Tech Science Press

ICCES, 2024, vol.30, no.4
DOI: 10.32604/icces.2024.012551

PROCEEDINGS

Numerical Simulation of Slot-Die Coating for Lithium-Ion Battery Electrode and Investigation into Coating Characteristics

Peng Wang[1,*], Ningbo Li[1], Ruolan Jiang[1], Bing Dong[1] and Dongliang Sun[1]

[1]Beijing Institute of Petrochemical Technology, Beijing, 102617, China

[*]Corresponding Author: Peng Wang. Email: wangp@bipt.edu.cn

ABSTRACT

Lithium-ion batteries, renowned for their lightweight design and voltage stability, have found widespread applications in portable electronic devices, stationary energy storage systems, and electric vehicles. Slurry coating stands out as a pivotal manufacturing process for lithium-ion battery electrodes. In particular, slot-die coating technology, known for its rapid coating speed, has seen extensive engineering adoption in recent years. Utilizing numerical simulations to study the slurry coating process for lithium-ion battery electrodes allows for a detailed analysis of the complex fluid dynamics involved, thereby playing a crucial role in improving coating uniformity and enhancing battery performance. This study addresses a practical engineering challenge by focusing on a PMI-type die head and developing a mathematical model for the slot-die coating process of lithium-ion battery electrodes. Through the integration of steady-state laminar flow and transient phase-field models, we have achieved precise simulation of non-Newtonian slurry flow within a large-scale differential channel featuring "millimeter-scale cavity - micrometer-scale outlet" dimensions. Comparative analysis with actual coating experimental data reveals that the predicted pressure drop at the die inlet is less than 10%, and the discrepancy in the wet film thickness distribution is below 5%. These findings underscore the accuracy of the model devised in this study. Based on the established mathematical model, this study investigated the influence of die head structural parameters, coating process parameters, slurry properties, and other factors on coating characteristics. The research indicates that factors such as the sub-cavity, spacer slot, and chamfer between GAPs, lip thickness, and slurry viscosity have significant effects on coating thickness and uniformity. Non-uniform velocity fields at the connection between the main cavity and spacer slot may contribute to edge tailing. The incorporation of a sub-cavity structure serves to mitigate slurry flow, thus substantially reducing edge protrusions in wet film thickness. Non-uniform velocity fields at the chamfer may also contribute to edge tailing; larger angles and depths at the spacer outlet result in more pronounced edge tailing in wet film thickness. Increased lip thickness and higher slurry viscosity are beneficial for alleviating mid-coating protrusions. Wet film thickness significantly affects inlet pressure and also has a certain influence on edge protrusions. This research provides valuable guidance for the design and optimization of lithium-ion battery electrode manufacturing processes.

KEYWORDS

Lithium-ion battery electrode; slot-die coating; numerical simulation; coating thickness and uniformity

Funding Statement: The study is supported by the National Natural Science Foundation of China (No. 52176150).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.