Title: Flow regulator design optimization for ion-exchange resin containers

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Abstract

Water, due to its ubiquitous presence on Earth, constitutes not only the foundation of the biology of known life, but also the basis for the majority of human-initiated processes. Utilizing water from food processing, heating, energy production, and industrial processes to art, a slightly different chemical characteristic of water will however be expected. For water used in household appliances, the key parameter is the amount of dissolved calcium and magnesium ions, commonly known as water hardness, which, due to technical implications, is expected to be as low as possible. Ensuring the highest possible ion capacity of deionizer systems, and thereby their efficiency, allows for the market competitiveness of products intended for use in household appliances, while also positively affecting the reduction of their production's carbon footprint by reducing the amount of raw material needed to assure functionality.

The aim of the dissertation was to develop a method for designing an ion exchange tank according to a patented design of the tank shape, utilizing a channel for regulating internal filtration pressure to optimize the use of the ion capacity of the raw material by increasing the homogenity of the flow velocity within the filter volume. The work focused on developing a simulational and analytical optimizaiton methodology for the tank geometry based on a mass production design, tailored to the assumptions protected by the author's patented solution.

The dissertation includes a description of the state of the art for industrial processes, ion exchange, fluid mechanics, and numerical modeling, a detailed description of the developed methodology through the study of the performance characteristics of ion exchange preparations, the scope of empirical research, along with the design and execution of a series of research prototypes and test stands, a description of the numerical model tuning methodology along with the statistical correlation analysis methodology, the simulation optimization study methodology, and a description of the developed calculation methodology for the adopted optimization criterion in the form of statistical dispersion characteristics.

The outcome of the work is a tuned simulation model, a two-stage tuning methodology for the simulation model validated by a series of laboratory tests, and a statistical analysis methodology of the dispersion parameters of the simulated velocity population within the volume of the granular ion exchange resin bed as an optimization criterion.

As a result of the work, an analytical method was developed, which, within the examined space of geometric solutions, demonstrated a variability in flow homogeneity through the bed exceeding 5.1% in terms of all proposed and considered statistical indicators of homogeneity. The effectiveness of the considered construction solution in terms of flow regulation was demonstrated. Optimal geometric parameters in terms of the considered statistical objective function were also identified.