Bringing frequency response analysis closer to Chemical Engineering

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Abstract

Process control has traditionally been considered a difficult subject among chemical engineering students. A particular aspect that differentiates process control from process design related courses is also that the former does not originate from the chemical engineering field but rather relies on automatics and electrical engineering. Frequency response analysis, the focus of this paper, is often poorly understood by students who find the concept too abstract, and struggle to see its many direct application.

Our opinion is that frequency response analysis is the most useful manner to to teach the trade-off between controller performance and robustness, the limits to performance that a time-delay introduces in the process, or ideas common in industrial control loop tuning such as phase and gain margin. Likewise, we believe that it is important to provide the chemical engineering student a more intuitive idea of what frequency responses, amplitude ratio, and phase angles mean, by illustrating such concepts with examples that are familiar for the chemical engineering student, namely the impact of disturbances on stirred tanks.

A colour change experiment, consistig of an Erlenmeyer flask that receives a periodic disturbance (base and acid addition) leading to yellow/blue coloration as a response to the change of pH (see video at www.dailymotion.com/video/x17mdjq). The dynamics of the colour change observed in the video provide better insight to the idea of forcing a sinusoidal input on the process, whose results are easy to observe thanks to the change of colour. Likewise, the effect of the input frequency on the output is demonstrated by carrying out the experiment at different frequencies. This illustrates how the effect of the input on the output (the gain) varies with the frequency of the input, as observed in the Bode plot (fig. 1 left). The well-known four tank process [1] (fig. 1, right) was used for an integral training in practice of concepts such as process modelling, derivation of transfer functions, analysing process dynamics in both the time and the frequency domain, and, in particular to get aquainted with tanks as low-pass filters. These experiments were included in a course called Introduction to Process Control at the Technical University of Denmark (DTU), in the Bachelor Programme of Chemical Engineering.

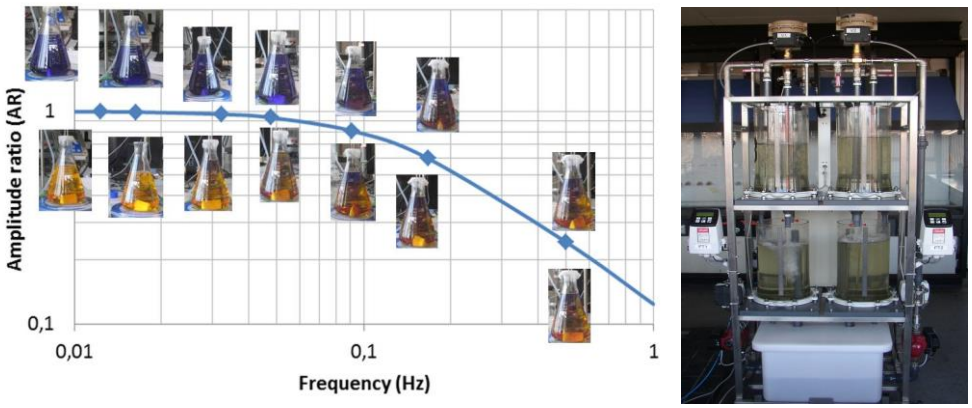

Figure 1. Left: Bode plot of the colour change experiment. At frequencies >0.1 Hz the yellow and blue are barely distinguishable, equivalent to a decrease in the process gain.. Right: The 4 tank process at DTU Chemical Engineering

References

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