Master’s Thesis Engineering Technology

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Improvement of an aerosol photoreactor operation

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Introduction

Photochemical reactions are chemical reactions that are initiated by the absorption of energy in the form of UV-light, visible light or infrared radiation. Photochemical transformations of molecules provide access to reaction pathways that are impossible to reach with classical thermochemical activation. In addition, photochemical reactions are performed at mild temperatures. In spite of these advantages, Photochemistry is not often used in industry due to sub-optimal reactor designs. Aerosol photoreactors present themselves as promising candidates for industrial applications to solve the problem of current photoreactors not being able to simultaneously have a high reaction rate and high throughput. Although promising, such reactors need characterization and optimization.

Objectives

The aim of this thesis was the improvement of an aerosol photoreactor:

- Transformation from batch to a continuous reactor
- Humidity measurements inside the reactor
- Determination of a continuous phase separation operation
- Measurement of the lamp reliability
- Measurement of the residence time distribution (RTD)

Methods & materials

- **Transformation batch to continuous**

Fig 1. and Fig. 2 show the continuous set-up which was assembled afresh after gathering the required components. Fig. 2 also shows the improvements made in the batch set-up Different air pressures and liquid flow rates were tested to check if the continuous reactor ran smoothly.

- **Humidity measurement**

The humidity was measured when only air flowed in the reactor and when aerosol flowed in the reactor.

- **Continuous phase separation operation**

Hydrophilic (glass) and hydrophobic (polyethylene) filters with different pore sizes were tested. A 20-minute run at 1 bar and 2 bar was carried out and the efficiency of each filter was calculated.

- **Lamp reliability**

The absolute spectral irradiance was measured for a gas-discharge tube and LED-strips. It was measured in 6 different points in the length of the lamps, as shown in Fig. 2 and table 1, and in point 4 during 1 hour. Using this data, the fluctuation was calculated.

Table 1. Different measuring points in the length of the lamps

Point on reactor	1	2	3	4	5	6
Length (cm)	4,5	11	18	25	33	41

- **Residence time distribution**

The RTD was determined for the continuous reactor using a step-experiment. A flow cell and spectrometer were integrated at the end of the reactor to measure the light transmission while introducing aerosol in the reactor. Table 2 gives an overview of the different parameter settings:

Table 2. Parameter settings to determine the RTD

Run	1	2	3	4	5
Air pressure (bar)	2.5	3.0	2.5	2.5	2.5
Liquid flow rate (ml/min)	2.5	2.5	2.0	1.5	1.0

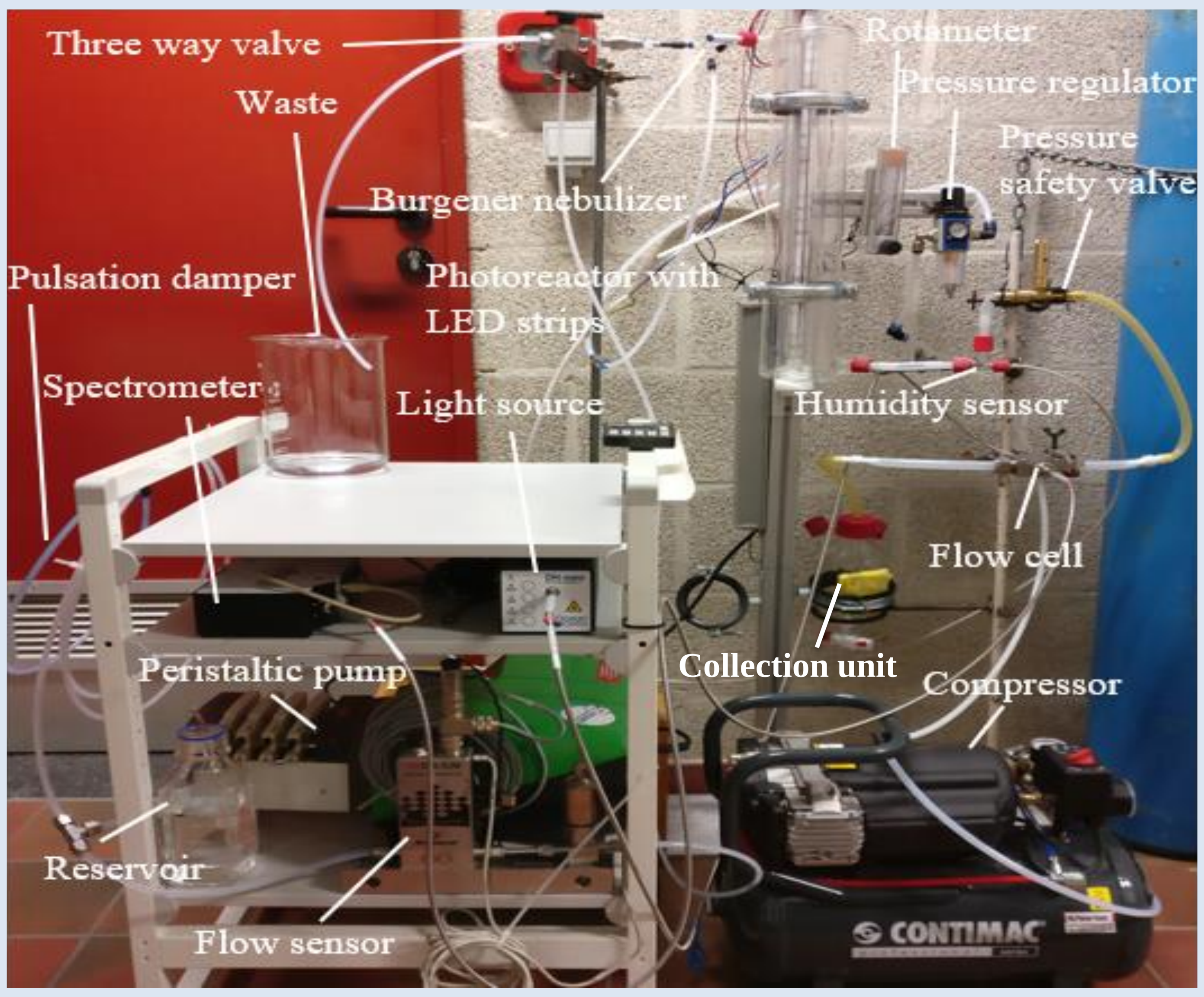

Fig. 1. Continuous reactor

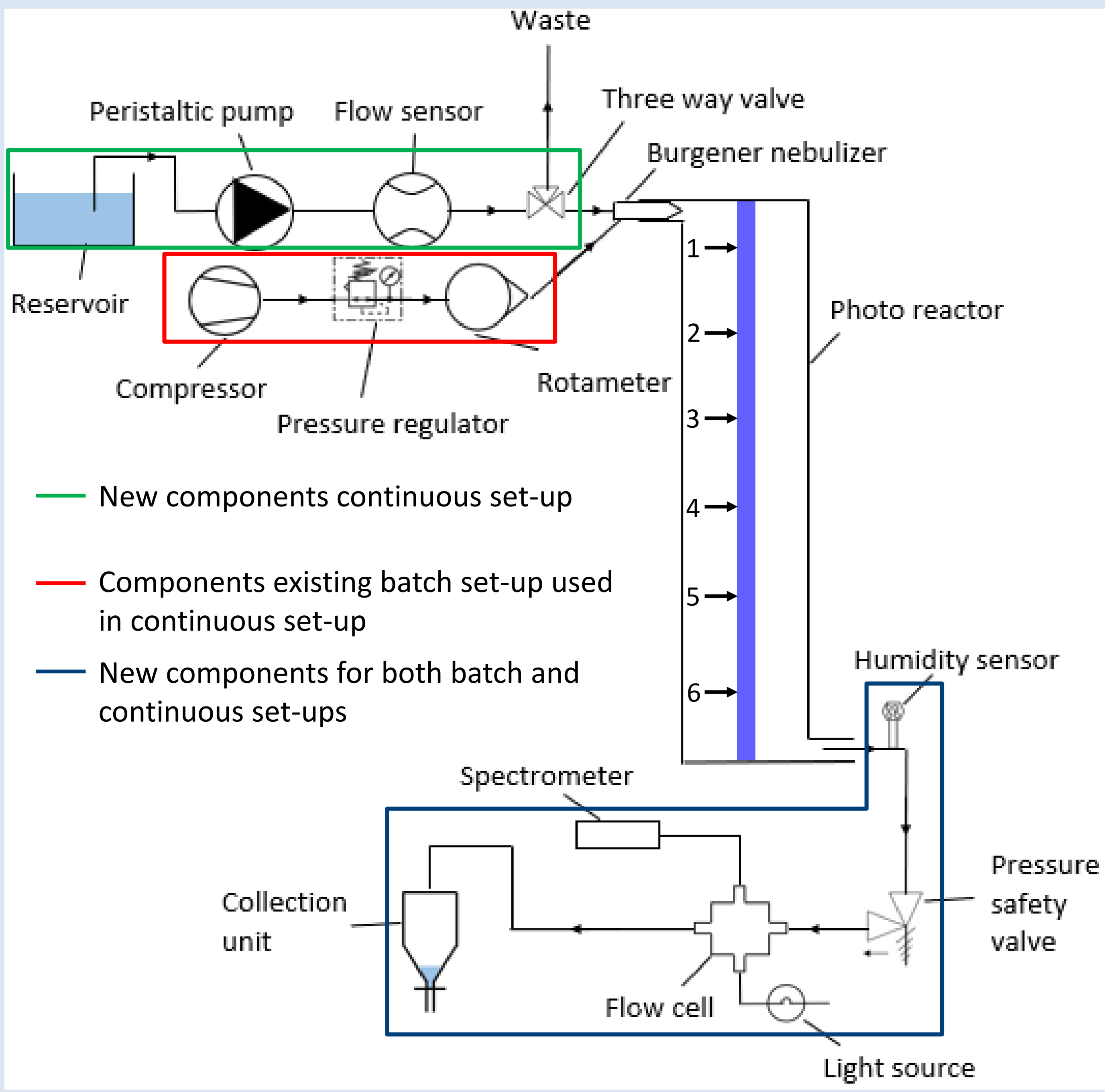

Fig. 2. Process flow diagram continuous reactor

Results & discussion

- **Transformation batch to continuous**

The freshly assembled continuous reactor runs smoothly. Although the gathered components work, the continuous nebulizer is unsuitable for the set-up and needs to be replaced.

- **Humidity measurement**

The humidity is 21% if only air is flowing in the reactor and increases immediately to 100% if aerosol is introduced.

- **Continuous phase separation operation**

Table 3 shows the results of the efficiency experiments:

Table 3. Results efficiency experiments different filter types and sizes

	Filter size (µm)	Pressure (bar)	Efficiency (%)
Hydrophilic (glass)	160-250	1	20,00
		2	10,00
	100-160	1	32,75
		2	43,32
Hydrophobic (polyethylene)	20-60	Leakage due to backpressure	
	40-100		
	80-130	1	44,00
		2	44,97

Filter size 100-160 µm of the glass filters is used due to its inertness.

- **Lamp reliability**

Fig. 3 shows the fluctuation in irradiance for both lamps. The fluctuation in time is negligible.

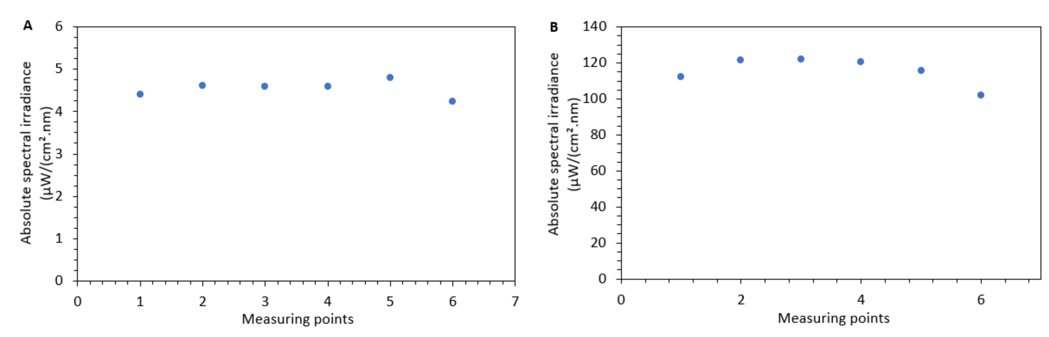

Fig. 3. Fluctuation in the length of A) LED-strips and B) gas-discharge tube

The maximum fluctuation is 20.10 µW/(cm².nm) for the gas-discharge tube and 0.57 µW/(cm².nm) for the LED-strips. The fluctuation in time is negligible.

- **Residence time distribution**

Fig. 4 shows the F-curve of the different RTD-measurements:

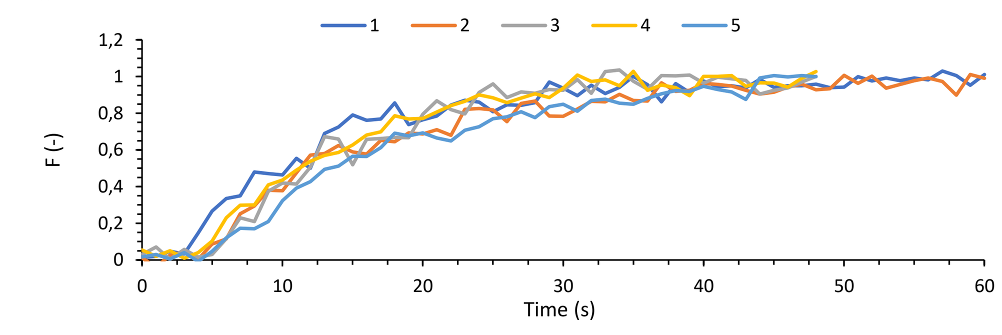

Fig. 4. F-curve of the different RTD-measurements

The average residence time is lower at a gas pressure of 3 bar. It is not possible to precisely calculate the average residence time due to data fluctuation.

Conclusion

This thesis shows that a transformation from batch to a continuous aerosol photoreactor is possible when using another type of continuous nebulizer. The humidity inside the reactor increases immediately to 100% when providing aerosol in the reactor. Glass filters with a particle size of 100-160 µm are the most suitable to use in the continuous phase separation operation due to the inertness of glass and the lower cost. A maximum absolute spectral irradiance difference of 20.10 µW/(cm².nm) for the gas-discharge tube and 0.57 µW/(cm².nm) for the LED-strips is measured between respectively point three and six and point five and six. The irradiance difference in time is negligible. The lamp can be dimmed efficiently according to point six. Lastly, it is not possible to precisely calculate the average residence time in the continuous reactor due to data fluctuation. Looking at the F-curves, the average residence time is lower when the gas pressure is 3 bar. The reactor is at 3 bar closer to a plug flow reactor then at 2 bar.

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