Whitepaper

Is battery consistency **the key to mass e-mobility success?**

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Could battery consistency hold the key to mass e-mobility success?

The hidden struggle for performance.

With lithium-ion battery packs responsible for up to 60% of the total cost of an e-vehicle in 2015, the global industry focused its efforts on cost reduction. This concentrated effort paid off. In 2019, battery costs were down to 33% of total e-vehicle costs and they continue to fall.[1] The next step toward mass market adoption is achieving consistent battery performance.

Dr. Adrian Spillmann, Director Market Segment Battery Solutions, Grinding & Dispersing, Bühler

Battery technology is key to the success of e-mobility – and cost has been a major focus for producers. But with lithium-ion (li-ion) battery costs falling from USD 1,200 per kilowatt hour (kWh) in 2010 to USD 175 kWh in 2018[1], prices are reducing significantly, year-on-year. According to The US Department of Energy, battery costs of below USD 125 per kWh make owning and operating an electric car comparable to an internal combustion engine (ICE) car in most parts of the world.[2] Predictions that prices could drop below USD 100 kWh by 2024[3] mean that li-ion battery costs may no longer be the problem they once were.

If cost is no longer a barrier to mass market adoption, is the e-vehicle industry – based on li-ion battery packs – ready for take-off? Not according to Dr. J. Simon Xue[4], renowned battery technologist with 24 years in li-ion battery research. “This predominantly cost-driven culture is leading to quality inconsistency and poor environmental performance in the production process,” he explains. He believes that this is a potential problem for e-mobility that needs addressing now.

Why does it matter?

As li-ion cells age, some of the electrolyte inside the cells is consumed and turned into new compounds. These reactions decrease the cell capacity, which can ultimately lead to cell death. Inconsistency in li-ion production can affect that process, with a number of serious consequences. Number one is safety. Inconsistencies can cause overheating or even explosions. All it requires is a small element of contaminants in the electrode slurry. In 2016, Samsung recalled over one million Galaxy Note 7 phones due to li-ion batteries overheating[5] and in January 2019, HP had to recall 150,000 laptops because of poorly d li-ion cells.[6] In China in 2019, there have been at least three reported incidents of li-ion electric minivans catching fire whilst charging – all of the same make and model.[7]

Secondly, inconsistency can lead to battery degradation problems, compromising the range of e-vehicles. In June 2019, Top Gear, the global TV car show, claimed an eight year-old Nissan Leaf with 80,000 road miles could only travel 35 miles on a single charge.[8] Damaging headlines like this can seriously effect consumer confidence.

Consistency problems in manufacturing can compromise the overall green credentials of li-ion battery vehicles. “The majority (60%) of the world’s li-ion batteries are produced in China, where typical production yields are at around 80%. This inefficiency wastes energy and materials and adds to the carbon footprint of the production process, reducing environmental benefits as a whole,” Dr. Xue explains.

The carbon footprint in production of e-vehicles is already under scrutiny. Munich-based automotive consultancy, Berylls Strategy Advisors, claims that, mainly because of the li-ion battery production process, the average German car owner could drive a traditional ICE vehicle for three and a half years, or more than 50,000 kilometers, before a Nissan Leaf with a 30 kWh battery would beat it on carbon-dioxide emissions in a coal-heavy country.[9]

Is inconsistency a problem?

According to Dr. Xue, inconsistency in the production process is compromising battery performance around the world. "In China, I have seen manufacturers switching cobalt suppliers in order to save on resource costs. This has had a profound effect on battery quality. In the US, one manufacturer cut gel drying from an overnight process to five hours to meet customer deadlines, which caused performance degradation."

At the moment, 80% of li-ion battery producers use a batch process for electrode slurry production, so inevitably there are fluctuations in the quality mix and performance between batches. "One of the big problems is that operators find it difficult to tell the difference between a good slurry and a substandard slurry. They have probes at key points in the process, but quality control and consistency relies heavily on the technical expertise of staff," says Dr. Xue.

Another challenge is defining consistency. Most manufacturers quote deviation and impedance as a measure of quality, but this is a static measure. Dynamic consistency over 1,000 cycles, is what is important, but this can take five to six months to test. With batch production, this also requires constant sampling.

What is the solution?

The solution, Dr. Xue argues, is better control over production, and better methods for proving consistency. To achieve better control, the key is to manage moisture, temperature and dust. One way to achieve that is to move away from batch production to a sealed continuous automated production system.

Dr. Xue says this approach appears to solve a number of problems in one technological step. "I think that the level of control that continuous production could bring to the li-ion battery production is really important. Firstly it's a sealed process, that minimizes the local environmental impact. Secondly, it's automated, so it gets rid of man-made errors and reduces reliability on technical expertise, which is not always easy to find. Thirdly, constant quality monitoring drives consistency, which could help to increase yields, reduce waste and ultimately improve battery cell performance." When it comes to proving consistency, Dr. Xue says that Professor Jeff Dahn's

> "I tell my students: We need a change of mindset. It's about quality across the whole – from materials and process, to equipment and people. Only then will we have battery consistency that consumers can have confidence in for the future."
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> **Dr. J. Simon Xue,**
> Member of the Expert Committee Energy Storage, Chinese Industrial Association of Power Sources (CIAPS)

Research Group at Dalhousie University[10] is developing advanced diagnostics to predict cell life without having to test cells for years. Dr. Xue, who studied under Professor Dahn in the nineties, says that pioneering work in Dahn's lab could help producers to define consistency in li-ion battery packs much faster, and with much more accuracy. These technologies may provide the efficiencies and confidence that consumers need to drive the mass adoption of li-ion battery powered e-vehicles that governments, regulators and environmentalists are striving to reach.

Of course, there are alternative battery technologies in development around the world. In particular, a consortium of Japanese battery and automotive manufacturers are working with the Japanese government to perfect solid state e-vehicle batteries.[12] By effectively replacing the wet electrolyte in today's lithium-ion batteries with a solid core, these cells could potentially be cheaper, and lighter. They won't need liquid cooling. They should also be longer-lasting and fireproof.

There are also other alternative chemical developments being explored within li-ion batteries. Silica anodes, which have higher energy capacity than graphite, the normal material for anodes, can offer theoretical increases in energy density of up to 40 percent, but currently tend to destroy themselves by expanding when charging. Blended options with graphite are a possibility. Many advanced-cathode chemistries also exist, such as lithium nickel manganese oxide (LNMO) bringing higher energy capacities. These high-voltage cathode materials are currently facing issues with the liquid electrolyte breaking down at higher voltages.

Conclusion

— **Lithium-ion battery costs are dropping, and more focus needs to placed on consistency. Drive for consistency will benefit producers, consumers and the environment.**

— **Performance can vary from batch-to-batch from the same plant. Continuous electrode slurry production could help solve this problem.**

— **Predictive testing technology may also play an important role.**

Call to action

Dr. Xue is adamant that now the li-ion industry has a clear pathway to meeting cost-reduction targets, consistency should be the next focus. “Governments and regulators quite rightly are targeting emissions from vehicles[13], but this is only part of the story. For the consumer, the entire life performance of their vehicle, and the entire life environmental footprint – including production – will be key to uptake. Consistency is at the heart of both of these issues,” says Dr. Xue.

One way of improving consistency is for the li-ion battery industry to adopt more efficient production techniques. Bühler’s new continuous mixing approach for the manufacture of the electrode slurry production offers significant potential for improvement for the 80% of the global industry that currently uses batch process manufacturing.[14] With continuous mixing, raw material dosing, pre-mixing, kneading, fine-dispersing, and degassing are all combined in one device. Greater powder- and liquid-dosing accuracy delivers constant slurry properties, eliminating batch-to-batch variations. The process requires three times less specific energy input to achieve the same product properties and uses less energy to maintain the production climate.

Continuous production is that it enables constant monitoring and control. Bühler’s inline quality control expert system, QuaLiB™, measures critical product characteristics and automatically adapts the process to optimize and homogenize product quality and reduce waste.[15] The result is higher product consistency, with smart algorithms ensuring that only high-quality product is forwarded to the next production step. QuaLiB™ also provides higher traceability, tracking raw materials from intake to coating line. Bühler’s Dr. Jan Marti, Data Scientist and Project Manager of QuaLiB™ says continuous production with inline quality control could have cost benefits too:[16] “We calculate that a slurry production line with production capacity of 1,000 liters per hour could make savings of up to USD 1.3 million a year, as well as improving consistency.”

Professor Jeff Dahn’s research lab at Dalhousie University is focused on the physics and chemistry of materials for energy storage, primarily in the area of lithium-ion batteries. One of its goals is to improve cycle and calendar lifetime of li-ion batteries. “Professor Dahn’s group are measuring deviations in voltage to a very high precision, and using this as a predictor of cycle life and degradation.[11] Once commercialized, instead of taking six months to confirm degradation over 1,000 cycles, this could be part of the production process. Combined with autonomous production, this could greatly improve consistency for the li-ion industry over the coming years,” Dr. Xue says.

New technologies?

Finally, it is important to note that there are new battery technologies being explored in laboratories around the world. In its study on the future of batteries, management consultancy, Arthur D Little concludes: “There is no ‘God Battery’… Many new technologies are still in their infancy, and there is likely to be a significant time overlap between technologies entering the mainstream and their final replacement of incumbents.”[17]

Bühler’s continuous mixing technology is ready for processing of next generation battery materials, such solid-state. Furthermore, the Bühler continuous mixing solution is able to process electrodes with less or even without solvent, which will be a key feature for future manufacturing processes. According to Avicenne Energy, typical commercialization of battery technologies can take decades.[18] Dr. Marti agrees. He says that while new technologies will slowly come to market, the industry must focus on improving consistency in li-ion batteries now. “E-vehicle demand is about to sky-rocket. Improving li-ion production efficiency and green credentials is a priority right now,” Dr. Marti explains.

References

1 The Incredible Shrinking Car Battery (2019). BloombergNEF: Available at: https://www.bloomberg.com/opinion/articles/2019-04-12/electricvehicle-battery-shrinks-and-so-does-the-total-cost

2 US Office of Energy Efficiency & Renewable Energy: Available at: https://www.energy.gov/eere/vehicles/batteries

3 Lithium-ion battery prices: Available at: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

4 Dr. J. Simon Xue: See biography page 4.

5 Samsung cell phone battery recall. Available at: https://newyork.legalexaminer.com/legal/defective-dangerous-products/samsung-announces-another-cell-phone-battery-recall/

6 HP expands recall of li-ion laptop batteries. Available at: https://www.consumerreports.org/laptop-computers/hp-expands-recall-of-li-ion-laptop-batteries/

7 Minivans catching fire in China. Available at: https://qz.com/1575817/electric-vehicles-from-chinese-car-maker-bjev-are-catching-fire/

8 Top Gear Series 27, Episode 2, Electric Car Special. Available at: https://www.bbc.co.uk/programmes/m00068rr

9 Carbon footprint of li-ion batteries in production. Available at: https://www.industryweek.com/technology-and-iiot/lithium-batteries-dirty-secret-manufacturing-them-leaves-massive-carbon

10 Professor Jeff Dahn's Research Group at Dalhousie University. Available at: https://www.dal.ca/diff/dahn.html

11 Advanced diagnostics to determine li-ion cell failure mechanisms. Available at: https://www.dal.ca/diff/dahn/research/adv_diagnostics.html

12 Japanese consortia for solid state battery development. Available at: https://asia.nikkei.com/Business/Business-trends/Japan-juices-efforts-for-new-electric-vehicle-battery

13 European Union's 28 member states agreed to new carbon-dioxide regulations. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable

14 Bühler's continuous electrode slurry production. Available at: https://www.buhlergroup.com/northamerica/en/downloads/BUZ_GD_Bro_Battery_EN_1118_Web.pdf

15 Bühler's inline quality control expert system, QuaLiB™. Available at: https://www.buhlergroup.com/northamerica/en/downloads/BUZ_GD_Bro_Battery_EN_1118_Web.pdf

16 Dr. Jan Marti, Bühler Date Scientist and Project Manager for QuaLiB™: See biography page 4.

17 Arthur D Little. The Future of Batteries. Available at: https://www.adlittle.com/sites/default/files/viewpoints/adl_future_of_batteries-min.pdf

18 Avicenne worldwide rechargeable battery report. Available at: http://www.avicenne.com/reports_energy.php#rapport2

Dr. Jan Marti

Data Scientist and Project Manager for QuaLib™ for Bühler

Dr. Jan Marti is a Data Scientist at Bühler Group and the Project Manager of QuaLiB™, an inline quality control system for the continuous production of battery slurries. He obtained his bachelor's and master's degrees in Mechanical Engineering from ETH Zurich (Swiss Federal Institute of Technology). He received his PhD in the field of Renewable Energy Technologies in 2015 from ETH Zurich, where he continued to work as a Research Associate. In this role, he managed ETH Zurich's contributions to the European Union's research project RICAS2020 with the goal of developing a large-scale energy storage system.

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Dr. Adrian Spillmann is Director Market Segment Battery Solutions, Grinding & Dispersing at Bühler Group. Following his Masters, he secured his PhD in Process Engineering at ETH Zurich (Swiss Federal Institute of Technology) in 2008. He has been working at Bühler in materials and processes for the manufacturing of batteries and photovoltaics since 2008. He now specializes in battery solutions.

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Dr. J. Simon Xue has spent 24 years in the research and development of lithium-ion batteries. Dr. Xue is currently a member of the Expert Committee in the Energy Storage section for the Chinese Industrial Association of Power Sources (CIAPS). He has authored or co-authored over 50 scientific articles, holds 12 patents relevant to battery chemistry and materials, and has participated, presented, and hosted more than 30 battery-material related international conferences.

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