IMAGE ANALYSIS AS METROLOGY TOOL FOR THICKNESS OF ELECTRODE COATING

Optical thickness profiling and rheological control of coating thickness

Goh Tian Jun, Dr. Carl Reynolds, Prof. Emma Kendrick

ABSTRACT

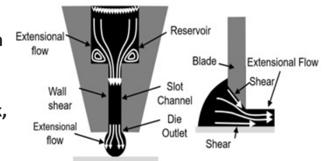
The project focuses on the usage of optical imaging and lighting as a metrology tool for the thickness of electrode coatings, detecting potential defects. MATLAB and Python code are used for frame-by-frame analysis of the recorded videos. The thickness variation data over time or relative to an initial distance from the starting point is plotted and compared with different settings, and with theoretical models.

MOTIVATION

- Optimal target thickness can be achieved to reduce wastage of coatings and batteries. Coatings which are too thick, must be discarded.
- High demand in electric cars and energy requirements for gigafactories prove the importance of scale-up in the manufacture of batteries.
- Measuring coat weight (Mesys software) is applicable but requires the assumption of constant density to model. [1]
- Laser thickness gauge is expensive and large, making it difficult to integrate into research setups. [1]

SETUP AND METHODS

- A hard carbon slurry is coated using a mini Ossila slot-die coater, with a 150µm gap from the surface.
- The formulation of the slurry consists of hard carbon, CMC, SBR and carbon black, mixed with the ratio of 90:2:3:5, and a 50% solid to water percentage.
- Hard carbon is chosen as the system since it is water based, easier to handle for lithium and sodium batteries and promising for replacing NMP based materials.
- A camera setup is arranged with a white background and sufficient lighting.
- The hard carbon slurry is injected from a reservoir (syringe) into the slot die channel.



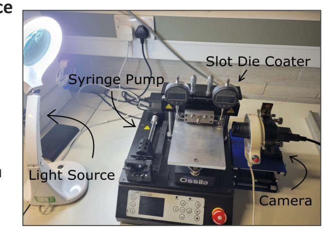
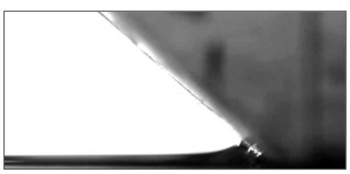
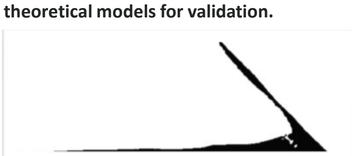


IMAGE ANALYSIS

- Step 1: The image is first transformed to grayscale. Binarization and thresholding are utilized to determine the contrast between the coating and the surface. Gaussian filter, disk opening and closing are used as functions to enhance the precision of defining the coating apart from the slot die.

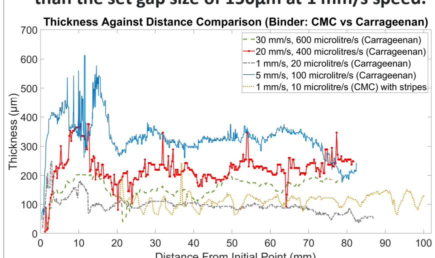


- Step 2: With the surface as the baseline, a vertical line is set and the thickness relative to the line is tracked. The edge function can be used to pinpoint the die outlet.
- Step 3: The thickness variation is plotted against the distance from die outlet, obtained from the speed of coating and frame rate. The results are compared with theoretical models for validation.

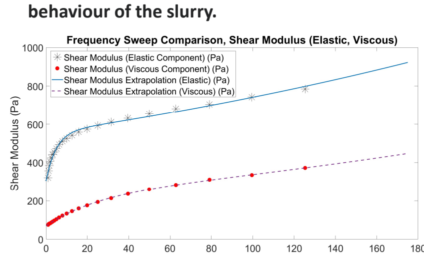


THICKNESS AND RHEOLOGY

- The thickness profile graph below demonstrates a pattern of undulations at faster speeds.
- The thickness is shown to be significantly larger than the set gap size of 150µm at 1 mm/s speed.

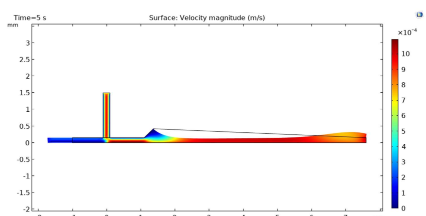


- With Carrageenan and nanotubes, the shear modulus components of the slurry changes significantly (G'>G''), shown in the frequency sweep graph, indicating a rubbery elastic behaviour of the slurry.



RESULTS AND CONCLUSIONS

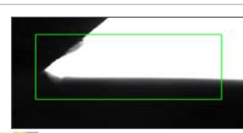
- For coatings of the tested speeds and dispense rates, the shape of the thickness profiles is supported by the physical model (Oldroyd-b viscoelastic model, Southampton) [2], as shown below.
- The 'bump', which appears initially in the model before levelling out, is represented by the pattern of the thickness profiles of the coatings.

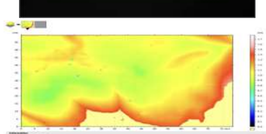


- Viscoelasticity is a crucial factor when predicting thickness, such as the initial peak before flattening and undulations at faster speeds.
- As shear rate increases, the coating will be thinner in the elastic regime.
- This pattern decreases with further increments in shear rate, due to build-up of back pressure.
- Image analysis managed to show the potential of detecting defects and the dependency of coatings on rheology and coating parameters.
- This method can be used to validate the theoretical models for electrode coatings.

IMPACT / NEXT STEPS

- Region selection is possible with Python, potentially removing myriad disturbances and easing adaptation to different setups.
- Utilization of feedback loop enables control of the coater to adjust accordingly with parameters for the desired coating.
- Usage of a live webcam allows real-time adjustments of flow rate.
- Microscopic detection of defects, potentially enabling monitoring of growth of cracks and the drying process of coatings.
- The code can be improved to output the thickness profile as the code runs, allowing changes to be made to the system in real time.





REFERENCES

[1] Reynolds, C.D., Slater, P.R., Hare, S.D., Simmons, M.J. and Kendrick, E., 2021. A review of metrology in lithium-ion electrode coating processes. Materials & Design, 209, p.109971.

[2] Gaurav Singh. Oldroyd-b Viscoelastic Model, Southampton. Ongoing Work of Nextrode.

BIOGRAPHY

Jun is a third-year student, currently studying MEng Chemical Engineering with Industrial Year at the University of Birmingham. Passionate about technology and software, he is interested in the application of coding and programming in the field of energy and process engineering. He is aspiring to be a chemical engineer who is well-versed with coding and presenting data. He strives to integrate his creativity into the vast world of engineering.

LinkedIn: Goh Tian Jun

THE FARADAY INSTITUTION ELECTRODE MANUFACTURING
NEXTRODE
UNIVERSITY OF BIRMINGHAM
UK Research and Innovation