QUANTITATIVE RISK ASSESSMENT FOR HIGH PRESSURE GREEN METHANOL SYNTHESIS FROM GREEN HYDROGEN AND WASTE CARBON DIOXIDE

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BACKGROUND

- Methanol economy proposed firstly by George Olah [1] has identified as the solution for reduction of carbon dioxide emission, boost for renewable energy usage and mass-adoption for hybrid fuel- electric vehicles [2]

- Small scale plant of green methanol (MeOH) production integrated with power and carbon capture plant was operated firstly by Carbon Recylce Internation (CRI) using geothermal power plant [3]. The project by EU called MefCO2 granted CRI to boost production of green methanol, thus will see such technology to produce methanol from green hydrogen and waste carbon dioxide put into first place. These highlight the importance of such mass production of carbon dioxide to methanol production within 10-15 years to come [4].

INTRODUCTION

- The progress of lab scale green methanol synthesizes using high pressure shows that there are possibilities future plant of carbon dioxide to methanol production will have higher pressure condition (as high as near 950 bar),no recycle stream (one pass full conversion) and design with much reduced reactor volume [5-10].

- Current lab scale experiments absolutely are not focused on the safety aspect in term of fatality consequences as lab scale experiments have much smaller size equipment, instead, they are focusing more on design of catalyst and methanol yield.

INTRODUCTION

- However, the question arise on how the effect of chemical release to fatality for large scale production operated at high pressure reactor condition, with recent assessment of carbon dioxide to methanol plant only involved for financial and energy [3, 11-13]. Furthermore, the pressure condition of reactor only selected at 76- 80 bar. There are no assessment studies for medium to large scale plant operated high pressure condition except one energy study from Tidona et al [7].

- Thus, established method of using quantitative risk assessment has been developed for methanol plant accident scenario [14-17].

OBJECTIVES

- To design green methanol synthesize plant from green hydrogen and waste carbon dioxide using simulation design software for mass balance and thermodynamic equilibrium calculation.

- To assess risk of high pressure green methanol using Quantitative Risk Assessment (QRA) via consequence model software for calculation of fatality.

LITERATURE

- Abundant of waste carbon dioxide (CO2) from industrialization has increased the global temperature, resulting in strong action from scientific community to have a systematic mitigation for CO2.
- Roughly around 40% of waste CO2 emission comes from fossil fuel of natural gas or coal power plant
- For a coal power plant, the estimation of CO2 emitted is 915 gram per kWh while the gas fired power plant produced 549 gram per kWh and combined cycle gas fired plant emitted roughly 436 gram per kWh
- Malaysia has about 22 combined cycle gas-fired plant and 7 coalfired power plants with capacity of 20 MW [6]. Therefore, roughly about 12kton per hour of waste CO2 are emitted from this fossil fuel power plant currently and this number will steadily increase as energy power plant in Malaysia shifts towards coal as the main electricity production [6]

LITERATURE

- To reduce its CO2 emission especially from coal and gas power plant using available established technology
- Utilization of CO2 has gained interest from researchers around the world. CO2 has been used for urea production process, building material, food and beverages industries, CO2 as working fluid for Enhanced Oil Recovery (EOR) and production of carbon to methanol
- Production of carbon to methanol comes from the reaction of hydrogen and waste CO2 emissions.
- Meanwhile, hydrogen can produce from surplus electricity of power plant and renewable energy by electrolysis of water. According to energy consumption analysis by Van Dal and Bouallou [9], production of 475kt per year of carbon to methanol needed 12.1 ton/h of H2 using 645.1 MW electricity of water electrolyzer. Therefore, it is a great opportunity for the growing consumption of renewable energy in Malaysia as there are sufficient amount of hydropower and solar energy to produce hydrogen.

METHODOLOGY

- Review and data compilation of carbon to methanol plant
- Design capacity of methanol production, amount of CO2 and hydrogen, reactor volume and electrolysis capacity using simulation software, HYSYS STAGE
- Using quantitative risk assessment by assess the severity and likelihood of the potential event
- List of potential event using hazard identification analysis
- Measure severity in term of fatality using fatality analysis
- Measure likelihood using the frequency analysis of all potential events

RESULTS AND DISCUSSION

- Fatality Assessment based on mixture of chemical release consists of unreacted H_2 and CO_2, with the product of reaction – Methanol (MeOH) and Carbon Monoxide (CO).
- Release of the chemical based on volume fraction and mass fraction of individual chemical in the mixture.
- Chemical releases are subjected to three size of leakage – 10mm, 25 mm and 160mm
- CO and CO_2 are treat as toxicity event while MeOH and H_2 are consider both toxic and flammable event which resulting toxicity, jet fire, flash-fire and vapor cloud explosion.
- Only events that produce red zone threat is consider in this simulation

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Plant 1 - 76 bar

	Chemical	Event	Wind direction	Leakage	Condition	**%Fatality**
15	H_2	VCE	W	160mm	DAY	**9**
16	CO	Toxic	SSW	25mm	NIGHT	**9**
17	H_2	VCE	W	160mm	NIGHT	**8**
18	H_2	VCE	SSW	160mm	NIGHT	**8**
19	H_2	VCE	WNW	160mm	NIGHT	**8**
20	CO	Toxic	W	160mm	DAY	**8**
21	CO	Toxic	W	25mm	DAY	**8**
22	CO	Toxic	WNW	10mm	DAY	**7**
23	CO	Toxic	W	10mm	DAY	**7**
24	CO	Toxic	WNW	10mm	NIGHT	**6**
25	CO	Toxic	SSW	10mm	DAY	**6**
26	H_2	VCE	SSW	25mm	NIGHT	**6**
27	H_2	VCE	W	25mm	NIGHT	**6**
28	H_2	VCE	WNW	25mm	NIGHT	**6**
29	H_2	VCE	SSW	25mm	DAY	**6**
30	H_2	VCE	W	25mm	DAY	**6**
31	H_2	VCE	WNW	25mm	DAY	**6**
32	CO	Toxic	W	10mm	NIGHT	**6**
33	CO	Toxic	SSW	10mm	NIGHT	**5**
34	H_2	Jet fire		160mm	NIGHT	**4**
35	H_2	Jet fire		160mm	DAY	**4**

Plant 2 - 442 bar

	Chemical	Event	Wind direction	Leakage	Condition	**%Fatality**
15	H_2	Jet fire		160mm	DAY	**10**
16	H_2	Jet fire		160mm	NIGHT	**10**
17	H_2	VCE	SSW	10mm	DAY	**8**
18	H_2	VCE	W	10mm	DAY	**8**
19	H_2	VCE	WNW	10mm	DAY	**8**
20	H_2	VCE	WNW	10mm	NIGHT	**7**
21	H_2	VCE	SSW	10mm	NIGHT	**7**
22	H_2	VCE	W	10mm	NIGHT	**7**
23	CO	Toxic	WNW	10mm	DAY	**7**
24	CO	Toxic	WNW	25mm	DAY	**7**
25	CO	Toxic	WNW	160mm	DAY	**7**
26	H_2	Jet fire		25mm	NIGHT	**6**
27	CO	Toxic	W	10mm	DAY	**6**
28	CO	Toxic	W	25mm	DAY	**6**
29	CO	Toxic	W	160mm	DAY	**6**
30	H_2	Jet fire		25mm	DAY	**6**
31	CO	Toxic	SSW	10mm	DAY	**6**
32	CO	Toxic	SSW	25mm	DAY	**6**
33	CO	Toxic	SSW	160mm	DAY	**6**
34	MeOH	Toxic	WNW	25mm	DAY	**4**
35	MeOH	Toxic	W	25mm	DAY	**4**

REFERENCES

1. G. A. Olah, "Beyond oil and gas: The methanol economy," *Angew. Chemie - Int. Ed.*, vol. 44, no. 18, pp. 2636–2639, 2005.
2. C. Mass-adoption and C. Mass-adoption, "Methanol : the Surprising Solution for Pollution , Global Warming and Electric Methanol : the Surprising Solution for Pollution , Global Warming , and Electric," pp. 1–21, 2019.
3. C. Bergins, K. Tran, E. Koytsoumpa, E. Kakaras, T. Buddenberg, and Ó. Sigurbjörnsson, "Power to Methanol Solutions for Flexible and Sustainable Operations in Power and Process Industries Mitsubishi Hitachi Power Systems Europe GmbH , Germany * Carbon Recycling International , Iceland," pp. 1–18, 2015.
4. G. C. C. Twitter, G. C. C. Twitter, C. R. International, and E. U. Horizon, "CRI awarded € 1 . 8M EU grant to scale CO2-to-methanol technology," pp. 1–8, 2019.
5. R. Gaikwad, A. Bansode, and A. Urakawa, "High-pressure advantages in stoichiometric hydrogenation of carbon dioxide to methanol," *J. Catal.*, vol. 343, no. April, pp. 127–132, 2016.
6. A. Bansode and A. Urakawa, "Towards full one-pass conversion of carbon dioxide to methanol and methanol-derived products," *J. Catal.*, vol. 309, no. January, pp. 66–70, 2014.
7. B. Tidona, C. Koppold, A. Bansode, A. Urakawa, and P. Rudolf Von Rohr, "CO2 hydrogenation to methanol at pressures up to 950 bar," *J. Supercrit. Fluids*, vol. 78, pp. 70–77, 2013.
8. A. B. Bansode, "Exploiting high pressure advantages in catalytic hydrogenation of carbon dioxide to methanol," *TDX (Tesis Dr. en Xarxa)*, 2014.
9. R. Gaikwad, "Carbon Dioxide to Methanol : Stoichiometric Catalytic Hydrogenation under High Pressure Conditions," 2018.
10. J. G. van Bennekom *et al.*, "Methanol synthesis beyond chemical equilibrium," *Chem. Eng. Sci.*, vol. 87, pp. 204–208, 2013.
11. É. S. Van-Dal and C. Bouallou, "Design and simulation of a methanol production plant from CO2 hydrogenation," *Journal of Cleaner Production*, vol. 57. pp. 38–45, 2013.
12. M. Pérez-Fortes, J. C. Schöneberger, A. Boulamanti, and E. Tzimas, "Methanol synthesis using captured CO2 as raw material: Techno-economic and environmental assessment," *Appl. Energy*, vol. 161, pp. 718–732, 2016.
13. E. S. Van-Dal and C. Bouallou, "Design and simulation of a methanol production plant from CO2 hydrogenation," *J. Clean. Prod.*, vol. 57, no. October, pp. 38–45, 2013.
14. L. Lahti, "A guideline for chemical process quantitative risk analysis," *J. Hazard. Mater.*, vol. 26, no. 1, pp. 101–102, 1991.
15. M. J. Assael and K. E. Kakosimos, *Fires, Explosions, and Toxic Gas Dispersions - Effects Calculation and Risk Analysis*. Boca Raton: CRC Press, 2010
16. U. de Haag and Ale, *Guideline for quantitative risk assessment*, 3rd ed. Netherland: CPR, 2005.
17. N. Oceanic, A. Administration, and O. Response, "(AREAL LOCATIONS OF HAZARDOUS," no. November, 2013.

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Thanks and Questions

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