PENGEMBANGAN *INTERNAL REBOILER* PADA DISTILATOR UNTUK PEMURNIAN BIOETANOL

ABSTRAK

Industri bioetanol tradisional membutuhkan alat distilasi yang efektif meningkatkan kadar etanol dari 30% menjadi 90%. Tujuan penelitian adalah mengembangkan proses distilasi bioetanol menggunakan distilator rektifikasi dengan modifikasi *internal reboiler*. Reboiler jenis *vertical tubular baffle* direkayasa dengan variasi ukuran diameter tabung (0,0381 m, 0,0254 m, dan 0,0127 m) dan tinggi tabung (0,08 m, 0,06 m, dan 0,04 m). Percobaan dilakukan dengan variasi konsentrasi etanol umpan 10%, 20% dan 30% dan parameter meliputi suhu, kadar etanol distilat, rendemen, energi dan waktu distilasi. Hasil penelitian menunjukkan bahwa distilator etanol dengan *internal reboiler* tipe *vertical tubular baffle* mampu memurnikan etanol dari konsentrasi 10% menjadi 95%. Variasi jenis *reboiler* dan konsentrasi etanol umpan berpengaruh nyata terhadap parameter penelitian. Model matematika perpindahan panas dan massa dikembangkan dengan analisis dimensi π-Buckingham dan didapatkan hubungan

$$\frac{dh}{k} = 1452{,}29\left(\frac{d\rho_b v}{\mu}\right)^{0{,}3568}\left(\frac{d}{L}\right)^{0{,}023}\left(\frac{TC_p}{v^2}\right)^{-0{,}148}\left(\frac{d\rho_b C_p v}{k}\right)^{0{,}4731}.$$

Model tersebut dapat digunakan untuk memprediksi koefisien perpindahan panas dengan valid yang ditunjukkan oleh R^2 = 0,88. Perubahan suhu bahan dianalisis dengan kinetika Gompertz yaitu $T = \exp\left[ae^{-e^{(b-(kt))}}\right]T_0$ dan didapatkan konstanta laju perubahan suhu (kT) = 0,052 - 0,071, konstanta suhu maksimum (a) = 1,203 - 1,320, serta konstanta integrasi waktu (b) = 3,171 - 4,677. Perubahan massa distilat dianalisis dengan kinetika Avrami yaitu $M_t = \left((1 - \exp(-kM.t^{nA}))(M_\infty - M_0)\right) + M_0$, dan didapatkan konstanta laju perpindahan massa (kM) = $8{,}67\times10^{-4}$ - $6{,}59\times10^{-3}$ serta konstanta Avrami (nA) = 1,20 - 1,51. Validasi model perubahan suhu bahan dan perubahan massa distilat didapatkan R^2 rata-rata = 0,999 yang menunjukkan bahwa model tersebut valid digunakan untuk memprediksi suhu bahan dan massa distilat pada waktu tertentu.

Kata kunci : distilasi bioetanol, *internal reboiler*, analisis dimensi, pindah panas dan massa

INTERNAL REBOILER DEVELOPMENT IN DISTILLATION DEVICE FOR BIOETHANOL PURIFICATION

ABSTRACT

The traditional bioethanol industry requires a distillation device that is effective to increase ethanol concentration from 30% to 90%. This study aimed to develop a bioethanol distillation process using a rectification distillation with an internally modified reboiler. The vertical tubular baffle reboiler was designed with different tube sizes i.e., diameters of 0.0381 m, 0.0254 m, and 0.0127 m and heights of 0.08 m, 0.06 m, and 0.04 m. The experiment was carried out with various concentrations of 10%, 20%, and 30% feed ethanol and parameters including temperature, distillate ethanol content, yield, energy, and distillation time. The results showed that an ethanol distillation with an internal reboiler-type vertical tubular baffle was able to purify ethanol from a concentration of 10% to 95%. Differences in tube sizes and concentration of feed ethanol significantly affected the research parameters. The mathematical model of heat and mass transfer was developed using Π-Buckingham dimensional analysis and obtained,

$$\frac{dh}{k} = 1452{,}29\left(\frac{d\rho_b v}{\mu}\right)^{0{,}3568}\left(\frac{d}{L}\right)^{0{,}023}\left(\frac{TC_p}{v^2}\right)^{-0{,}148}\left(\frac{d\rho_b C_p v}{k}\right)^{0{,}4731}.$$

This model can be used to determine the heat transfer coefficient with a valid indicated by R^2 = 0.88. Material temperature rise was analyzed by Gompertz kinetics, i.e., $T = \exp\left[ae^{-e^{(b-(kt))}}\right]T_0$ and temperature constant rate was obtained (kT) = 0.052 - 0.071, maximum temperature constant was obtained (a) = 1.203 - 1.320, and the time integration constant (b) = 3.171 - 4.677. The increase in distillate mass was analyzed by Avrami kinetics, i.e., $M_t = \left((1-\exp(-kM.t^{nA}))(M_\infty - M_0)\right) + M_0$, and the mass transfer rate constant was obtained (kM) = 8.67×10^{-4} – 6.59×10^{-3} and Avrami constant (nA) = 1.20 - 1.51. Model validation of material temperature rise and increases in distillate mass obtained an average R^2 = 0.999, which indicates that these models are valid to determine material temperature and distillate mass at a certain time.

Keywords: ethanol distillation, internal reboiler, dimensional analysis, heat and mass transfer