Carbon2Chem®

L-III | Non-thermal Plasma for the Oxygen Removal in Coke Oven Gas

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The success of the economic conversion of steel mill gases to chemical products is dependent of the efficient usage of the available hydrogen sources. Coke oven gas (COG) contains hydrogen, which can be purified by means of pressure swing adsorption (PSA). An upsteam oxygen removal is advantageous for the economics of the PSA and handles COG streams above the critical oxygen threshold of the PSA. Due to various trace compounds in the COG, poisoning in a catalytic oxygen removal unit can occur. Thus, a oxygen removal process with non-thermal plasma is developed.

AIM AND METHOD

The feasibility of the plasmachemical oxygen removal is demonstrated within Phase I of the Carbon2Chem® project. In a model COG up to 90 % of 1.000 ppmV O_2 can be removed with a non-thermal plasma with 40 W power input at a total volume flow rate of 0.1 Nm³/h without additional usage of packing material or a catalyst. The non-thermal plasma was generated via dielectrical barrier discharge (DBD) in a laboratory reactor system with quartz glass as reactor jacket.

Within Phase II the scale-up of the plasma oxygen process is researched. Therefore, the reactor design was adapted resulting in a plasma reactor with a steel jacket (Figure 1) for higher volume flow rates, pressure and manufacturing accuracy. With this reactor, the influence of the reactor geometry and trace components at higher volume flows are investigated. Beside the laboratory trials, a scale-up plant at the Carbon2Chem® pilot plant station in Duisburg is prepared for experiments with COG from the steel mill (Figure 1) with a surface DBD reactor (Ruhr University Bochum) and volume DBD reactor (Fraunhofer UMSICHT).

CURRENT RESULTS

Supported by design of experiments, the conversion of the reactor was tested under variation of the oxygen inlet concentration, reactor pressure and volume flow rate at constant power input of 40 W. A higher load of molecules to be converted either caused by higher inlet oxygen concentration or total volume flow rate results in a drop of the conversion performance. The increase of the overpressure from 0.1 to 0.3 bar(g) had no considerable influence on the conversion outcome. At higher pressures than 0.3 bar(g) the current reactor setup needs higher voltages to generate a plasma.

In order to compensate the drop of conversion a higher molecule load the effect of higher power inputs and the electrode geometry are investigated. A constant ratio of power input to total volume flow rate (also known as specific power input) of 1,440 J/L can partially compensate the conversion drop at higher volume flow rates (Figure 2). Furthermore, a higher area of the high-voltage electrode has a beneficial effect. However, these methods have to be further investigated before a scale-up can be conducted.

Figure 1: Experimental volume DBD reactor with steel jacket at Fraunhofer UMSICHT in Oberhausen (left) and test rig with surface DBD unit for the treatment of COG from the steel mill of thyssenkrupp in Duisburg (right)

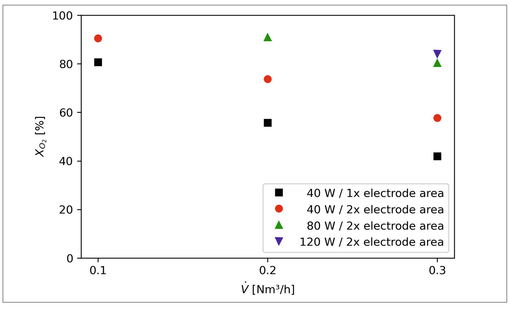

Figure 2: Effect of power input and electrode area on the conversion at increasing volume flows at $\varphi_{O2,Start}$ = 1,000 ppmV, T_{Start} ≥ R.T., p = 0.1 barg, d = 2 mm

A KEY BUILDING BLOCK FOR THE CLIMATE PROTECTION

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