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Design of a Process Control for the Degradation of Polyvinyl Alcohol (PVA) in a UV/H_2O_2 Photoreactor

Zahra Parsa, Ramdhane Dhib, Mehrab Mehrvar
Department of Chemical Engineering, Toronto Metropolitan University
350 Victoria St, Toronto, Canada M5B 2K3
zahra.parsa@torontomu.ca, rdhib@torontomu.ca, mmehrvar@torontomu.ca

Abstract- Polyvinyl alcohol (PVA), a non-biodegradable polymer, presents significant environmental concerns when found in natural aquatic ecosystems due to its film-forming characteristics, which induce oxygen depletion and pose a threat to aquatic ecosystems [1-3]. Consequently, the development of effective treatment methods for wastewater containing PVA is imperative, as it is prevalent in various industrial sectors worldwide, with prominence in textile industry. The UV/H_2O_2 process, an advanced oxidation technique, has demonstrated notable efficacy in degrading PVA [4,5]. Despite several attempts to optimize treatment facilities, residual PVA levels in effluent streams remain quite elevated. Besides, the amount of PVA in the upstream influents is substantially unpredictable causing large disturbances into the treatment process. Thus, an effective control strategy must be put in place to reduce, or even eliminate PVA content in effluents. To further consolidate the potentiality of the UV/H_2O_2 process in treating wastewater contaminated with large water-soluble macromolecules, the implementation of a feedback process control system is discussed in this study.

In this study, PVA-contained wastewater is exposed to UV light in the presence of H_2O_2, inside a tubular photoreactor. The direct photolysis of H_2O_2 leads to the formation of highly reactive hydroxyl radicals, which nonselectively target macromolecules of the polymer, causing their degradation into shorter molecular fragments and mineral end products. Research studies, utilizing a black-box modelling approach, have been conducted on a laboratory-scale photoreactor [6]. These studies have succeeded in identifying the dynamic behaviour of the process, thereby facilitating the tuning of a proportional-integral-derivative (PID) controller to monitor the UV/H_2O_2 process by tracking the desired setpoint trajectory and reducing the impact of PVA content disturbances [7,8].

It's worth noting that black-box models, while effective for the reactor in question, are inherently tailored to its specific characteristics, making them less adaptable to diverse photoreactor designs. To enhance the model's versatility and applicability across various photoreactor configurations, exploring alternative modelling techniques is essential, allowing for the more efficient implementation of feedback control strategies. The development of a controller founded on process kinetics confers the notable advantage of facilitating result extrapolation across various reactor sizes and configurations. It obviates the necessity for extensive system identification experiments and, notably, accommodates situations characterized by limited data availability. The primary objective of this study revolves around the control of residual PVA concentration at the effluent of the UV/H_2O_2 photoreactor, with the aim of maintaining it at the desired threshold. To achieve this objective, control systems integrating P, PI, or PID controllers within a feedback loop framework were designed. This design leverages the kinetic model to establish the dynamic model, resulting in a control system with a solid theoretical foundation. The performance and efficacy of these control systems were assessed through simulation. These simulations, executed within the Simulink environment using the MATLAB software platform, were conducted to quantitatively evaluate the capacity of the proposed control approach in order to effectively regulate the process, ensuring its safety and stability.

Keywords: Polyvinyl alcohol (PVA); UV/H_2O_2 Photoreactor; AOPs; Kinetics-based control; PID controller; wastewater treatment; Process modelling, Process control

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References

[1] D. Hamad, R. Dhib, and M. Mehrvar, "Effects of hydrogen peroxide feeding strategies on the photochemical degradation of polyvinyl alcohol," *Environmental Technology (United Kingdom)*, vol. 37, no. 21, pp. 2731–2742, Nov. 2016, doi: 10.1080/09593330.2016.1160959.

[2] D. Hamad, M. Mehrvar, and R. Dhib, "Experimental study of polyvinyl alcohol degradation in aqueous solution by UV/H2O2 process," *Polym Degrad Stab*, vol. 103, no. 1, pp. 75–82, 2014, doi: 10.1016/j.polymdegradstab.2014.02.018.

[3] S. Ghafoori, M. Mehrvar, and P. K. Chan, "Photoreactor scale-up for degradation of aqueous poly(vinyl alcohol) using UV/H_2O_2 process," *Chemical Engineering Journal*, vol. 245, pp. 133–142, Jun. 2014, doi: 10.1016/j.cej.2014.01.055.

[4] D. Hamad, M. Mehrvar, and R. Dhib, "Photochemical Kinetic Modeling of Degradation of Aqueous Polyvinyl Alcohol in a UV/H2O2 Photoreactor," *J Polym Environ*, vol. 26, no. 8, pp. 3283–3293, Aug. 2018, doi: 10.1007/s10924-018-1190-y.

[5] D. Hamad, R. Dhib, and M. Mehrvar, "Photochemical Degradation of Aqueous Polyvinyl Alcohol in a Continuous UV/H2O2 Process: Experimental and Statistical Analysis," *J Polym Environ*, vol. 24, no. 1, pp. 72–83, Mar. 2016, doi: 10.1007/s10924-016-0750-2.

[6] M. M. Shahwan, S. Ghafoori, R. Dhib, and M. Mehrvar, "Modeling PVA degradation in a continuous photochemical reactor using experimental step testing and process identification," *J Environ Chem Eng*, vol. 9, no. 1, Feb. 2021, doi: 10.1016/j.jece.2020.104983.

[7] Y. P. Lin, R. Dhib, and M. Mehrvar, "ARX/NARX modeling and PID controller in a UV/H2O2 tubular photoreactor for aqueous PVA degradation," *Chemical Engineering Research and Design*, vol. 195, pp. 286–302, Jul. 2023, doi: 10.1016/j.cherd.2023.05.042.

[8] Y. P. Lin, R. Dhib, and M. Mehrvar, "Nonlinear system identification for aqueous PVA degradation in a continuous UV/H2O2 tubular photoreactor," *Ind Eng Chem Res*, vol. 60, no. 3, pp. 1302–1315, Jan. 2021, doi: 10.1021/acs.iecr.0c04637.