FRAUNHOFER WATER SYSTEMS ALLIANCE (SYSWASSER)

# BIOLOGICAL GROWTH CONTROL

Methods for continuous fermentation are constantly gaining in importance in research and development as well as in industrial production. The main objective here is to provide biomass or products with defined physiological parameters. Unlike in bench scale tests, the realization of large technical processes often causes problems induced by frequently elaborate scale-ups. With the present established off-line determination methods for process-related parameters a longterm stable and interference-free system management is difficult to realize.

Conventional approaches to control biological substance conversion processes utilize the phenomenon of the self-stabilization of the process in the chemostate in the case of an existing substrate limitation. A robust stationary physiological condition can only be set at non-economical operating points. Optimal productivity is achieved in areas with great amplifications in which the biological state variables react extremely sensitively to even minimal interferences and there is a danger of elution.

Excellent process know-how, a high technical standard (sterility, safety, automation) and great effort during the process preparation phase are required to successfully exploit the advantages of continuous fermentation.

**Standard Strategy**

Closed access to the on-line control unit of the growth processes was developed for biotechnological processes. A novel fundamental idea for the treatment of the typical mathematical approaches for these processes facilitates the derivation of a control rule which has been adapted to the biological growth process. Control targets may be stabilization of the growth of biomass or product formation at operating points with a high yield and control of the population milieu. The stipulated targets are potentially achievable by adapting the control unit to the structure of the process.


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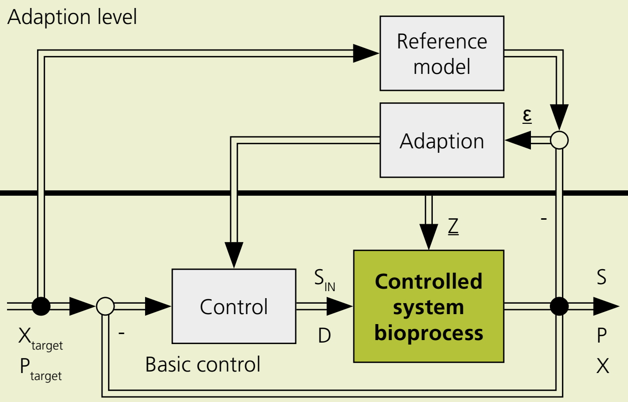
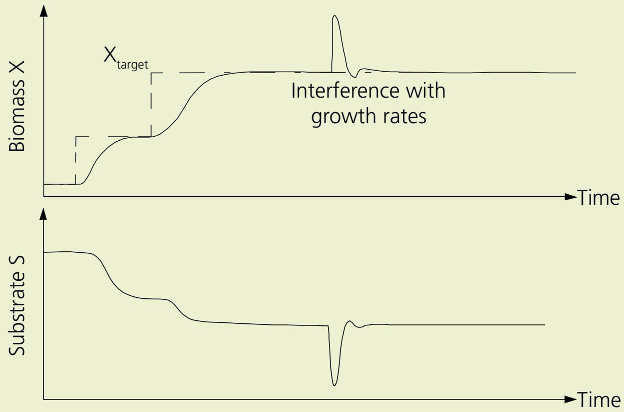



Structure of the model adaptive control
S: Substrate concentration; P: Product concentration; X: Biomass concentration; $S_{IN}$: Input concentration of substrate; D: Flow rate




Stabilization of the biomass concentration in the continous fermentation operation
(simulation of growth kinetics of Rhodococcus spec. 1)

Changes to the reference variables or invading interferences do not lead to a failure of the control function or to instability. This way,

- the process can run smoothly,
- the micro-organisms can be cultivated gently and
- the growth and production output can be optimized.

Both substrate-limiting and product-inhibiting processes are controlled. An elaborate determination of biological growth parameters is not necessary due to the utilization of adaptive methods.

The method described solves the problems of the stabilization of the biomass, substrate and product concentrations as well as those of startup processes and switch mechanisms with a consistent and controlled reaction volume. The process can be operated at a fixed operating point or admitted with control trajectories. Exploratory preliminary investigations for selected processes with product inhibitions confirm the capability of this method.

**Approach**

The basic component of the strategy is a non-linear adaptive multivariable control unit for the single-level continuous reactor with perfect blending. The starting point of the design of the control unit is the mathematical description of both the growth kinetics and the mi-lieu (pH value, temperature, oxygen concentration) by means of a system of nonlinear differential equations.

The approach uses special nonlinear, process-related transformations to translate the process description into an integrable form. This method enables practicable filters to be designed and causal controllers to be constructed. The actual control algorithm is developed at the transformed signal level (image plane). For practical reasons, this is done by applying model adaptive methods.

Potential control targets are the stabilization of the growth of biomass or product formation at operating points with a high yield and the control of the population milieu.

**Properties of the Process**

The stipulated targets are potentially achievable by adapting the control unit to the structure of the process. Changes to the reference variables or invading interferences do not lead to a failure of the control function or to instability. This way, the process can run smoothly, the micro-organisms can be cultivated gen-tly and the growth or production out-put can be optimized. Both substrate-limiting and product-inhibiting processes are controlled. An elaborate determination of biological growth parameters is not necessary due to the utilization of adaptive methods.

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