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Research area: Process aims
Paper and paperboard production // Papermaking

Keywords:
Dying, simulation, process control

Title:
Optimizing stock dyeing processes in the paper and textile industries

Background/Problem area

Colored papers, as well as colored textile products, are produced almost exclusively in small and medium-sized mills, since the batch sizes for such production runs are usually small. This means frequent, time-intensive grade changes and the associated fluctuations over time until the dye is again within the tolerance limits. In spite of the use of online measurement techniques and controlling systems, in this time high shares of not sellable products are produced.

Objectives/Research results

The objective of the research project was to develop physical, chemical and mathematical tools that can be used for the modelling of textile and paper dyeing based on continuous dye dosage.

Cotton fabrics of different structures were dyed with direct and reactive dyes to determine the exchange factor x (quotient of the dye concentration of the feeding liquor and the dye concentration of the dye liquor under stationary equilibrium dyeing conditions) and the coefficient of the velocity of exchange γ by varying the concentration of the dyes and auxiliaries and the time of dipping and impregnating. Within the project a small lab dyeing plant for simulation of a pad dyeing process was developed to be able to carry out the dyeing experiments. The exchange factor x was indirectly determined by spectrophotometric measurements of the residual liquor and calculated by applying multivariate mathematical methods. The curve shape of all dyes (exchange factor vs number of dyeing cycle) was qualitatively reproducible but the standard deviation of each data set was very high in all experiments. In contrast, the velocity of exchange γ showed a better correlation between the certain dyes and the differently structured cotton fabrics. Moreover, from γ it can be estimated, when dyeing equilibrium is reached. The dyeing experiments showed no influence of the contact time of the fabric to the dye liquor on the colour depth or shade. This was confirmed by the factor of the velocity of exchange γ and the exchange factor x within the accuracy of the measurements.

For the papermaking process, variables relating to the circuitry, mode of operation and wet end parameters and their impact on dyeing behaviour were ascertained. A paper mill was analyzed comprehensively as a test case. Variables relating to the circuitry and process mode were found to be well suited to control dye dosage during grade changes. They could be dynamically modelled and used to develop a model-based control strategy. Wet end parameters did not prove to be significant for controlling dye dosage, or their fluctuations during continuous production were too small. Disruptions in the wet end with a significant impact on dyeing behaviour such as charge swings are process conditions that should generally be avoided and which should not be used to control dye dosage. Model-predictive dye dosage control during grade change was successfully tested using the model and considerably reduced grade change times.

Application/Economic benefits

The research results provide a basis to transfer the model-based control systems to industrial scale. The know-how of critical parameters and suitable processes that was gathered is a prerequisite for successful modelling.

Cutting down grade change durations by 10 min with two grade changes per day enhances the plants productivity by 1.4 %. At 40,000 t/a, this means additional proceeds of about 170,000 €/a. The results showed that the implementation of a model based dye dosage control is feasible without extensive additional online-sensor requirements.

Project period: 1st January 2004 – 30th April 2006

Remarks

The research project AiF 13768 N was funded by the German Federal Ministry of Economics and Technology BMWi and was carried out in cooperation with the Institute “Deutsches Textilforschungszentrum Nord-West (DTNW)”.