Model-based optimization of photochemical reactors: single- and multi-lamp reactors

Thomas Coenen, Filip Logist, Wim Van de Moortel, Jan Luyten, Jan F.M. Van Impe, Jan Degrève
BioTeC, Dept. of Chemical Engineering
Katholieke Universiteit Leuven
W. de Croylaan 46, B-3001 Leuven, Belgium
Email: {thomas.coenen, filip.logist,jan.vanimpe,jan.degreve}@cit.kuleuven.be

1 Introduction

One of the emerging technologies for water purification are the Advanced Oxidation Processes (AOPs) which use hydroxyl radicals as oxidant. The performance of the AOP can be increased by increasing the amount of hydroxyl radicals produced. This is possible by using high energy electromagnetic waves, usually UV-radiation. These are the so-called photochemical AOPs which are carried out in a photochemical reactor. This reactor consists of a vessel in which one or more UV-lamps are present in order to irradiate the water. However, the use of these lamps gives rise to a relatively high energy and operating cost. A prediction of the operation and energy costs is possible based on mathematical models. [1]

2 Reactor configurations

This study deals with the modeling and optimization of photochemical reactors. The optimization consists of the minimization of the above-mentioned costs of the UV-lamps which is possible via a model-based optimization of the reactor geometry. [2] First, a 2D steady-state model is built taking into account the reaction kinetics, the reactor geometry and the radiation intensity distribution in the reactor. Afterwards, two different configurations of photochemical reactors are optimized. The first modeled reactor configuration is a single-lamp reactor and consists of a cylindrical UV-lamp that is present inside a quartz sleeve, outside of which the water flows between it and the external reactor wall (annular channel reactor). The second reactor configuration is similar to the first one but now contains multiple lamps positioned symmetrically in a circular pattern (i.e. multi-lamp reactor).

3 Optimization results

For the single-lamp reactor, a rigorous optimization problem is formulated consisting of the calculation of the optimal reactor geometry (length and radius) in such a way that, for a given reactor volume and a given flow rate of the water to be treated, the mean outlet concentration of an organic pollutant is minimized. If the reactor volume, the volumetric flow rate of water, the reaction rate constant, the absorption coefficient of the aqueous medium, the radiation power and the outside radius of the UV-lamp are provided, it has been shown that an optimal reactor length exists. In addition, the influence of different process parameters on the optimal reactor length is evaluated, yielding the following results: an increase in the absorption coefficient of the water or the reaction rate constant leads to an increase in the optimal reactor length. [2]

For the multi-lamp reactor, the optimization problem consists of the calculation of the optimal lamp position inside the reactor in such a way that the mean outlet concentration of an organic pollutant is minimized. The lamp position is given by the radial distance between the centers of the reactor and a lamp. If the reactor length and radius, the volumetric flow rate of water, the reaction rate constant, the absorption coefficient of the water, the total radiation power of the lamps, the number of lamps and the outside radius of the lamp are provided, again a well-posed optimization problem is obtained and an optimal lamp position exists. In addition, the influence of different process parameters on the optimal reactor length is evaluated, yielding the following results: an increase in the number of lamps or the reaction rate constant as well as a decrease in the absorption coefficient of the aqueous medium leads to an increase in the optimal distance between the centers of the reactor and the lamp. [2]

4 Conclusions

A single-lamp and a multi-lamp photochemical reactor have been optimized using 2D steady-state models. These models have been included in two well-posed optimization problems. From the results, it follows that an optimal reactor diameter (and length) exists for the single-lamp reactor (and for the multi-lamp reactor). For the multi-lamp reactor, an optimal radial lamp position exists.

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References

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