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PUBLISHED 2Q 2020

Mitigating Battery Safety Challenges in Micromobility Applications

April 2, 2020

The micromobility services industry has grown significantly in recent years. In 2018 alone, the global electric scooter market was valued at $17.4 billion, and two of the largest e-scooter operators in the United States reached billion-dollar valuations.[1,2] Both docked and dockless e-scooters and bikes have the potential to better connect people with public transit, lessen reliance on private vehicles, and reduce greenhouse emissions. However, while international standards providing safety requirements for micromobility battery pack and electrical system design exist[3], not all of the products being introduced to the rapidly-expanding global micromobility market meet these design and test requirements. Additionally, these standards continue to evolve as additionally field failures occur. As lapses in battery safety and quality can contribute to fires, property damage, and bodily injury, it is important for micromobility operators to identify and address potential safety issues before incidents occur. Careful selection of platform vendors, reviewing designs and prototypes before qualification and purchase, and battery pack condition monitoring are three important considerations that can help mitigate battery safety challenges in micromobility applications.

Careful Selection of Platform Vendors

The physical and electrical safety requirements for batteries in micromobility applications are more stringent than typical consumer electronics requirements. E-scooters and bikes are frequently exposed to moisture, mechanical shock and vibration, and extreme temperatures, all of which can damage the battery cells and their protective electronics. As micromobility battery packs are significantly (5–10x) larger than common power tool or laptop computer battery packs, the consequences of a battery pack failure can be more significant and severe than for smaller systems.

Many micromobility operators purchase fully designed platforms from third-party vendors. While this is a widespread and acceptable practice, vendors may not always conduct thorough evaluations to ensure that surrounding electronics safely perform in an outdoor environment with repeated mechanical shock, thermal loads, and moisture exposure. To help mitigate this challenge, we recommend that micromobility operators conduct upfront testing and characterization, including the battery cells and surrounding electronics, before completing platform qualification and purchase agreements. This is especially important when purchasing designs from contract manufacturers in China, as there may be large variations in quality between manufacturers.

Review of Designs and Prototypes Before Qualification and Purchase

Upfront inspection of battery management units at both the pack and system levels can help operators ensure that cells are protected during charge and discharge and that the circuit layout design is not contributing to catastrophic failures.

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[1] https://www.forbes.com/sites/adeyemiajao/2019/02/01/everything-you-want-to-know-about-scooters-and-micro-mobility/#11700de05de6

[2] https://www.grandviewresearch.com/industry-analysis/electric-scooters-market

[3] For example, EN 50604-1:2016 (Secondary lithium batteries for light EV applications), UL2271 (Batteries for Light Electric Vehicles), UL2272 (formerly Hoverboards, now Electrical systems for personal e-mobility devices), and UL2489 (Electrical systems for e-bikes).

Mitigating Battery Safety Challenges in Micromobility Applications

Our team at Exponent recently partnered with a client who was working with multiple vendors to qualify the safety and quality of battery packs for their new micromobility device. Our team reviewed the design documentation and physical construction of the packs and cells from multiple vendors. In two designs, the battery management systems posed significant safety risks, lacking sufficient electronic protections and redundancy in the system to keep the battery cells within safe operating conditions. Upon cycling, one or more of these cells would have a high likelihood of thermal runaway, subsequently leading to thermal runaway of the entire pack. Furthermore, multiple packs employed cells with poor manufacturing quality, which can exacerbate the risk of thermal runaway posed by poor battery management systems. Based on our recommended design and manufacturing practice changes, several of the vendors worked with our client to improve their designs and address the safety issues we identified. From our subsequent thermal testing of improved designs, two vendors' pack designs were able to prevent cell-to-cell propagation after a single cell was forced into thermal runaway. These vendors became qualified as trusted suppliers for our client, and significant improvements to the client's and vendors' qualification processes occurred as a result of our reviews and recommendations. Our design review not only avoided potential field failures and recalls for our client but also resulted in long-term improvements to both our client's and their vendors' device and pack safety and quality.

Our team frequently conducts design reviews to examine both the circuitry and the quality of battery packs and cells. We can also assist with the factory auditing process for the safety qualification of battery cells, packs, and systems.

Monitoring Battery Pack Conditions

Monitoring battery pack conditions both on road and in depot can help mitigate potential safety issues and optimize available up-time for vehicles and battery packs. If a micromobility operator monitors how its battery packs are behaving in the field or depot, the operator can predict how many vehicle miles it can expect per charge cycle and how many cycles may be expected out of any given pack during its lifetime. The operator can also identify abnormalities (e.g., a battery not holding its charge or taking longer than expected to charge) that can be leading indicators for potential safety issues.

While proper vendor selection and design are critical to ensuring battery pack safety, even the best lithium-ion battery manufacturers can occasionally experience failures. It is important for operators to consider what will happen if a system suffers a catastrophic failure. Could a user be exposed to flaming vent gases or high heat? Could failure of the battery pack lead to the ejection of battery cells and cause a subsequent fire that leads to property damage and injuries? Our team can perform forced catastrophic failure testing and analyze these failures in a controlled environment. We can also verify electrical performance at both the pack and system levels, provide guidance on safe storage and charging of battery packs, and help operators design systems to effectively manage safety issues before they propagate.

Exponent's Expertise

Exponent's multi-disciplinary team of mechanical, electrical, and chemical engineers and materials scientists has investigated failure modes and performed root-cause analyses across micromobility brands and system components. We can support the platform vendor selection process; review system and component designs and prototypes; evaluate safety and quality in battery cells, battery management systems, and packs; and enable battery pack condition monitoring across the entire product lifecycle.

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