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Carbon Dioxide Capture Using Airlift Pumps

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Abstract – Carbon dioxide (CO_2) is the main greenhouse gas, remarkably contributing to global warming and climate change. Nonetheless, CO_2 is an inevitable output of a vast variety of industries relying on fossil fuels for addressing the energy demand. On the other hand, CO_2 is a valuable compound and can be used in many processes; for instance, CO_2 plays a vital role in plant growth (i.e., photosynthesis) and it is extensively consumed in greenhouses. Thus, not only is capturing CO_2 substantial for protecting the environment but it can also be utilized by many industrial processes. Due to the technical restrictions, CO_2 capture and reutilization are typically carried out as separate processes. However, in certain cases, these two processes can be combined and implemented simultaneously; this, in turn, can bring about several advantages such as lower costs and increased sustainability. Greenhouses are among such cases; pure CO_2 is utilized in greenhouses to generate CO_2-enriched water used for irrigation to increase crop growth and yield. On the other hand, the heating load in greenhouses is typically met by burning natural gas, which is a clean fuel that predominantly produces water vapour and CO_2 when combusted, along with minimal levels of NO_x. Therefore, there exists an opportunity to develop and apply a technology that can not only capture CO_2 but also directly integrate it into plant growth process in greenhouses. A newly designed airlift pump is evaluated for its use as a CO_2 capture device while dissolving it into water if operating by exhaust flue gases. A series of experiments were conducted to investigate the impact of volumetric CO_2 concentrations (ranging from 10% to 25%) and inlet gas flow rate (5-30 LPM, covering slug, intermittent, and churn flow patterns) on the mass transfer and pumping performance of a 25.4 mm airlift pump operated by a mixture of air and CO_2. High-speed imaging as well as a capacitance sensor were used to characterize the gas-water two-phase flow structure within the riser pipe of the pump. The results revealed that higher volumetric CO_2 concentrations in the feed gas led to higher volumetric CO_2 mass transfer coefficients (i.e., faster CO_2 dissolution in water). Also, CO_2 mass transfer exhibited a proportional increase with inlet gas flow rate in the slug flow regime, followed by an almost constant level in the transitional region to churn flow. Eventually, in churn flow, this variable reaches its peak before experiencing a slight decline as the flow approaches an annular pattern. Moreover, the highest efficiency of the pump as a mass transfer device was achieved in slug flow, while the highest water flow rate was obtained for the churn flow pattern conditions.