Optional Advanced Exersise SCR

You have the task to calculate the catalytic converter volume filled with a vanadium-based SCR catalyst for a biomass power plant. NO emissions of 800 mg/m^3 have been measured at an exhaust gas temperature of 250°C and the NO emissions shall be reduced by 80%. For this purpose lab tests have been conducted with the catalyst and 80% NO reduction has been achievd at 250°C at a GHSV of 3000 h^{-1}. In the biomass power plant 10 t wood (dry) is burned per hour at an air excess of $\lambda = 1.8$.

Hints:

The composition of wood can be described by the formula $CH_{1.49}O_{0.67}$. Write down the reaction equation for complete combustion to CO_2 and water. Assume ideal gas behavior of all gases and calculate the volumes/volume flows at standard conditions. To this the gas volume/volume flow you have to add the volume/volume flow of uncombusted nitrogen and of the air excess. The DeNOx performance is assumed to be proportinal to the catalyst volume.

Solution Exercise SCR

Stoichiomety of combustion:

$CH_{1.49}O_{0.67} + 1.0375\ O_2 = CO_2 + 0.745\ H_2O$ Hinweis: $1.0375\ O_2 = (2 + 0.745 – 0.67)/2\ O_2$

Combustion product gas in mol/mol wood:

1 mol CO_2 + 0.745 mol H_2O = 1.745 mol combustion product gas

Combustion gas in m^3 per mol wood at STP (1 bar, 0^oC = 273.15 K):

$p \cdot V = n \cdot R \cdot T$ => $V_{Comb.} = 1.745\ \text{mol} \cdot 8.3144\ \text{Jmol}^{-1}\text{K}^{-1} \cdot 273.15\ \text{K} / (1 \cdot 10^5\ \text{Pa})$

$V_{Comb.} = 1.745\ \cancel{\text{mol}} \cdot 8.3144\ \cancel{\text{kg}}\text{m}^2\cancel{\text{s}}^{-2}\cancel{\text{mol}}^{-1}\cancel{\text{K}}^{-1} \cdot 273.15\ \cancel{\text{K}} \cdot 10^{-5}\ \cancel{\text{kg}}^{-1}\text{m}\cancel{\text{s}}^2$

$V_{Comb.} = 0.03963\ \text{m}^3$

Inert gas through the power plant:

Air: 79% inert gas, 21% O_2 $n_{inert} = 1.0375\ \text{mol} \cdot 79/21 = 3.903\ \text{mol}$

Inert gas in m^3 per mol wood at STP (1 bar, 0^oC = 273.15 K):

$p \cdot V = n \cdot R \cdot T$ => $V_{inert} = 7.806\ \text{mol} \cdot 8.3144\ \text{Jmol}^{-1}\text{K}^{-1} \cdot 273.15\ \text{K} / (1 \cdot 10^5\ \text{Pa})$

$V_{inert} = 0.08864\ \text{m}^3$

Additional air in the power plant at $\lambda = 1.8$:

$V_{Excess} = V_{inert} \cdot 100/79 \cdot 0.8$

$V_{Excess} = 0.08864\ \text{m}^3 \cdot 100/79 \cdot 0.8 = 0.08976\ \text{m}^3$

Total gas volume per mol wood:

$V_{total} = V_{Comb.} + V_{inert} + V_{Excess} = 0.2180\ \text{m}^3$

Solution Exercise SCR

Gas volume for 10 t Holz pro Stunde bei Normbedingungen:

$$V_{10t} = m_{Holz}h^{-1} / \text{Molmasse Holz} \cdot V_{total}mol^{-1}$$

$$\text{Molar mass wood } (CH_{1.49}O_{0.67}) = 1 \cdot 12\ gmol^{-1} + 1.49 \cdot 1\ gmol^{-1} + 0.67 \cdot 16\ gmol^{-1} = 24.21\ gmol^{-1}$$

$$V_{10t} = 10 \cdot 10^6\ gh^{-1} / (24.21\ gmol^{-1}) \cdot 0.2180\ m^3mol^{-1}$$

$$V_{10t} = 90'045\ m^3h^{-1}$$

Required catalyst volume for 80% reduction:

$$V_{cat.} = V_{10t} / GHSV$$

$$V_{cat.} = 90'045\ m^3h^{-1} / 3000\ h^{-1} = 30.0\ m^3$$