

Cost Effective Topsøe DME Production Technology Gasochem 2007

RESEARCH | TECHNOLOGY | CATALYSTS



COST EFFECTIVE TOPSØE DME PRODUCTION TECHNOLOGY

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ABSTRACT

This paper presents a cost effective design for large-scale DME production using Topsøe DME Technology. It is demonstrated how catalyst development can be utilised to design a DME plant, where investment costs may be reduced by about 30%.

The Topsøe dehydration catalyst DMK-10 is at the same time very robust towards variations in feed-stock composition and product specifications having a high selectivity and high activity with low by-product formation.

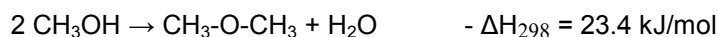
INTRODUCTION

DME, di-methyl-ether, may be used as spray propellant (>99.99% wt), chemical intermediate or as a clean and economical fuel alternative (e.g. LPG substitute, diesel substitute, power generation, etc.). The properties of DME are similar to those of LPG:

Boiling point, °C	-24.9
Vapour pressure @ 20 °C, bar	5.1
Liquid density, @ 20 °C, kg/m ³	668
Specific gravity, gas	1.59

TOPSØE INDUSTRIAL DME TECHNOLOGY

The Topsøe technology for large-scale production of DME includes the process of methanol dehydration. The reaction scheme is as follows:



The Topsøe DME process in industrial plants features the dehydration of methanol where the feedstock may be:

1. High purity refined methanol, i.e. Grade AA (e.g. min. 99.85 %wt. methanol), or GOST 2222-95 (e.g. min. 99.95 % wt. methanol) or
2. Crude methanol, e.g. 94 wt% methanol

The methanol may be taken directly from any methanol synthesis process without any methanol purification before entering the Topsøe DME process.

The process is based on well-proven technology and process elements, which comprises DME synthesis by methanol dehydration followed by two-step separation, firstly by DME product and off-gas separation and secondly by recycle methanol and process water separation (Figure 1).

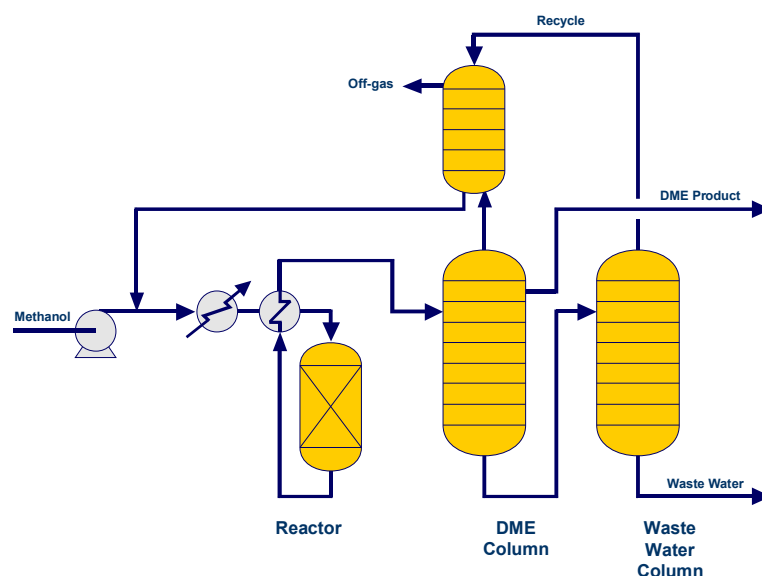


Figure 1: Main overall process layout – DME synthesis

In the Topsøe DME process the dehydration of methanol into DME is carried out in an adiabatic reactor. The inlet temperature to the reactor is above 250°C and at stable operation the outlet temperature is determined by the adiabatic temperature increase, which in turn is dependent on the actual required conversion in the reactor. The Topsøe DME reactor technology together with the Topsøe DMK-10 enable large temperature operation intervals resulting in a flexible process, which can be tailor shaped to meet all industrial DME product specifications. The Topsøe know-how on thermodynamics and phase equilibrium data does also allow an overall optimization of reactor operation and separation column design.

By using the Topsøe DME process with efficient heat integration between the synthesis section and the purification section, the result will be a low specific energy consumption.

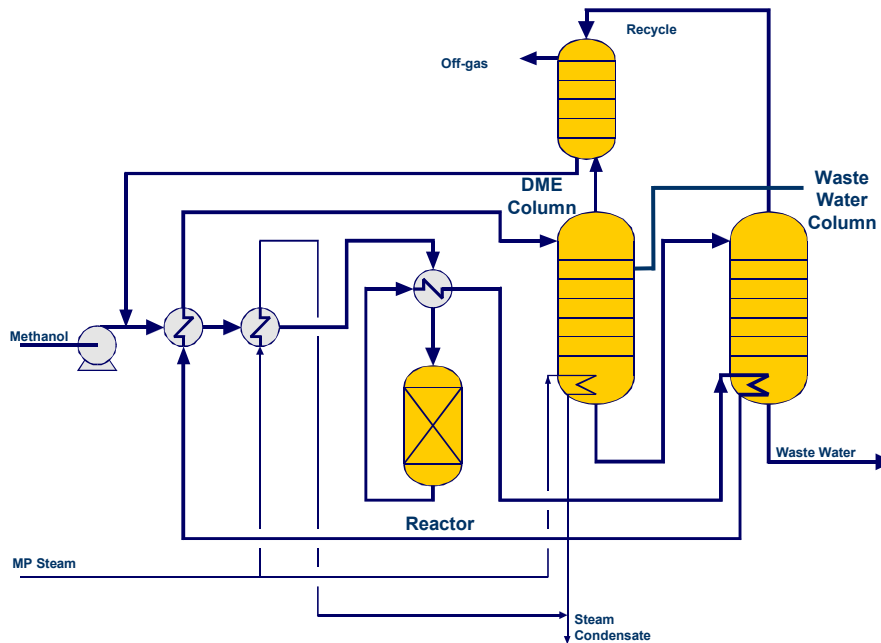


Figure 2: Effective heat integration layout

The effective heat integration is possible due to the high adiabatic temperature increase in the DME reactor, which is allowed when using the Topsøe DMK-10 catalyst. Thereby the reaction heat is used partly as reactor feed-effluent heat exchange and partly as reboiler duty in the Waste Water Column.

Despite high adiabatic temperature increase, the by-product formation is kept low by adjusting the water partial pressure accordingly. However, high water partial pressure can only be used for DME synthesis processes using catalysts with high water tolerance such as Topsøe DMK-10.

TOPSØE DMK-10 CATALYST

The Topsøe DME catalyst, DMK-10, (Figure 3) is used for the selective and cost efficient dehydration of methanol. The DMK-10 catalyst is manufactured in the form of three-lobe extrudates, which increases the surface/volume ratio of the individual particles and hence helps to reduce diffusional resistances.



Figure 3: DMK-10 formed as three-lobe extrudates

The catalytic process is designed to assure production of DME corresponding to the adiabatic equilibrium conversion – the deactivation of the catalyst can thus easily be monitored by progress of the adiabatic temperature profile in the reactor as depicted in Figure 4. The productivity of the reactor thus remains constant throughout the lifetime of the catalyst.

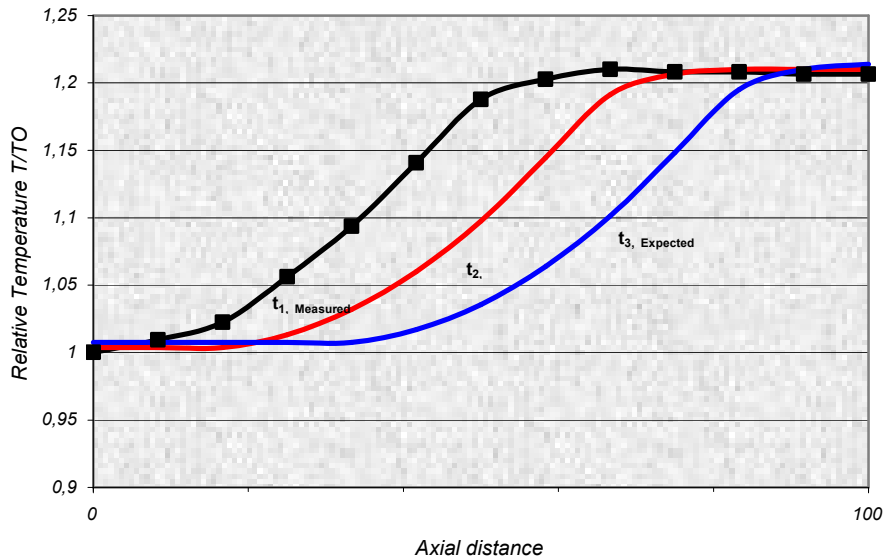


Figure 4: Progress of adiabatic temperature profile

The DMK-10 catalyst is designed for high activity and selectivity having both low deactivation and low by-product formation within the operating temperature range determined by the inlet temperature and the adiabatic temperature range.

The adiabatic temperature increase as a function of the inlet temperature and presence of water is depicted in Figure 5.

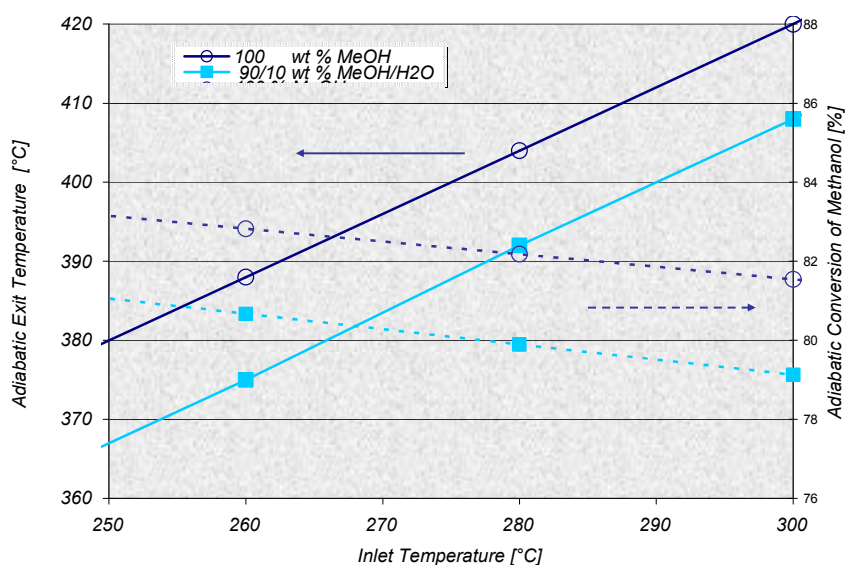


Figure 5: Catalyst exit temperature and corresponding conversion of methanol depicted as a function of the inlet temperature. Adiabatic conditions

For a given inlet temperature, the maximum possible temperature experienced by the catalyst is lower with increasing water concentration in the feed gas – this is due to a correspondingly slightly lower equilibrium conversion of methanol per pass. In the Topsøe DME-process the unconverted methanol is recycled to the DME-synthesis reactor maintaining high overall methanol conversion.

The DMK-10 catalyst is composed of surface stabilized, alumina where the actual presence of medium strength acidic sites assures a highly active and selective catalyst for synthesis of methanol. During operation, the selectivity of the catalyst is dependent on the actual operating temperature and water vapour pressure. The selectivity of the catalyst is favoured by lower temperature and by the presence of water.

Thus the DMK-10 catalyst is highly versatile and able to operate with either grade AA methanol or, alternatively, crude methanol.

Operation with grade AA methanol corresponds to operation with > 99.85 % wt. pure methanol as feedstock. Crude methanol corresponds to operation with 94 % wt. or less methanol; the concentration of methanol is balanced by water and typically less than 0.1 % impurities that originate from the methanol synthesis section.

The DMK-10 catalyst has an excellent selectivity, including allowance for the high exit temperature with respect to production of DME. In particular, when using crude methanol as feedstock there are high requirements to the catalyst quality to ensure long catalyst lifetime and low by-product formation.

The conceivable by-product formation, only observed at high temperatures, is due to the possible decomposition of methanol according to:

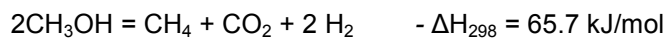


Figure 6 shows the relative amount of methane formed as a function of temperature.

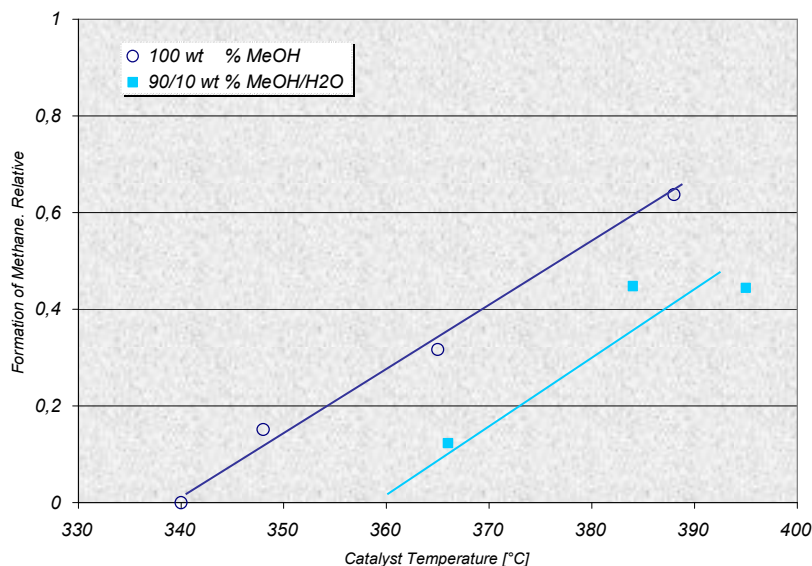
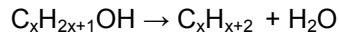


Figure 6: Relative formation of methane as a by-product as a function of the DMK-10 catalyst temperature

As illustrated, the presence of water and lower temperature retards the formation of methane as a by-product. This is advantageous when operating DMK-10 with crude methanol as feedstock.

The impurities that may be present in the crude methanol are typically alcohols (C₂- and minor amount of; C₃-; C₄), ketones and formates. When the DMK-10 catalyst is operated with crude methanol the enclosed by-products are converted to more volatile components in the DME reactor.

The major products originating from the conversion of the impurities in the crude methanol are methane and unsaturated alkenes produced from the conversion of higher alcohols.



The predominant fraction of by-products converted in the DME-reactor leaves the process via the off gas. Due to the high selectivity, the DMK-10 catalyst can be used for producing both fuel and propellant grade DME.

PRODUCT AND SPECIFIC CONSUMPTION

The Topsøe DME process can be tailor-made to meet client DME product specifications ranging from fuel grade (typical 98 % wt.) to propellant grade (>99.99 % wt.).

The Topsøe DME process is highly effective typically having a specific feedstock consumption of only 1.4 MT methanol per MT DME produced. The low methanol consumption is the result of the combination of process design - with an efficient separation and recycle of methanol, and catalyst design - where the DMK-10 is characterized by having a high activity and especially a high selectivity.

In addition, the efficient heat integration in the Topsøe DME process results in low specific steam consumption within the typical range of 1.28 – 1.4 MT steam MT DME produced. The specific steam consumption will within the typical range of 1.28 – 1.4 MT steam MT DME produced, where the actual value will depend on the import steam conditions.

ECONOMIC EVALUATION

The DME production price is depending partly on initial plant investment cost and partly on operating costs. For large scale industrial plants, the DME production price may be correlated to a simple function of methanol price with almost linear relation.

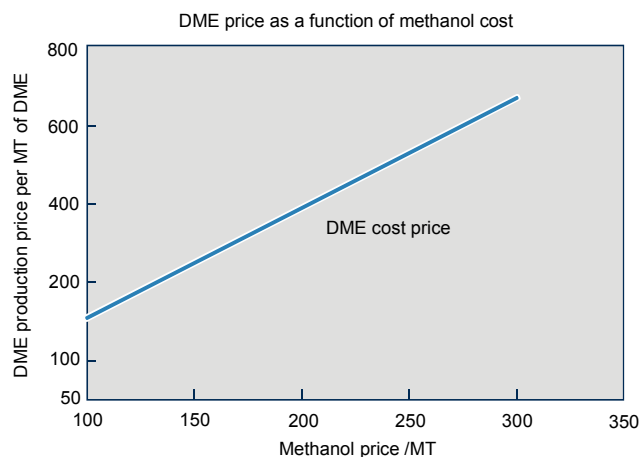


Figure 7: DME production price

An economic evaluation of the Topsøe DME process shows that the production of DME using raw methanol feedstock instead of pure methanol results in significant savings.

For an industrial DME plant with a production capacity of 800,000 MTPY DME, the overall investment costs will be about 72 million EUR (2006 prices).

Based on a crude methanol price of 230 EUR/MT and a DME price of 650 EUR/MT, the DME/methanol price ratio is 2.8. Based on AA methanol (335 EUR/MT) the DME/methanol price ratio is only 1.9.

The production costs for DME based on pure methanol feedstock (e.g. grade AA or GOST 2295) compared with the production costs for DME based on crude methanol are as follows:

Grade AA	Index 100
Fuel grade	Index 70

Thereby the internal rate of return will depend on the DME/methanol price ratio as shown in Figure 8.

With savings of about 30% in production costs the total figure for an 800,000 MTPY DME plant will be about 110 million EUR/annum.

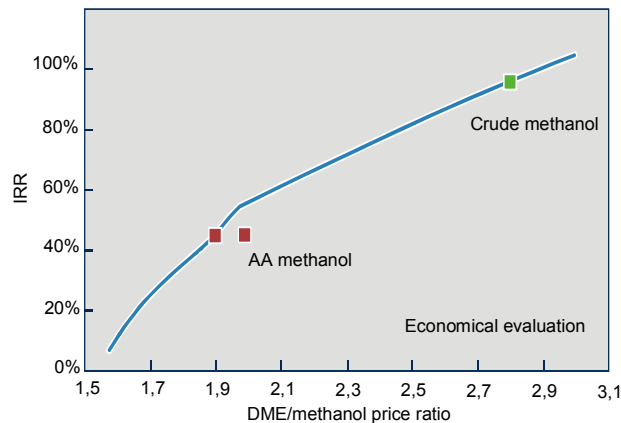


Figure 8: Internal rate of return

CONCLUSION

Through long-term commitment to DME, Topsøe has gained the expertise in DME synthesis technology by combining the knowledge of catalyst development and engineering technology. The advantages include:

- Flexible methanol dehydration technology
- Proprietary DME catalyst, DMK-10 with low by-product formation
- Wide operation range
- DME product quality: From fuel grade to propellant grade
- Methanol feed quality: Refined methanol or CRUDE methanol
- Low cost installation: Add on to methanol plant at low cost

DME synthesis based on crude methanol dehydration is an attractive alternative because it offers process synergies and low investment and thereby a high internal rate of return.