The Wave Based Model Reduction Applied to a Binary Distillation Column

AACHENER VERFAHRENSTECHNIK

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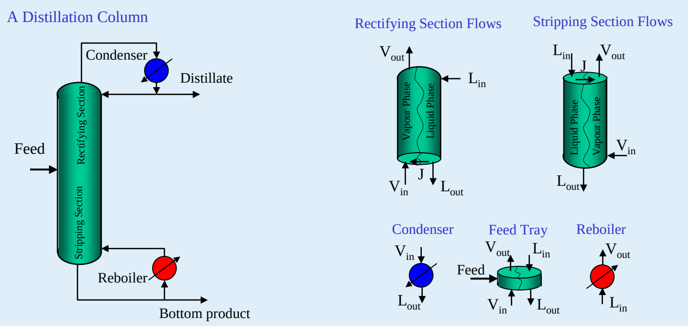
Process and Its Integral Parts



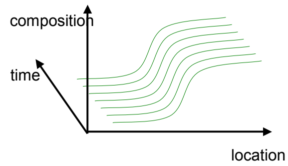
Wave Based Model Reduction

WBMR means:

- Simplify equations for both sections (described below).
- Being usually relatively simple modeled, condenser, reboiler and feed tray needn't to be simplified.

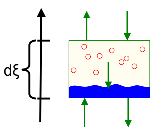
Advantages of WBMR:

- physically justified
- incorporates process knowledge
- considers nonlinearities
- creates a low order model, which allows online simulation
- suitable for development of controllers superior to those using linear, in frequency domain designed models, which don't capture the process structure and have to be experimentally identified
- suitable for reconstruction of entire product concentration profile from a few temperature and concentration measurements



Equations of a Section

- Obtained from mass balance and additional transformations the equations for a section with neglected holdup in the vapour phase read as shown on the right.



Section equations:

$$\frac{\partial x}{\partial t} - (1+w)\frac{\partial x}{\partial \xi} = -\frac{B}{A}\cdot\left(f(x)-y\right),$$

$$\frac{1}{A}\frac{\partial y}{\partial \xi} = \frac{B}{A}\cdot\left(f(x)-y\right),$$

Boundary conditions:

$$x(t,1-z^*) = x_e(t)$$

$$y(t,-z^*) = y_e(t)$$

Where

$t > 0$: time domain
$-z^* \le \xi \le 1-z^*$: space domain
$\dot{z}^* = w$: wave velocity
$x = x(t,\xi)$: liquid composition (light comp.)
$y = y(t,\xi)$: vapour composition (light comp.)
f : vapour liquid equillibrium function
B : number of transfer units in gas phase
$A = L_{in}/V_{in}$: liquid to vapour flow ratio

Model Reduction Steps

According to a postulate[1], the dynamic behaviour of a real separation process can be described by an inherently stable wave propagation. So, parametrize x suitably, i.e. find a function H, also known as the form approach, such that $x(t,\xi) \approx H(\xi,\gamma,p_1,p_2)$.

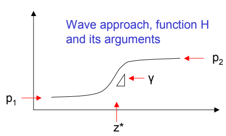
Substitute the form approach H for x in added section equations as well as in boundary equations and velocity equation.

Add section equations and get rid of vapour composition y.	Rewrite the boundary condition for y in terms of liquid composition x.	Find a relation describing wave velocity, e.g. dz*/dt=w.

Wave Form Approach

- The form approach $H=H(\xi,\gamma,p_1,p_2)$ (parametrization of x) with four arguments which are actually the states of our reduced model can be chosen like follows:

z^* : position of point of inclination
γ : determins the slope at z^*
p_1 : lower limit composition
p_2 : upper limit composition



Reduction Results

- Wave model reduction results in a DAE system of index 1:

M : nonlinear matrix function
r : nonlinear vector function
p : state vector $[z^*,\gamma,p_1,p_2]$

$$\underbrace{\begin{pmatrix} * & * & * & * \\ * & * & * & * \\ * & * & * & * \\ 0 & 0 & 0 & 0 \end{pmatrix}}_{\mathbf{M}(\underline{p})} \underbrace{\begin{pmatrix} \dot{\gamma} \\ \dot{z}^* \\ \dot{p}_1 \\ \dot{p}_2 \end{pmatrix}}_{\dot{\underline{p}}} = \underbrace{\begin{pmatrix} * \\ * \\ * \\ * \end{pmatrix}}_{\mathbf{r}(\underline{p})}$$

- There are a variety of solvers, you can easily submit this DAE to. They deliver the evolution of the state vector, which is used, together with the form approach H, to describe compositions at each point of the section.

References

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[2] Mathematische Modelle von Destillationskolonnen zur Synthese von Regelungskonzepten, B. Retzbach, VDI Reihe 8 Nr. 126, Düsseldorf 1986
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Acknowledgement

The work related to the wave based reduction method has been done within the DISCO O&O project in cooperation with IPCOS NV and Bayer Antwerpen Comm. V. and supported by IWT Flanders.