DIMETHYL ETHER PRODUCTION FROM METHANOL AND/OR SYNGAS

ACKNOWLEDGMENT OF GOVERNMENT SUPPORT

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FIELD

Disclosed herein are processes and systems for producing dimethyl ether from syngas and/or methanol.

BACKGROUND

Biomass feedstock, such as agriculture and forestry residues, plays an important role in developing alternatives to fossil fuels. Although there are several methods of generating energy from biomass, gasification, in which a hydrogen-carbon monoxide gas mixture (syngas) is produced, offers several advantages. For example, syngas, like natural gas, can be burned in gas turbines, which are more efficient than steam boilers. Another key feature of syngas is, like petroleum products, it can be converted to useful chemicals, including dimethyl ether (DME). Syngas is also an available "raw" fuel from sources other than biomass, such as from coal gasification and natural gas stem reforming and other sources.

DME can be used as building blocks for synthesizing important chemicals, including dimethyl sulfate, high value oxygenated compounds, and lower olefins. Because of its environmentally benign properties, it can also be used as an aerosol propellant in products such as hair spray and shaving cream. Recently, DME has been suggested as an alternative fuel for diesel engines. Engine performance tests indicate that DME has thermal efficiencies equivalent to traditional diesel fuel. Other advantages of using DME as a diesel replacement include the reduced NO_x emissions, near-zero smoke production, and less engine noise. However, there are obstacles to producing DME from biomass syngas at an economical scale. For example, unlike petroleum, coal, and natural gas plants, which are established for central, large-scale applications, biomass feedstock and gasification systems are widely distributed geographically. If conventional DME process technology is adopted, a scale of 2500 t/d may be required for production economically comparable to conventional LPG fuel. Because it is difficult to deliver enough biomass to satisfy this criterion using conventional technology, a more compact and efficient portable process for converting the biomass or other source of syngas to DME is needed.

SUMMARY

Disclosed are methods for producing dimethyl ether (DME) from methanol and for producing DME directly from syngas, such as syngas from biomass. Also disclosed are apparatus for DME production. The disclosed processes generally function at higher temperatures with lower contact times and at lower pressures than conventional processes so as to produce higher DME yields than do conventional processes. For example, disclosed are processes for producing dimethyl ether comprising providing a source of methanol, providing a catalyst, reacting the methanol and the catalyst at a temperature from about 200° C. to about 500° C. with a contact time of from about 15 milliseconds to about 250 milliseconds, at about 1 atm to about less than 9 atm, and producing greater than about 70% yield (molar percent yield) of dimethyl ether. Certain embodiments of the processes are carried out in a system comprising multiple microchannel reactors.

Also disclosed are processes for producing dimethyl ether comprising providing a source of syngas, providing a hybrid catalyst, reacting the syngas and the hybrid catalyst at a temperature from about 200° C. to about 400° C. with a contact time of from about 25 milliseconds to less than about 500 milliseconds, and producing greater than about 60% conversion of CO to dimethyl ether. Certain embodiments of the processes are carried out in reactors providing greater surface to volume ratios than the presently used DME reactors. Certain embodiments of the processes are carried out in systems comprising multiple microchannel reactors.

Also disclosed are systems for producing DME from methanol wherein the system includes a module including a plurality of microchannel reactors, a source that feeds methanol to a methanol dehydration catalyst, or a plurality of microchannel reactors and a source that feeds syngas to a hybrid catalyst, and wherein the microchannel reactors are operable at temperatures of greater than about 250° C. and with a contact time of less than about 250 milliseconds to produce a DME yield of greater than about 70% (molar percent yield when referring to DME production from methanol and percent conversion of CO to DME when referring to DME from syngas). An alternative application includes on-demand synthesis of DME from either syngas or methanol

The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a reactor system and microchannel reactor assembly that may comprise certain embodiments of the disclosed invention.

FIG. **2** illustrates an embodiment of a microchannel device.

FIG. **3***a* illustrates DME yields in certain embodiments of the disclosed process for producing DME from methanol.

FIG. **3***b* illustrates DME yields in certain embodiments of the disclosed process for producing DME from methanol.

FIG. **4***a* illustrates DME yields in certain embodiments of the disclosed process for producing DME from methanol.

FIG. **4***b* illustrates DME yields in certain embodiments of the disclosed process for producing DME from methanol.

FIG. **5** illustrates an embodiment of syngas conversion to methanol: equilibrium CO conversion under different conditions; equilibrium is calculated for the reaction $CO+5H_2+CO_2=2CH_3OH+H_2O$.

FIG. **6** illustrates an embodiment of direct syngas conversion to DME: CO equilibrium conversion under different conditions; equilibrium is calculated for the reaction $CO+5H_2+CO_2 \leftrightarrows CH_3OCH_3+2H_2O$.

FIG. **7** illustrates the effect of GHSV on methanol synthesis in certain embodiments disclosed herein.

FIG. **8** illustrates the effect of pressure on dehydration of methanol in certain embodiments disclosed herein (H-ZSM-5 dehydration catalyst, T=234° C., GHSV=10 600 h^{-1}).

FIG. **9** illustrates the effect of catalyst ratio on CO conversion in certain embodiments disclosed herein (MeOH synthesis catalyst: dehydration catalyst; T=260° C., P=3.8 MPa, $H_2/CO=3$, GHSV=10 000 h^{-1}).