Objective of the project

The scientific goal of the project is to investigate numerically and experimentally the possibility of usage a Molten Carbonate Electrochemical Cell (MCEC) for CO_2 capturing from exhaust gases by the electrolysis method (Fig. 1). The proposed scientific novelty is the process innovation of Molten Carbonate Electrolysis (MCE) usage, when the resulting product is not a fuel (such as H_2, CO, CH_4), but only CO_2 directly captured from the flue gases.

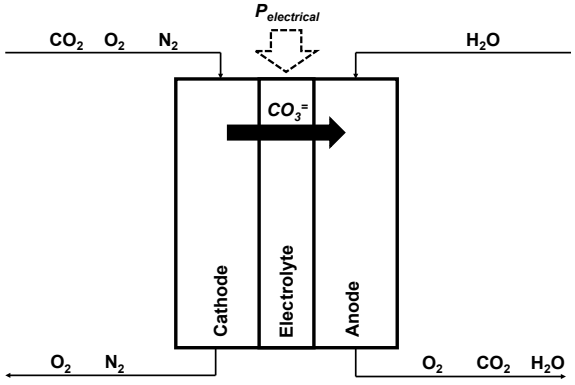

Figure 1 The proposed Molten Carbonate Electrochemical Cell for advanced CO_2 capturing

The main idea behind the research hypothesis is to use electrical current directly to move CO_2 in the form of carbonate ions ($CO_3^{=}$) instead of breaking the water molecule into hydrogen and oxygen and then create the carbonate ions. The proposed solution has a strong advantage in that it uses little power delivered to capture and move CO_2 from the flue gas to the anode channel.

Flue gases (mainly CO_2, O_2, and N_2) are pushed directly into the cell's cathode, while steam is supplied to the anode. The applied electrical current moves CO_2 in the form of carbonate ions from the cathode to the anode, where water steam transfers the captured CO_2 out of the cell. Later, the water steam might be condensed and removed from the CO_2/O_2 mixture. The resulting gas might then be cooled, separating CO_2 from O_2. The pure CO_2 obtained would be appropriate for storage or consumption.

Motivations for choosing the research topic

Environmental pollution reduction has become a critical challenge for industry and society in recent years. Reducing greenhouse gas emissions, such as CO_2 from the industrial sector, is widely recognized as an essential challenge for our society's long-term growth. Carbon Capture and Storage (CCS) is regarded as a realistic option for reducing CO_2 emissions.

One of the novel and promising methods implies the use of high temperature fuel cells to capture CO_2. Many researchers regard the Molten Carbonate Fuel Cell (MCFC) as a promising technology for CO_2 capture from exhaust gases. The molten carbonate electrolyte is the key element of the MCFC, that provides the ability to conduct the carbonate ions ($CO_3^{=}$) under the cell operation. The reversal of MCFC operation mode from fuel cell to electrolysis (MCE) provides an additional possibility for reducing CO_2 emissions. The MCE technology is an innovative electrolyser capable of converting H_2O and CO_2 into a mixture of H_2 and CO in a single step. MCE offers the possibility of connecting hydrogen production with carbon dioxide capture and utilization (CCU).

There could be situations when the production of additional electrical power is not the goal, and even utilizing it presents some challenges. The continuous necessity of fuel delivery (H_2, CH_4) and the necessity of utilizing the generated power is the MCFC's primary shortcoming in its capacity to capture carbon dioxide. While the limitation of MCE technology as a solution for carbon capture is the impossibility of delivering pure flue gases directly to electrolyzers (due to presence of O_2, N_2 components in the gases). The requirement to store or consume produced syngas is also a limiting factor.

This project application proposes a solution in the event that the aforementioned restrictions occur: a Molten Carbonate Electrochemical Cell for direct CO_2 extraction from exhaust gases by applying an electrical current. The concept is inspired by the MCE operation principle and was never reported in the available literature sources.

Research description and substantial results expected

The expected result of the project is a broad feasibility study of Molten Carbonate Electrochemical Cell for CO_2 capturing from exhaust gases by the electrolysis method.

It is planned to provide a series of experiments in order to get a set of experimental data demonstrating the cell's operational relationships. Situational part of the project will be focused of implementing the proposed idea as reduced order model and kinetic model to get a powerful numerical tool capable of precisely estimating the cell's operation parameters.

The most beneficial results obtained under the project will be summarized as scientific articles and published in the top rated journals. The process innovation, studied in terms of the proposed project, is suitable to be submitted as patent application.