Sustainable and Efficient CO2 Utilization: Production of Dimethyl Carbonate By an Indirect Route Using Ethylene Oxide and Methanol

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Global warming is one of the most challenging phenomena to be faced by humankind in recent history. Anthropogenic greenhouse gases (GHG) are a major

emitted. This calls for additional means for CO_2 reduction. Such means could be the capture of CO_2 and using it as a new carbon source to produce a variety of chemicals. However, such process are few and not widespread.

The process considered consist of two parts: CO_2 capture plant and a CO_2 utilization plant that converts CO_2 to DiMethyl Carbonate (DMC). DMC is a versatile, non-volatile chemical compound used as reactive intermediate for methylation and carboxylation reactions, as fuel additive, as solvent for coating as well as in polymerization reactions [2, 3]. The market value for this green agent is rapidly on the rise; valued at US$ 390 mn in 2014 and projected to reach US$ 690 mn by 2023 [4]. The high demand for DMC represents the perfect platform for this sustainable design problem. The problem is mainly concerned with the sustainable design and optimization of the utilization plant. The design is preformed based on a 12-step hierarchical decomposition strategy. Starting from collecting information about the raw materials and the possible reaction pathways to generation of a preliminary flow-sheet based on which the process parameters are set. This is followed by mass and energy balance, which are then verified by performing a process simulation with a commercial simulator like PRO/II. Sizing and costing are then performed on all equipment used to enable a full economic evaluation of the process.

A brief description of the proposed process is as follows: CO_2 is reacted in excess with ethylene oxide (EO) to produce ethylene carbonate (EC), eventual impurities are removed by means of a distillation. EC is then reacted with excess methanol (MeOH) to produce ethylene glycol (EG) alongside the product of interest DMC. The recovery of the DMC and EG is done by: separating {DMC+MeOH} from {EG+EC} by regular distillation. The unreacted EC is hydrothermally converted into EG. The system {DMC+MeOH} form a pressure sensitive azeotrope and are therefore separated by pressurized distillation. The proposed process design is able to supply 100,000 metric tons DMC and similar quantity of EG, utilizing around around 53,000 metric tons of CO_2 and consuming around 75,000 metric tons EO and 74 metric tons MeOH on a yearly basis.

The base case is then subjected to environmental impact analysis as well as an investigation into further improvements and optimization e.g. mass and heat integration, enabling the setting of design targets for further improvement so that a more sustainable process design can be obtained. The original design is thus further developed to incorporate a more thorough sustainability analysis and a life-cycle assessment (LCA) to determine process bottlenecks that when removed through, for example, process intensification or alternative hybrid operations, leads to a more sustainable process design.

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