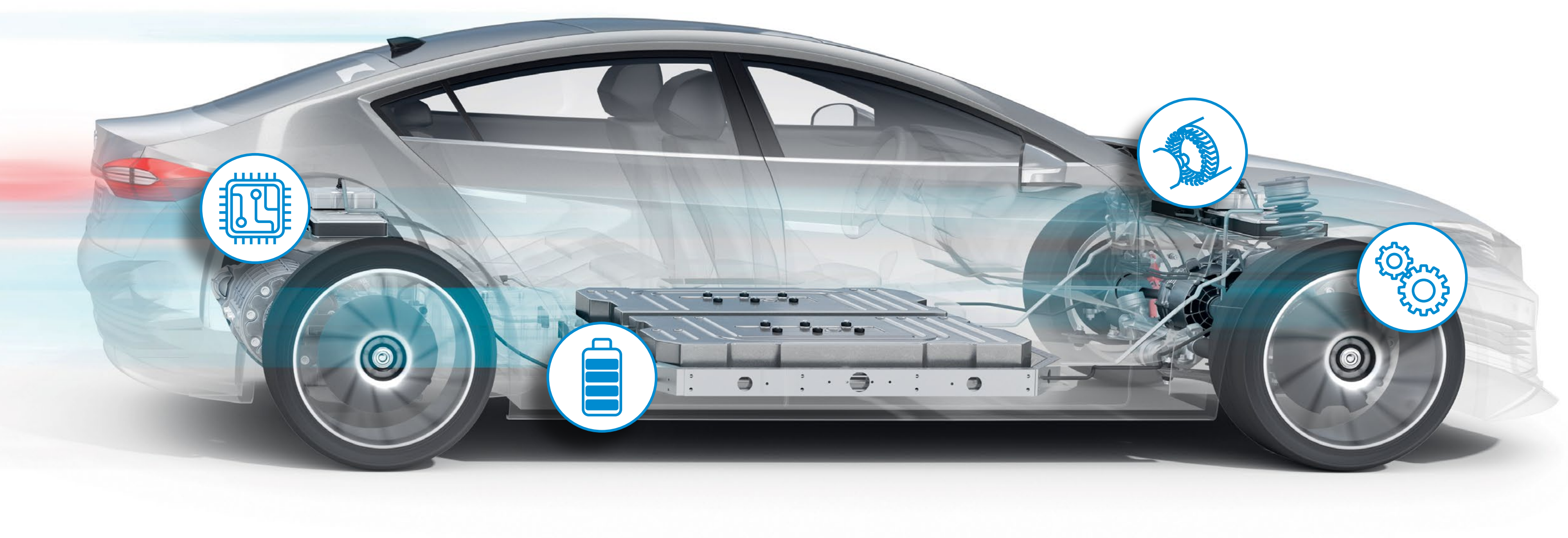
Seeing beyond

From Energy to eMotion — Electric Vehicle Inspection Overview

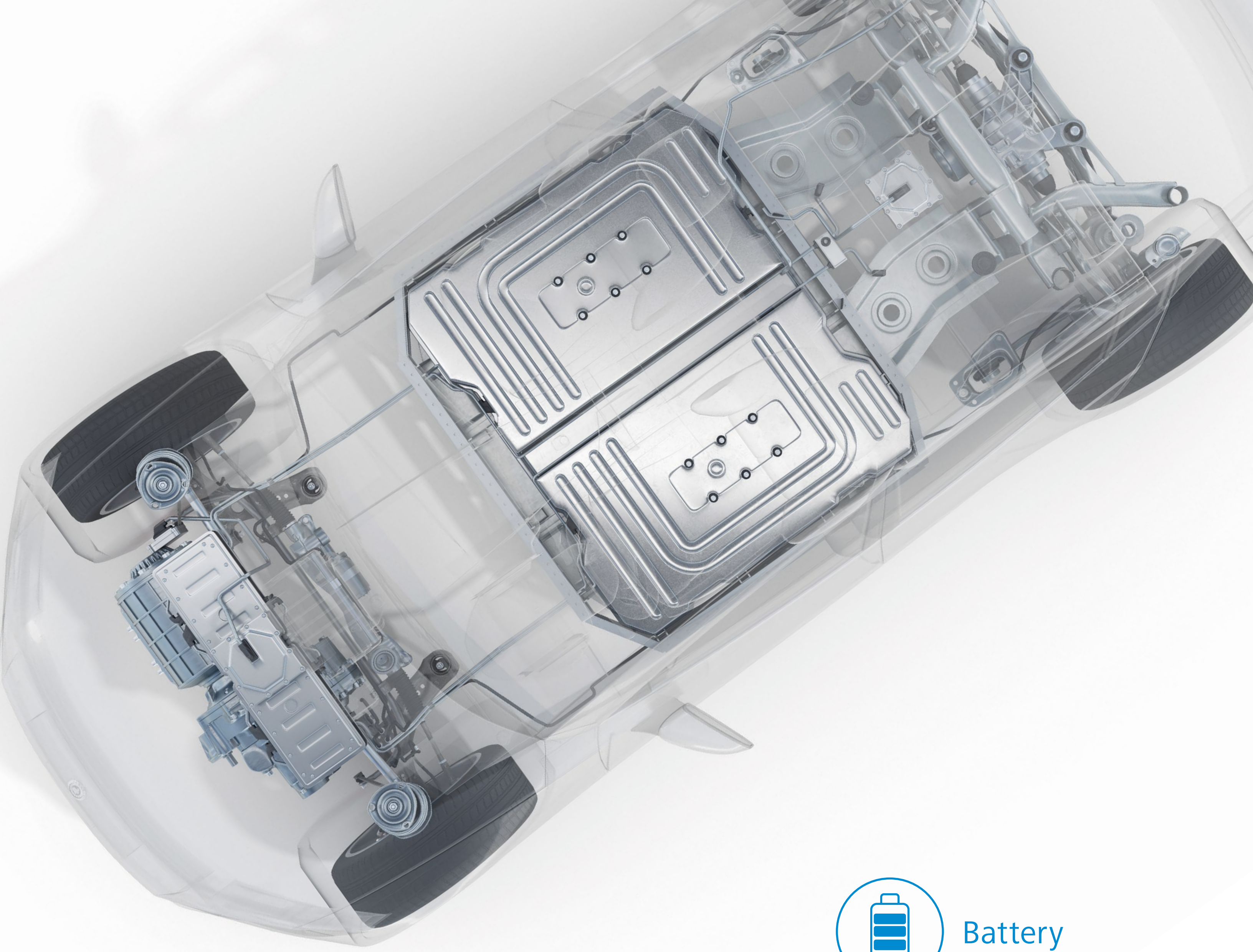
ZEISS eMobility Solutions



To the consumer, an electric vehicle (EV) may seem to have a lot in common with a vehicle powered by an internal combustion engine (ICE). Designing, manufacturing and assembling EV components is significantly more complex due to stringent demands for reliability, efficiency and safety. These demands must be met over wide temperature ranges under extreme driving conditions and in harsh operational environments. Therefore, the reduction of overall components — as compared to an ICE vehicle — is met with a significant increase in the number of quality assurance challenges.

For example, a combustion engine is made up of around 1,400 components, while an electric powertrain only consists of about 200. Those components, such as the electric motor with hairpins, stator, sheet stack and rotor, are often expected to multitask and are utilized in compact arrangements. They are a nesting doll of components to be measured, requiring precision to ensure optimal efficiency when completely assembled.

Unique, precision metrology solutions are needed to meet the challenges of EV manufacturing — present and future. And while there may not be a set standard for all the different inspection applications involved with EVs, there are several tried and true methods available to ensure quality throughout the production process.



Battery

Power Electronics

eMotor

Transmission

Quality Inspection of the Four Core Components of Electric Vehicles

Innovations in electric vehicle manufacturing are generating new measurement tasks and initiating a paradigm shift in quality inspection. EV manufacturers may have fewer components to worry about, but those parts require holistic quality inspection solutions ranging from tactile and optical measurements to X-ray microscopy. This starts with the four main components of eMobility: batteries, power electronics, electric motors and transmissions.

Battery

Electric vehicles currently on the market vary widely in terms of performance, range and longevity. The battery is critical to pushing these metrics to the limit. Manufacturers that understand, control and optimize the properties of the battery down to its individual components will be well-positioned as market leaders.

Electric vehicle batteries consist of five critical components that require quality inspection:

- Cells
- Electrodes
- Materials
- Battery Trays
- Battery Packs

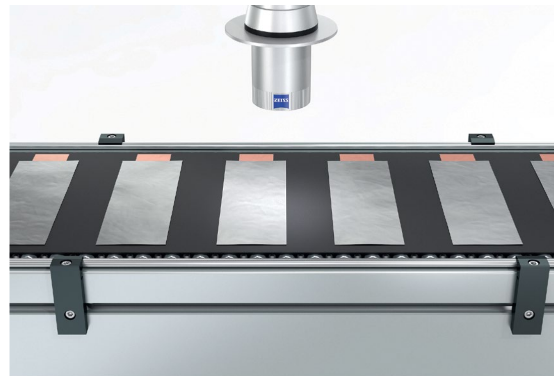
Cells: Battery cells are the main unit of the battery, which makes the stacking of battery sheets inside the cell critical, since misplacement can lead to short circuits. EV manufacturers must be capable of measuring the geometry of electrodes inline to produce cells with non-overlapping electrodes. A coordinate measuring machine (CMM) with an optical sensor is ideal for this process.

Electrodes: Due to the massive quantity of electrodes required to construct a complete battery pack, manufacturing lines cut and stack electrodes at rapid speeds. The geometry of the electrodes inside a cell is vital to the efficiency and safety of the cell. An optical multisensor CMM is essential to ensure quality throughout the cutting and stacking process. An efficient machine vision system can also assist in identifying surface defects, cleanliness and coating defects.

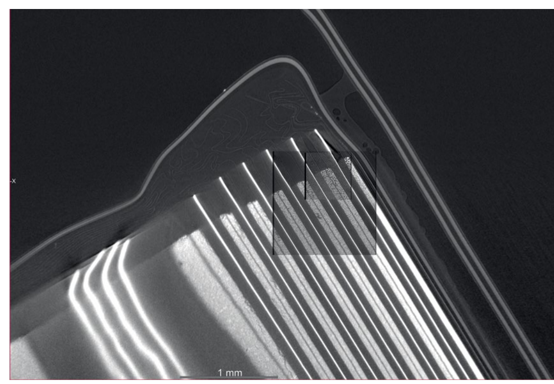
Materials: The raw materials of a battery are the lowest level of materials in the battery, and the energy density can make or break the efficiency of the battery when it comes to charging cycles. The materials also determine and dominate the cost of battery cells. Controlling the quality of battery cells can ensure that overhead costs remain low and efficiency remains high. Microscopy systems will give you the insights needed to overcome these challenges.

Battery Trays: The battery tray has a particular set of challenges because of the thermal expansion of the battery pack. Since the chassis interacts directly with the battery, the length, diameter and position of slots must be evaluated for tight tolerances prior to final assembly. Non-contact optical laser scanners can be a robust solution for 100% inspection of battery trays to efficiently collect and analyze measurement data.

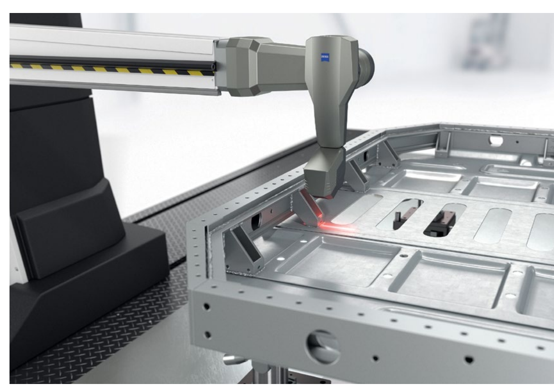
Battery Packs: Battery packs enclose the battery cells and are essential to the safety of the cells. Without proper enclosure, electrical shorting may occur, leading to thermal runaway and combustion — posing a hazard to end users. EV manufacturers can use traditional CMMs for quality inspection of these components.



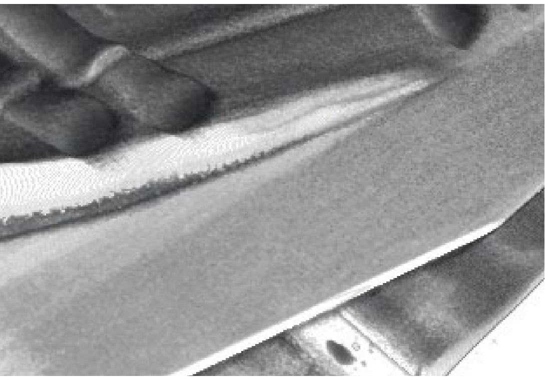
Electrode inline inspection with machine vision system



3D X-ray microscope tomography of a pouch cell



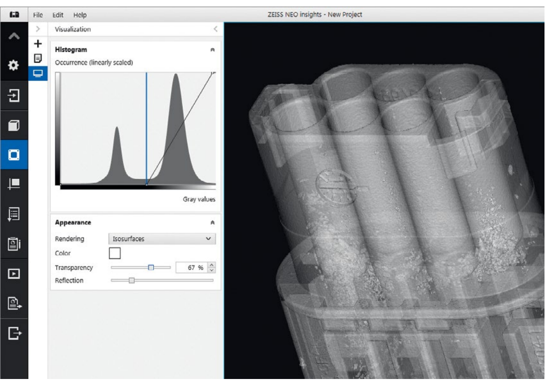
Non-contact laser scanning of a battery tray with a horizontal arm CMM



3D X-ray tomography of a power diode

Power Electronics

More so than any other component, the power electronics of EVs need to be able to withstand the harsh environmental conditions that they will inevitably face. Quality inspection can ensure an EV's power electronics are up to the challenge.



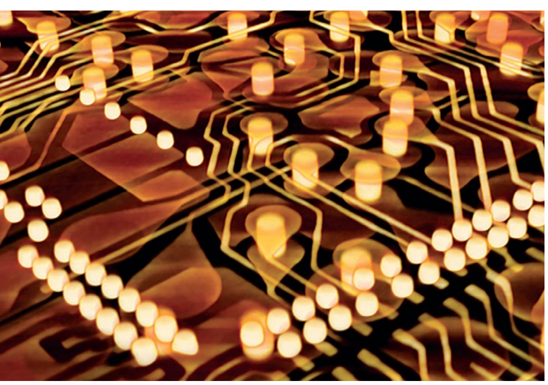
Connector X-ray data analysis

Electric vehicle power electronics consist of four critical components that require quality inspection:

- Housing
- Connectors
- Printed Circuit Boards
- Semiconductor

Housing: The housing plays an important part in the safety and reliability of the power electronics and the battery, as its encasement moderates vibration and temperature. It is critical to determine the reliable positioning of all encased components for peak performance, like connector plugs for optimal electrical charging contact. Traditional CMMs provide highly-accurate data when measuring these components to meet these types of tight tolerances.

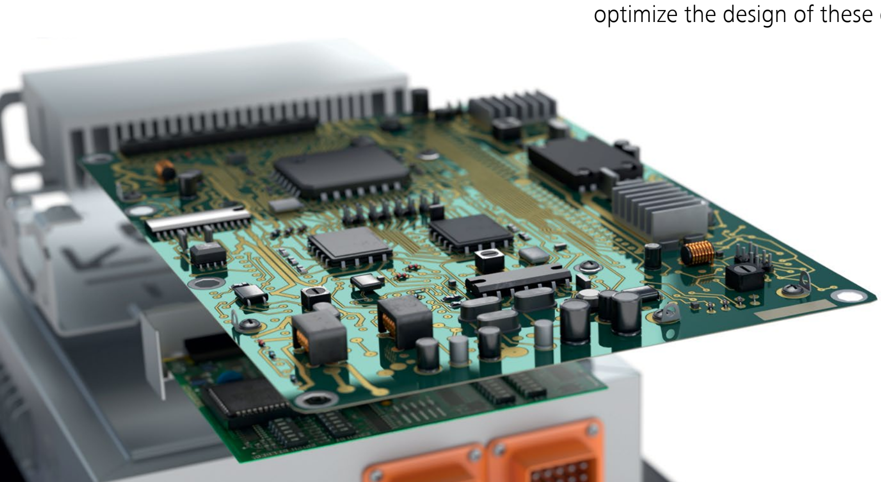
Connectors: Connectors ensure efficient and reliable distribution of electrical power within the EV. The small size of the pins inside the connector and the long and deep geometry present challenges for tactile or optical measuring technology. Fortunately, X-ray scanning technology can quickly visualize and detect defects that can impact these critical connections.

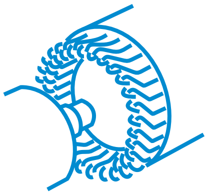


3D visualization of a PCB using X-ray microscopy

Printed Circuit Boards (PCBs): PCBs require small and tightly integrated components for use in harsh environments. As such, they can be susceptible to temperature fluctuations, vibrations and particle contamination. Non-destructive inspection methods, such as X-ray and optical inspection technology, collect thousands of data points allowing you to measure critical-to-quality elements and detect flaws such as cracks, inclusions and damage during production.

Semiconductor: The control of the driving experience in EVs is increasingly compact and integrated within the electronic control system of the vehicle. The semiconductor functions to transfer battery power in consistent quantities throughout the vehicle. Electron microscopy can identify costly manufacturing irregularities and map the electrical and material properties to optimize the design of these devices.





eMotor

Electric vehicles are not just differentiated by their electric power source, but also in the construction of the eMotor.

The eMotor is compact and light as compared to ICE powertrain components. At the same time, it must create an enormous amount of torque to power an EV. To accomplish this, all of its components must fit together precisely. While combustion engines consist of cylinder blocks, pistons, crankshafts and camshafts that at most must interact reliably, an eMotor calls for micrometer-level accuracy to provide the smooth, quiet riding experience commonly associated with EVs.

Electric vehicle eMotors consist of five critical components that require quality inspection:

- Stator
- Sheet Stack
- Rotor
- Shaft
- Hairpins

Stator: The stator and hairpins must have an exact fit within the grooves of the sheet stack for efficiency and reliability over the lifetime of the vehicle. Measuring these components requires an assessment of the dimensional accuracy and lacquer thickness. These can most easily be obtained through optical measurement tools such as 2D cameras, 3D laser scanners and confocal white light sensors.

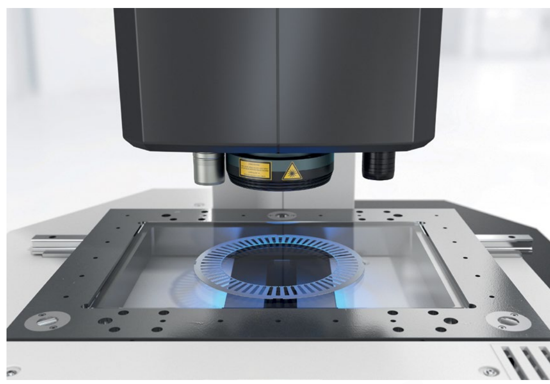
Hairpins: Current-carrying conductors within the stator of an eMotor are not wound from thin wires. They are bent from solid copper into hundreds of hairpins, which boosts efficiency. An automated CMM, equipped with a confocal white light or laser line scanning optical sensor, is one option to accurately measure the hairpin shape and lacquer while helping control the bending in real-time.

Sheet stack: Stack sheets are composed of multiple layers of single sheets, laser cut from electrical steel. The ultra-precise positioning of these sheets in order to welcome hairpins makes the task of measuring them laborious. These quality inspections are most efficiently and accurately obtained by multisensor CMMs equipped with 2D cameras and confocal white light sensors.

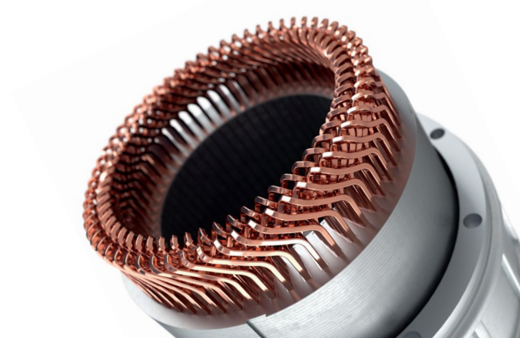
Rotor: Unlike combustion engine rotors, the rotors of EVs operate based on the intricate placement of permanent magnets to enable the high performance and speed of the eMotor. CMMs with long stylus extensions make it possible to measure the rotor with enough distance from the magnetic field to ensure accurate quality results.

Shaft: To meet necessary rotation speeds, the shaft has very tight form characteristics. These require quick quality inspections, especially in relation to shape and position tolerances. As shaft geometrics change and tolerances narrow to improve eMotor efficiencies, a versatile CMM can ensure quality while increasing throughput, even with manufacturing changes over time.

Hairpin measurement on a CMM with a confocal white light sensor



Single sheet inspection on a multisensor CMM



3D X-ray inspection of an eMotor housing

Gear measurement on a CMM with a rotary table

Transmission

While an EV's two-speed transmission and eMotor are contained within a single housing, the impact on noise reduction is minimal at best. This is due to the thin wall thickness of the transmission, a characteristic used to increase the range of the electric vehicle. The transmission is capable of speeds up to 20,000 rpm, which can cause a large amount of turbulence.

However, with precise mating of the components involved, turbulence can be reduced and the efficiency of the EV powertrain can be maintained. This can only be achieved by meeting highly demanding geometric tolerances and surface quality standards.

Electric vehicle transmissions consist of three critical components that require quality inspection:

- Housing
- Gear
- Shaft

Housing: The housing typically encloses both the electric motor and the gearbox. It must be light enough to minimize weight yet thick enough to neutralize noise. The quality of the casting can increase driving range, safety and cooling cycles of eMotors and transmissions. X-ray technology can detect variances in casted aluminum, while tactile scanning technology can provide quality assurance for the integration of the eMotor and transmission.

Gear: Gears of EVs have very tight tolerances that allow them to be virtually silent in comparison to combustion engines. High speeds and torque make dimensional accuracy and surface quality critical. A contact probing system equipped with a rotary table is the perfect solution for gear metrology.

Shaft: As part of the gear system, the shaft must fit the tight tolerances to reduce noise and drive harshness at revolution speeds of up to 20,000 rpm. All deviations in shape, size and location as well as surface irregularities can be identified with tactile measuring technology.

ZEISS — the One-Stop Shop for EV Quality and Production Control

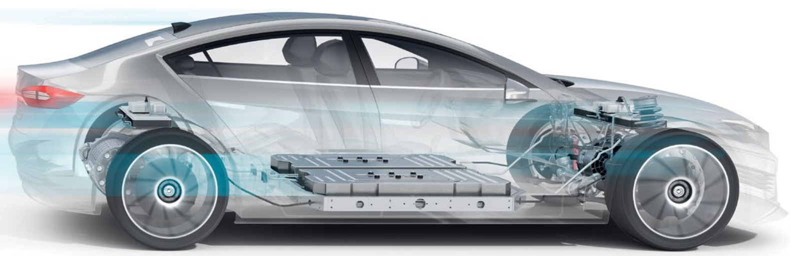
EV manufacturers are facing increasing precision requirements in e-mobility and need multiple advanced technologies for quality assurance to ensure the reliability, efficiency and safety of their vehicles.

ZEISS experts work hands-on with your team to help you anticipate which characteristics are critical to success and which technologies are most effective in evaluating them. ZEISS Application Engineers are uniquely positioned to assist your team with your EV component manufacturing challenges. They help you develop the right combination of technologies and metrology equipment that is uniquely tailored to your needs.

From optical to tactile to X-ray image-processing technologies, ZEISS Industrial Quality Solutions offers a diverse portfolio that will leave you well-equipped to handle any measurement challenge — regardless of the e-mobility application.

Contact us for a demo of
ZEISS eMobility Solutions —
From energy to eMotion.

Request A Demo



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