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Economic Impact of an Improved Methanol Catalyst

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Economic Impact of an Improved Methanol Catalyst

Abstract

The economic future of methanol is reviewed in light of its potential uses as a substitute for traditional hydrocarbon fuels and feedstocks as well as some evolving new uses. Methanol's future market position will depend strongly on its production cost in comparison with competitive products. One promising way to reduce the production cost is by use of an improved catalyst in the process by which methanol is obtained from the feedstock—which can be either natural gas or a similar product such as synthesis gas from coal gasification. To estimate the potential cost savings with an improved catalyst, we have based our analysis on a recent study which assumed use of synthesis gas from underground coal gasification as a feedstock for making methanol. The improved catalyst we studied was an actinide oxide whose features include high tolerance to sulfur and heat, and a yield of about 4 mol% methanol per pass with a 2/1 mixture of H_2/CO . We calculated the effect of this catalyst on methanol production costs in a 12,000-bbl/day plant. The result was a saving of from 1¢ to 2.5¢ per gallon on the total methanol synthesis cost of 23¢ per gallon (i.e., a saving in the conversion process of 4.4% to 10.9%), excluding the cost of the raw feed gas.

Introduction

The size of future methanol markets will depend strongly on the extent to which methanol replaces traditional hydrocarbon fuels and feedstocks. That in turn will depend on the availability and price of methanol in comparison with competing fuels. It is impossible to predict with confidence either the availability or the price of all competing fuels and feedstocks; hence an assessment of future methanol demand must necessarily rely on a projected market. Any significant reductions in the cost of producing methanol will be important.

At present methanol is made from natural gas. However, as the price of natural gas continues to rise in the U.S., coal is gaining increasing consideration as an alternate, less expensive feedstock. For either coal or natural gas, the feedstock is converted to a synthesis gas of hydrogen and carbon monoxide by steam re-forming or partial oxidation followed by purification. A small amount of carbon dioxide facilitates methanol

synthesis in most catalyst systems. The simplified synthesis reaction is:

Another possible way to decrease the price of methanol is to develop new catalysts with improved properties over those now in industrial use. Synthesis of methanol from carbon monoxide and hydrogen is currently carried out by one of two processes¹: (1) high-pressure synthesis at 100 to 600 atm, using ZnO/Cr_2O_3 catalysts operating at 250–400°C, or (2) low-pressure synthesis at 20 to 100 atm, using CuO/ZnO catalysts operating at 230–300°C. Both these catalysts are very susceptible to poisoning by sulfur and chlorine, and both processes thus require elaborate and costly gas-purification schemes.

This study was prompted by some encouraging results from preliminary work at the Lawrence

Livermore National Laboratory, indicating that certain actinide oxides are superior methanol catalysts. Further research in this area would be justified if these catalysts could significantly reduce the cost of methanol production, especially if a favorable market trend should bring about increased use of methanol.

Future Demand for Methanol

Uses of methanol can be divided into two groups. One group encompasses traditional uses including production of formaldehyde, dimethyl terephthalate, methylhalides, methylamines, solvents, acetic acid, etc. The second group includes new, evolving, and potential uses. The most important evolving uses for methanol are fuel uses, such as in blends with gasoline as an octane booster and in the synthesis of methyl tertiary butyl ether. Potential applications include use of methanol as an unblended fuel in the transportation end-use sector and in stationary power generators especially for peaking. New and possible nonfuel uses include use as a feedstock for single-cell proteins or for chemical manufacture of ethanol, styrene, etc. Methanol-coal slurry pipelines have also been proposed.

By the year 2000 it is possible that the second group of new and evolving uses will overtake the traditional uses (Table 1).

The largest potential new market for the alcohol fuels is as a blending or pure fuel for automobiles. The upper limit is about 40 billion gallons per year by the year 2000, assuming that use of methanol as a neat fuel (i.e., unblended) starts in the early 1990s.³ If we add potential use in peak power production of about 11 billion gallons per year,³ the total market for methanol, including all the new as well as traditional uses, could be as

Table 1. Estimated methanol market shares.²

	1980	1990	2000
Traditional uses (%)	91	63	46
New and evolving uses (%)	9	37	54

This report presents an analysis and projection of the methanol market and an assessment of potential cost savings in methanol production by use of a catalyst with improved properties over those currently used.

high as 40–60 billion gallons per year (1–1.4 billion barrels/year) in 1995 by some estimates. More conservative estimates of future use assuming expanded markets and new uses are summarized in Table 2. By all estimates, usage will increase in the next decades regardless of whether nontraditional uses become substantial (Fig. 1).

Table 2. Methanol demand for traditional uses and anticipated new uses, from 1976 through the year 2000. Demands for 1983 and later are estimates.

Year	Annual methanol demand			Source
	(10 ⁶ tonnes)	(10 ⁹ gal)	(10 ⁶ bbl)	
1976	2.84	0.95	23	Davy Powergas ⁴
1978	3.15	1.05	25	IGT ⁵
1980	4.71	1.57 ^a	37	IGT ⁵
1981	3.60	1.20 ^b	29	Chem. Eng. ^h
1982	4.44	1.48 ^a	29	Stokes ⁷
Demand for traditional uses				
1983	5.55	1.85 ^a	44	Catalytica Assoc. ⁸
1985	5.94	1.98	47	Stokes ⁷
	4.78 ^c	1.59 ^c	38 ^c	Davy Powergas ⁴
1990	6.39 ^c	2.13 ^c	51 ^c	Davy Powergas ⁴
Demand for both traditional and new uses				
1990	0.25	2.75	65	AlCl ₃ E ⁹
	9.90	3.00	71	Chem. Systems ²
1995	17.0	5.67	136	Chem. Systems ²
2000	13.5–15.6	4.5–5.6	107–124	Catalytica Assoc. ⁸

^aCapacity rather than demand.

^bIncludes 1.15 domestic + 0.05 imported.

^cAssumes 6% annual increase.

Figure 1. Projected methanol demand.

Factors Determining Current Price of Methanol

Expansion of methanol into new markets will be strongly affected by its price, which in turn is influenced by the cost of synthesis gas. Currently, methanol production utilizes natural gas as a feedstock. But impending complete deregulation of natural gas may well lead to doubling of the wellhead price and thus severely impact the cost of all processes utilizing it. Methanol could not then compete as a transportation fuel unless it were formulated from an alternative feedstock or from cheap natural gas from abroad. Table 3 summarizes recent fuel costs.

By analogy with historical trends, the price of natural gas will probably not rise to the equivalent price of the associated "swing fuel," i.e., No. 2 distillate, computed on the basis of heat content. Rather, it probably will command a somewhat lower price, e.g., comparable to the price of crude oil, which may be 25% less than distillate. Future price estimates are shown in Fig. 2.

Approximate cost equations (1982 dollars) for synthesis of methanol from natural gas are given

below,^{2,10,11} where we define Q_s , Q_n , and Q_m (all in units of \$/million Btu) as follows:

$$\begin{aligned} Q_s &= \text{cost of synthesis gas,} \\ Q_n &= \text{cost of natural gas,} \\ Q_m &= \text{cost of methanol.} \end{aligned}$$

Synthesis gas from natural gas

$$Q_s = 1.24Q_n + 1.52 \text{ (\$/million Btu).} \quad (1)$$

Methanol from synthesis gas

$$Q_m = 1.22Q_s + 2.00 \text{ (\$/million Btu).} \quad (2)$$

Thus, combining Eqs. (1) and (2):

Methanol from natural gas

$$Q_m = 1.51Q_n + 3.85 \text{ (\$/million Btu).} \quad (3)$$

Table 3. Current fuel prices (fall-winter 1982).

Fuel type	Retail price	
	(\$ per million Btu ^a)	(\$ per standard unit)
No. 2 fuel oil	7.21	\$1.00/gal
Crude oil:		
Contract	5.79	\$33.60/bbl
Spot price	5.43	\$31.50/bbl
Natural gas:		
Wellhead	2.30	Avg. U.S. price
Electric utility	3.42	Avg. U.S. price
Methanol:		
Gulf Coast	10.32-12.70	65-80¢/gal
California	15.64	98.5¢/gal
Gasoline	10.65	\$1.32/gal avg. all types

^aBased on the following conversion factors for millions of Btu per standard fuel unit: No. 2 distillate, 5.825/bbl; crude oil, 5.80/bbl; natural gas, 1.02/thousand cubic feet; methanol, 2.646/bbl (63,000 Btu/gal); gasoline, 5.205/bbl.

If natural gas prices follow the estimated crude oil costs in Fig. 2, coal is likely to become a more desirable feedstock for methanol synthesis. For example, if natural gas costs \$8.00/million Btu in 1990, the estimated 1990 price of methanol synthesized from natural gas is \$18.70/million Btu, assuming Eq. (3) and inflation of 7%/yr. On the other hand, synthesis gas derived from underground coal gasification is estimated to cost \$4.85/million Btu (1982 dollars).¹² Using Eq. (2) and 7%/yr inflation, we find that the estimated 1990 price of methanol derived from underground coal gasification is \$13.60/million Btu. Although both methanol cost estimates exceed the estimated 1990 fuel oil cost of \$11.00/million Btu shown in Fig. 2, the coal-derived product appears to be lower in cost than that from natural gas. Thus methanol synthesized from coal may find increasing uses in the transportation and utility sectors.

Figure 2. Projected prices of crude oil and fuel oil, assuming a 25% differential between crude and fuel.

Economic Impact of an Improved Methanol Catalyst

Although the present feedstock for methanol production is natural gas, in the future coal will probably be the primary feed in the U.S. The following analysis is based on a study by the Pritchard Corporation¹² of methanol production in a 12,000-barrel/day plant, where the feedstock is gas produced by the underground coal gasification process. We compare an improved actinide oxide catalyst with the CaO/ZnO catalyst assumed by Pritchard.

The methanol catalyst proposed for this review reduces the pressure requirement of a typical low-pressure synthesis loop from about 100 to 30 atm ($H_2/CO = 2/1$) and produces 4 mol% methanol per pass in the reactor effluent as contrasted to about 2.5 mol% for the CuO/ZnO catalyst.¹³ The proposed actinide catalyst is very sulfur-resistant, which allows for the elimination of some sulfur removal equipment; it is also stable to temperatures up to 600°C. We have estimated the impact that this catalyst would have on a 12,000-bbl/day methanol plant described by Smith and McCown.¹²

Capital investment (Table 4) may be reduced in three areas that account for 23% of the total plant investment: sulfur removal, gas compression, and methanol production and purification.

The sulfur tolerance of the improved catalyst will eliminate sulfur removal steps except for those necessary to produce the required product purity. Thus sulfur removal can be downstream of MeOH synthesis. A conservative estimate requires the entire \$3.1 million sulfur removal plant; but an optimistic assessment using the improved catalyst would be about 50% of the total or \$1.6 million.

The largest capital saving results from reduced compressor costs because of the reduction from 100 to 30 atm pressure. Compressor costs are thereby reduced 51%, from \$10 million to \$4.9

million. Reduction in circulating load is less important, since the circulation will still be required, at least in part, for heat transfer and prevention of excessive catalyst temperatures. An optimistic estimate would reduce overall compressor investment to \$3.6 million.

There may be a similar saving in the methanol synthesis units themselves, although it will be mitigated by the requirement for equal or larger heat exchange surface with the new catalyst. A conservative estimate would show no change in this cost; an optimistic one would show a reduction of 26%, to \$3.4 million.

The other possible major saving is in methanol purification, primarily a distillation step, in which equipment size is related rather directly to feed purity (and thus to separating load). A reduction in cost of 24%, to \$7 million, should occur in the optimistic case.

Operating cost reductions (Table 5) occur from reduced use of catalysts and chemicals, the reduction occurring in (1) the Stretford plant, from none to 50%, (2) the COS converter, which can be eliminated, (3) the ZnO guard bed, which can also be eliminated, and (4) the MeOH catalyst, which will have greatly extended life (the saving amounts to less than 0.1¢/gal over the conventional catalyst case). Unaffected operating costs in Table 5 include all expenses for production of feedstock less catalyst and purification costs upstream of the methanol unit.

The sources of all cost savings with the improved catalyst are summarized in Table 6, for both conservative and optimistic assumptions. From Table 6 we see that the impact of the improved catalyst on methanol production cost is a saving of 1.0¢/gal (4.4%) to 2.5¢/gal (10.9%) on the total methanol synthesis cost of 23¢/gal (excluding raw feed gas costs).

Table 4. Effects of improved catalyst on cost of capital items for methanol production plant.

	Conventional catalyst (\$ million)	Improved catalyst	
		Conservative (\$ million)	Optimistic (\$ million)
Stretford plant (sulfur removal)	3.1	3.1	1.6
Compressors	10.0	4.9	3.6
Methanol purification	9.2	9.2	7.0
Methanol synthesis	4.6	4.6	3.4
Total for catalyst-dependent items	26.9	19.6	15.6
Items independent of catalyst	90.1	90.1	90.1
Total plant capital costs	117.0	109.7	105.7

Table 5. Annual catalyst and chemical costs for methanol synthesis.

	Conventional catalyst (\$ million)	Improved catalyst	
		Conservative (\$ million)	Optimistic (\$ million)
Stretford plant (sulfur removal)	1.2	1.2	0.6
COS removal	0.5	0	0
ZnO guard bed	0.03	0	0
MeOH catalyst	0.16	0	0
Unaffected costs	0.5	0.5	0.5
Totals	2.4 (1.4¢/gal)	1.7 (1.0¢/gal)	1.1 (0.7¢/gal)

Table 6. Summary of methanol production costs with conventional and improved catalysts.

	Conventional catalyst	Improved catalyst	
		Conservative	Optimistic
Capital investment ^a (\$ million)	117 (21¢/gal)	112.2 (20.4¢/gal)	106 (19.2¢/gal)
Chemicals and catalyst (\$ million/yr)	2.4 (1.4¢/gal)	1.7 (1.0¢/gal)	1.1 (0.7¢/gal)
Utilities (\$ million/yr)	0.84 (0.5¢/gal)	0.84 (0.5¢/gal)	1.1 (0.5¢/gal)
Total synthesis cost	(22.9¢/gal)	(21.9¢/gal)	(20.4¢/gal)
Unaffected costs	(36.0¢/gal)	(36.0¢/gal)	(36.0¢/gal)
Total methanol cost	(58.9¢/gal)	(57.9¢/gal)	(56.4¢/gal)

^aAt 30%.

Conclusions

We conclude from this study that the improved catalyst could bring important savings in methanol production. The estimated savings range from 4.4% to 10.9% in the cost of methanol synthesis from the feedstock material. Another possibility for lowering methanol production costs

in the future may lie in switching from a natural-gas-based feedstock to a coal-based feedstock—for example, using synthesis gas from underground coal gasification as the raw material. Our projections suggest that coal will eventually become a less expensive feedstock than natural gas.

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