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$_2$ uti-
lization plant that converts CO$_2$ to DiMethyl Carbonate (DMC). DMC is a versa-
tile, 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 infor-
mation 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 inter-
est 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 con-
verted into EG. The system \{DMC+MeOH\} form a pressure sensitive azeotrope
and are therefore separated by pressurized distillation. The proposed process de-
design is able to supply 100,000 metric tons DMC and similar quantity of EG, utiliz-
ing 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.

References

[1] Intergovermental Panel on Climate change (IPCC) IPCC fifth Assessment