Pressurized chemical looping process for power/chemical production with inherent CO₂ capture: a review

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Abstract

Greenhouse gas emissions can be reduced from fossil fuel power plants by many options, include: improving the efficiency of power plants, switch to renewable fuel, replacement of coal by natural gas (containing less carbon content) and applying CO₂ capture and storage concept. According to the Intergovernmental Panel on Climate Change (IPCC) the latter one is the most promising technique that has the potential to reduce CO₂ emission following the 2D scenario. Three main configurations has been explored for CO₂ capture technologies: (i) post-combustion, (ii) pre-combustion and (iii) oxy-combustion. All these concepts incurs a very significant loss of efficiency and power output that has a large effect on the LCOE economics. Chemical looping process is an alternative option that have the potential to intrinsically reduce the energy losses and capital costs associated with CO₂ capture. In this concept, the fuel is indirectly combusted with an oxygen carrier (MeO which is reduced to Me), which results in a stream that contains mainly CO₂ and steam avoiding NOₓ formation and CO₂ dilution with other gases. After steam condensation, a rather pure CO₂ stream is obtained that can be compressed and stored. Figure (1) shows an overview of various technologies that utilize oxygen carriers in a chemical looping system.

Pressurized chemical looping system promise the potential for increasing the power plant efficiency compared to atmospheric process, hence gas turbine can be used in a combined cycle operation, this is especially important for the use of gaseous fuels in power industry. In addition, depending on the operation pressure, less or no energy would be needed for CO₂ compression to levels necessary for pipeline transportation for final sequestration. Considering this potentials, several experimental and modelling studies reported in the literature investigating pressurised chemical looping system.

While elevated pressures have a positive influence on the power plant efficiency, looking through the reported results, there are many contradictions on the effect of pressurized condition on the overall performance of chemical looping system. Pressurized operation influences the oxygen carrier performance in terms of reaction kinetics, heat and mass transfer, surface texture and particle structure. While affecting the process performance in term of CO₂ capture efficiency and fuel conversion. Considering these parameters, experimental campaigns in the literature carried out in various system and configurations such as pressurized thermos-gravimetric analyzer (TGA), fluidized-bed, packed-bed and moving-bed system. Likewise, modelling and simulation study carried out to gain an insight of the effect of pressure on the behaviour of several oxygen-carriers for chemical looping system. The need for pressurized operation also has prompted other researcher into novel reactor concepts, focussing on configurations avoiding external solids circulation. Alternative concepts include the internally circulating reactor and gas switching based concepts.

This paper aimed to establish a comprehensive review of the research outcomes of pressurized chemical looping process, in order to gain a fundamental understanding of the effect of operating
pressure on chemical looping system, as well as assessing various reactor configurations reported. Furthermore, this paper also provide an overview of the future research needs based on critical analysis of the current knowledge. To the best of our knowledge, this provides the first attempt to review findings obtained by different research groups about pressurized chemical looping process.

Figure (1) Chemical looping process for different application