APPLICATION NOTE

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Continuous twin-screw compounding of battery slurries in a confined space

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Key words
Cathode slurry mixing, twin-screw extruders, battery rheology, Process 11 Compounder, HAAKE MARS Rheometer

Battery slurry production is commonly realized by batchwise compounding of active materials, carbon black, solvents, binders, and additives in stirred vessels. This bears the risk of batch to batch variations, is labor-intensive, and requires production downtimes. Also, the transfer from lab scale preparation of novel formulations to production scale is difficult.

Twin-screw compounding offers a continuous production process with precisely controlled material shear, heat transfer, material throughput, and residence time. It provides high reproducibility, less cleaning time, and high material efficiency. Two parallel, co-rotating and intermeshing screws, embedded in a cylindrical barrel with dosing ports, mix, knead, and shear materials and eventually convey the compound through an outlet at the barrel end. Attaching a die to the outlet, extends the system to a twin-screw extruder. Scalability of twin-screw extruders' geometry enables for easy transfer from lab to high-throughput production of slurries.

Thermo Scientific lab scale compounder

The Thermo Scientific™ Process 11 Twin-screw Compounder represents all functionalities of a production extruder scaled down to lab size with throughputs ranging from 0.1 to 4.5 kg/h. Its small footprint allows to place it entirely into glove boxes or other containment systems, together with liquid and solid feeders placed on its housing, as demonstrated in Figure 2. This is required for cathode materials that need to be handled in a dry environment and for protection of the operators from hazardous chemicals. Liquid barrel cooling and controlled degassing ensures safe operation. With a flexible screw design and five dosing positions along the barrel, the composition of the slurries and the processing route can be changed quickly.

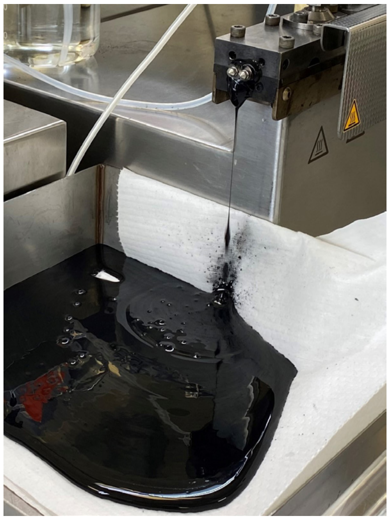

Figure 1: Thermo Scientific Cathode slurry compounded using Process 11 Twin-screw Compounder.

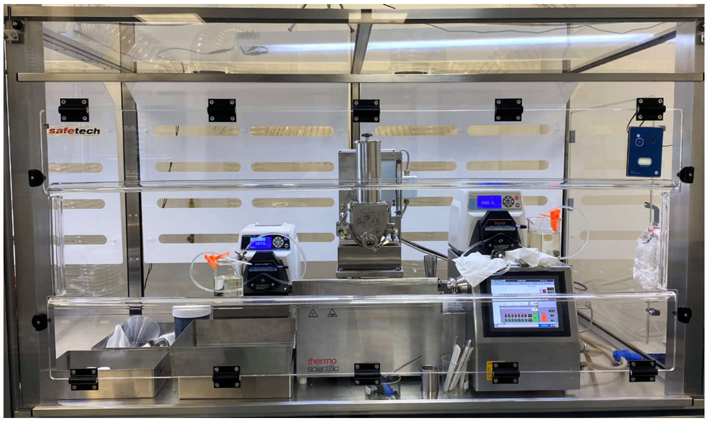

Figure 2: Thermo Scientific Process 11 Twin-screw Compounder, two liquid and one solid feeding system in a safety work bench. The setup captures a space of 770 mm height, 830 mm length, and 730 mm width.

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Slurry characterization

A broad variety of slurry properties can be achieved within minutes, and producibility of novel formulations can be tested. Examination of the freshly compounded slurrieson a grindometer shows differences in the grain size depending on the throughput, for instance, as shown in Figure 3.

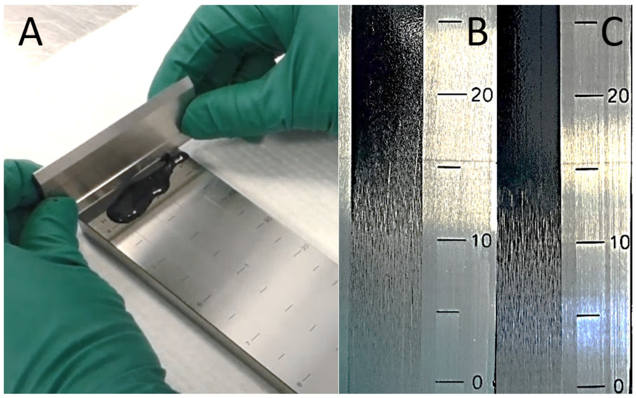

Figure 3: Examination of cathode slurry on a grindometer (A). Average particle size of cathode slurry is bigger when produced at high throughput (B) than low throughput (C), here.

Rheological characterization of the slurries using the Thermo Scientific™ HAAKE™ MARS™ Rheometer reveals variations in the strain rate dependent viscosity (see Figure 4). The characteristic flow curve determines the stability of the slurry suspension and its further processability in coating systems. For slurries stored in buffer tanks prior to coating, high viscosity at low shear rates (10^{-3} s^{-1}) is advantageous as it reduces sedimentation. During coating, however, high shear rates (10^{3} s^{-1}) occur and a high shear thinning behavior is advantageous. After coating, the slurries ideally quickly regain a high viscosity, which prevents the coating from spreading.

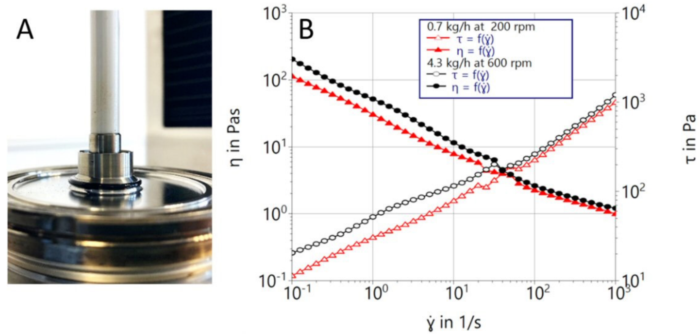

Figure 4: Rheological characterization of cathode slurry in HAAKE MARS Rheometer with plate-plate geometry (A). Strain rate dependent viscosity function of cathode slurries produced at low and high throughput and screw speed, respectively (B).

Conclusion

Downsides of batchwise battery slurry production are conquered by continuous twin-screw compounding. Thermo Fisher Scientific provides lab scale twin-screw extruders for battery slurry development fitting into small spaces as glove boxes. The twin-screw compounding process is scalable, easing the transfer of process parameters established in the lab to application of production scale extruders. Precise characterization of the slurries' rheology using HAAKE rheometers allows to predict the storage stability, coatability and spreading behavior.

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