

## Driving Reliability in EVs: The Science Behind Your Smooth Ride

Electric vehicles (EVs) are transforming the automotive industry in ways that were unimaginable just a decade ago. Sure, the sleek exteriors, powerful acceleration, and whisper-quiet operation get all the attention, but let's peel back the shiny surface and talk about what really makes an EV tick - and stay ticking. Spoiler alert: it's not magic, it's materials science! There's a whole world of innovation and engineering going on beneath the hood (or floor), and it's what keeps these cars reliable, durable, and road-ready day after day.



**Figure 1.** Showing an example of an EV powertrain for heavy duty trucks  
~ Courtesy of Magna

The electric drivetrain is, in many ways, the backbone of an EV. It's not just about the motor or battery; it's about the supporting cast of components that keep everything working smoothly and seamlessly. To make sure your EV delivers the smooth ride you expect, engineers perform meticulous metallographic and metallurgical assessments on these components.

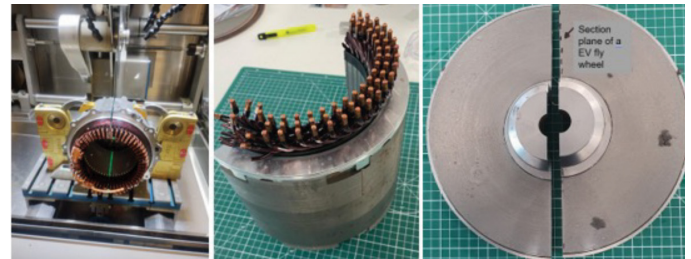
Let's dive into the unsung heroes of the EV drivetrain—seven key elements that undergo rigorous testing to keep your EV a marvel of engineering for years to come.

### 1. Motor Components: Rotor and Stator - The Power Couple

The rotor and stator are the heart and soul of your EV's motor, working together to convert electrical energy into the mechanical motion that drives your car. They're a power couple - quite literally - but that means they must deal with a lot of pressure. Think high speeds, intense heat, and constant magnetic forces.

**The Science Behind the Scenes:** The stator is usually made of electrical steel that needs specific magnetic properties to operate efficiently. Metallurgically, we're talking about steel microstructures such as grain size, texture, and phase composition - essentially making sure that the magnetic properties of the steels are optimized for performance. Micro-cracks or any kind of microstructural defects? That's a red flag. The rotor on the other hand, often includes rare-earth magnets, also needs a clean bill of health. Metallurgical testing ensures there are no inclusions/deleterious phases or defects that could

lead to a breakdown. We're also checking that the magnets stay where they belong and that the steel laminations are insulated just right to minimize energy losses. After all, less energy loss means more zip for your ride.

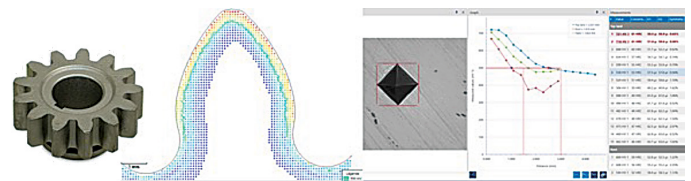


**Figure 2.** Illustrating a stator with its housing and flywheel through metallographic sectioning

### 2. Gearbox Components: Gears, Shafts, and Bearings - The Torque Titans

EVs might not have as many gears as their gasoline-guzzling counterparts, but the gears they do have need to handle serious torque. Electric motors produce torque like nobody's business, and that's great for acceleration—but tough on the drivetrain.

**The Science Behind the Scenes:** Gears and shafts are typically made of case-hardened steel, giving them the resilience to handle the load while keeping wear to a minimum. Metallographic testing checks the depth of surface hardening from heat treatment processes such as carburising, nitriding, or induction hardening, desirable case microstructures, and carbide distribution to ensure the components can take the beating they're designed for. Residual stress analysis is also critical here. Properly managed residual stress can actually make these parts stronger, but if things go wrong, it's a ticking time bomb for fatigue failure. Bearings? They're all about rolling smoothly at high speeds without breaking under the load. That means checking for surface hardness, rolling contact fatigue, and anything that could cut their life short.



**Figure 3.** Illustrating hardness testing of a heat treated gear to establish case depth

### 3. Power Electronics Cooling Plates and Heat Sinks - Keeping It Chill

Power electronics, like inverters and chargers, are basically the brains of your EV. But all that brainpower generates heat—lots of it. Keeping these systems cool is essential to keep everything running smoothly.

**The Science Behind the Scenes:** Enter the cooling plates and heat sinks, often made from aluminium or copper because of their fantastic thermal properties. Metallurgical assessments focus on thermal fatigue—these materials go through a lot of heating and cooling cycles, and we need to make sure they won't crack under pressure. Metallographic analysis looks at the grain structure, hunting for porosity or other flaws that could lead to inefficiencies or even failure. We also look at the anodized surface layer on aluminium heat sinks because it's key to corrosion resistance. You know, so it keeps doing its job even when exposed to harsh environments.

#### 4. Battery Pack Structure and Electrical Contacts - Getting Connected

The battery pack is the beating heart of your EV. It's a collection of thousands of lithium cells working together, but they only work if they stay connected—literally and figuratively. Electrical contacts and structural enclosures are what keep everything safe and efficient.

**The Science Behind the Scenes:** Metallurgical assessments are used to make sure that every weld, joint, and battery module frame is perfect. Welds connecting cells to busbars are particularly important - voids, inclusions, or any weaknesses in these welds could compromise the whole system. Laser and ultrasonic welding techniques are great, but they're not foolproof without testing. Then there are the intermetallic compounds (IMCs) that can form at joints between aluminium and copper. IMCs are brittle, and brittleness is not what you want in a battery connection. Routine checks help us catch and mitigate these risks. The structural enclosures, usually aluminium, are also tested for casting defects - anything that could affect the pack's ability to protect those precious cells from the shocks and bumps of everyday driving.

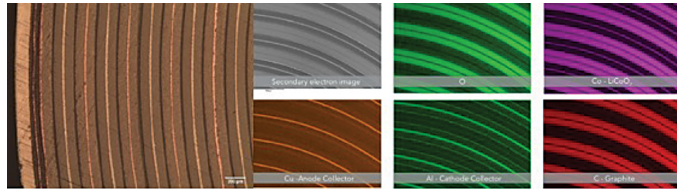


Figure 4. Illustrate electron microscopy (EDS) analysis of the laminate structure of a cross-sectioned Lithium ion cell



Figure 5. Illustrate welds tests on a lithium batteries with left - spot weld, middle - ultrasonic weld and right laser weld

#### 5. Drive Shafts and Axles - Torque Delivery Experts

Drive shafts and axles are like the final link in the chain—they take all the torque generated by the motor and deliver it to the wheels. But with great torque comes great responsibility, and these parts need to be up for the challenge.

**The Science Behind the Scenes:** Drive shafts and axles are put through both metallographic and mechanical tests. We're checking the grain structure for impurities that could cause fatigue failures. A solid grain structure means better resistance to those repeated torque loads. Case hardening is also used to make sure these parts are tough on the outside but still have a flexible core—think of it like an M&M, but for power delivery.

This combination of surface hardness and internal toughness is what allows drive shafts to endure both wear and sudden shock loads without cracking.

#### 6. Powertrain Cooling Pipes and Connectors - Corrosion Warriors

Cooling isn't just for power electronics—the motor, battery, and powertrain also need to stay cool. Pipes and connectors are the arteries of the cooling system, circulating coolant to keep everything running within optimal temperature ranges.

**The Science Behind the Scenes:** Cooling pipes are usually made from aluminium alloys or stainless steel because they resist corrosion well. But where they're welded is where things get tricky—dissimilar metals and weld joints are vulnerable to failure attributed to corrosion. Metallographic analysis is used to check weld quality and to make sure that only desirable microstructures exist from the base material, through the heat affected zone into the weld (high heat input area). Thermal fatigue is another major consideration. These pipes experience constant temperature changes, which can lead to cracking. Routine testing helps catch early signs of thermal fatigue so we can address the problem before it leads to real-world failures.

#### 7. High-Voltage Cables and Connectors - The Silent Power Brokers

High-voltage cables and connectors distribute electricity throughout the EV—from the battery to the motor and all the other systems that need power. They need to be reliable despite facing mechanical vibrations, temperature changes, and possible exposure to the elements.

**The Science Behind the Scenes:** Copper or aluminium conductors are often used, but we need to ensure that they stay connected under all conditions. Metallurgical testing focuses on stressed points like connector ends, where fatigue often starts. Fretting corrosion is a big issue - those tiny vibrations can wear down connectors over time. And when copper oxidizes, resistance goes up, which leads to hotspots, which leads to problems. Routine metallurgical assessments identify these issues early, allowing engineers to take steps to protect and prolong the life of these components.



Figure 5. Illustrates example of a crimped connector with cross-sectional and longitudinal views

## Why All This Matters for EV Reliability?

Every component we've talked about plays a role in making sure that an EV drivetrain operates efficiently and reliably. From the rotor and stator to the smallest connector, every piece must be carefully designed, meticulously tested, and continuously improved to withstand the unique stresses of electric vehicles—high torque, rapid thermal cycling, and heavy electrical loads.

Reliability in an EV isn't just about making sure the car runs today—it's about building a vehicle that continues to operate smoothly for years to come. Every grain boundary analysed, every micro-crack identified, and every weld inspected contributes to the overall robustness of the vehicle.

The future of transportation so far is electric and making that future reliable and robust depends heavily on materials science. Metallographic and metallurgical testing of drivetrain components isn't just a "nice-to-have" - it's what makes the dream of reliable, high-performance EVs a reality. So, the next time you slide into an EV and marvel at its seamless acceleration, remember the invisible army of metallurgists, engineers, and scientists who worked behind the scenes to make that smooth ride possible.

For further inquiries please contact us on [lab.eu@buehler.com](mailto:lab.eu@buehler.com) [lab.us@buehler.com](mailto:lab.us@buehler.com) or our website at [www.buehler.com](http://www.buehler.com) and for solutions applicable to automotive industry.



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