-state condition. A kinetic model will be developed.

This PhD project is carried out in collaboration with and funded by Boldrocchi Group, a company based in Milan, which provides plant solutions in various engineering sectors, including gas cleaning systems and pollutant emission control. Based on laboratory data, the project's final step will be to design and construct a pilot-scale absorption column that operates in real conditions thanks to the support and experience of Boldrocchi in this field.

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