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Developing ultrasonic evaluation tools for battery manufacturing processes

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ABSTRACT

As the electrical revolution accelerates, the global battery manufacturing capacity is projected to quadruple from 1570 GWh/yr in 2022 to 6790 in 2030 [1]. However, due to the lack of effective real-time, in-process evaluation techniques of the battery manufacturing steps to enable closed-loop controls, gigafactories, especially newly built ones, typically suffer from low overall yield rates. This results in enormous energy and economic losses [2]. In addition, recent high-profile incidents of defective battery cells (see, e.g. [3]) highlighted the needs for defects to be captured during manufacturing steps, to ensure safety as well as performance of the cell products. These requirements demonstrate the importance of in-process non-destructive evaluation (NDE) solutions during battery manufacturing [4].

Here we give an overview of the progresses made at the NDE group at Imperial College London, towards ultrasonic evaluations of the slurry mixing and electrode sheet coating/drying step at the very beginning of the manufacturing process. For battery slurry, in order to characterise its dispersion and homogeneity, a set of experiments are conducted where slurry samples were taken offline at various stages of mixing, to be examined by different techniques such as rheometer, microscopy and ultrasound. The purpose is to establish phenomenological correlation between ultrasonic behaviours (velocity, attenuation and backscattering) and slurry microstructures, which serves as a benchmark for acoustic theoretical frameworks to be developed and further applications (e.g. detecting metal particulate inclusion, and online monitoring of the mixing process) to be researched in the future.

As for electrode sheets, we have developed a novel quantification method of porosity and tortuosity based on air-coupled ultrasonic waves. We utilise the fundamental fact that in a porous material with a rigid frame (i.e. dry electrode in the air), there exists three Biot wave modes (two compressional and one shear) which interact with both the solid frame and the gaseous phase. These waves can be exploited to enable quantitative evaluation of the properties from simple, real-time ultrasonic testing. To achieve this, we have established a wave physics model fully incorporating the propagation of the Biot waves in porous multilayers [5], and then employ it to perform a multivariant search to investigate its sensitivities of to the parameters, for the optimization of experimental ultrasonic tests for quantitative inversion. We then demonstrate this evaluation with a lab-based air-coupled ultrasound setup, which has the potential for NDE of certain defects (e.g. cracks, delamination) and may be integrated to the manufacturing line.

Keywords: ultrasound, NDE, battery manufacturing, slurry, electrode sheet

[1]. Website link [2]. Website link [3]. Website link

[4]. https://doi.org/10.1016/j.jpowsour.2023.232742 [5]. https://doi.org/10.1016/j.ijengsci.2023.103888