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Engineering IK10-Compliant Charging Station Housings

A Design-Driven Approach Using Advanced Materials and FEA Validation

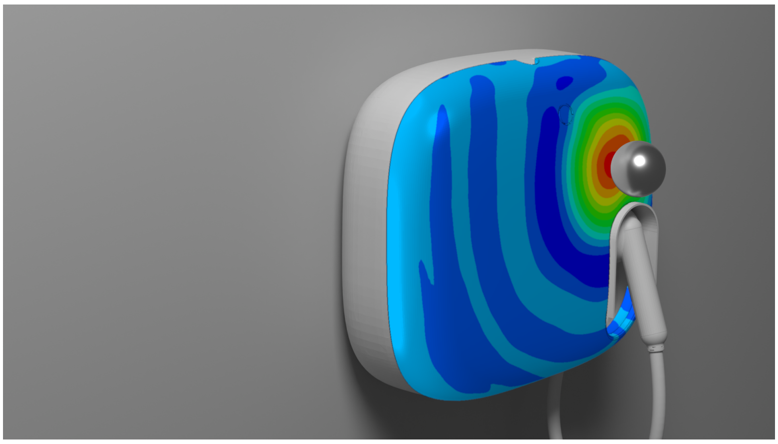

Figure 1: Simulation of IK impact testing for charging station housings

Abstract

Charging stations must withstand various physical impacts throughout their service life, from accidental bumps to vandalism attempts. The IK (Impact Protection) rating system, defined by IEC 62262, provides a standardized method to evaluate the robustness of electrical enclosures against mechanical impacts.

Charging station housings typically require impact protection ratings from IK08 to IK10, with IK10 being the highest common standard, predominantly in North American markets. For IK10 certification, a 5kg steel striker drops from 400mm height, delivering an impact energy of 20 Joules. Makrolon® grades excel in these scenarios due to their high ductility and energy absorption capabilities. While IK testing is standardized at room temperature, Makrolon® demonstrates good low-temperature impact resistance with standard grades, while specialized versions offer enhanced low-temperature ductility.

Housing designs with conventional wall thicknesses of 3-4mm typically undergo short-term deformations of 10-15mm in IK10 test conditions without compromising integrity. This controlled deformation advantageously uses the material's ability to absorb energy rather than creating rigid structures that might crack under impact. This inherent capability often eliminates the need for extensive ribbing, thereby avoiding potential optical defects on visible housing surfaces.

Things to consider

- IK10 testing (20 Joules) is standard for public charging stations, requiring designs to withstand impacts from a 5kg steel striker dropped from 400mm height
- Makrolon®'s ductility enables beneficial temporary deformation (10-15mm) during impact, absorbing energy without permanent damage - a preferable approach to rigid designs prone to cracking
- Standard wall thickness of 3-4mm typically provides sufficient impact resistance without extensive internal ribbing, simplifying design and reducing visual defects
- Strategic internal feature placement and FEA simulation help avoid stress concentration points and validate impact performance before physical testing

Introduction

The rapid expansion of electric vehicle infrastructure has created unprecedented demands for durable, vandal-resistant charging station housings. Public charging stations face unique challenges: they must operate reliably in rather uncontrolled environments while maintaining aesthetic appeal and functional integrity over extended service lives.

The IK rating system (IEC 62262) quantifies impact resistance, with IK10 representing the highest common classification for electrical enclosures. This documentation focuses on part design strategies to achieve IK10 compliance, as lower classifications present minimal design challenges and can be addressed through conventional approaches.

Advanced polycarbonate materials, particularly Makrolon® grades, have emerged as the preferred solution for IK10 applications due to their exceptional ductility and energy absorption capabilities. Unlike brittle materials that fail catastrophically under impact, these thermoplastics enable controlled deformation strategies that absorb impact energy while maintaining structural integrity. This material advantage, combined with finite element analysis validation, allows engineers to optimize designs for both performance and manufacturing efficiency.

IK Testing Requirements

Parameter	**IK08**	**IK09**	**IK10**
Impact Energy (Joule)	5	10	20
Impact Mass (kg)	1.7	5	5
Drop Height (mm)	300	200	400
Striker Radius (mm)	25	50	50

Table 1: IK classes according to IEC 62262

Table 1 provides a comparison of the most relevant IK classifications for charging station applications, highlighting the significant energy increase from IK08 to IK10 that drives the need for advanced design approaches.

IK10 is predominantly specified in North American markets where vandalism resistance is paramount. The standard mandates that enclosures withstand a 20 Joules impact from a 5 kg steel striker dropped from 400 mm height. Testing occurs at room temperature, though many specifications require validation under low-temperature conditions where Makrolon® maintains reliable performance even at significantly sub-zero temperatures. However, the material's temperature-dependent mechanical properties necessitate careful consideration during both selection and design phases, with specialized low-temperature variants available for extreme climate installations.

Part Design for Impact Protection

Successful housing design optimizes wall thickness distribution to achieve both structural integrity and impact absorption. The fundamental design strategy **Design For Ductility** should embrace controlled material deformation rather than trying to prevent it entirely. Excessive ribbing should be avoided as it:

- Requires additional installation space
- Cannot effectively prevent deformation in IK10 tests
- Increases risk of sink marks
- May reduce ductility of the material if rib bases are not properly rounded

Material Selection

Makrolon® polycarbonate grades offer unique advantages for IK10 applications through their dual-phase mechanical behavior. In the elastic region, they provide high stiffness and strength, typically withstanding loads up to yield stress without permanent deformation. This enables the material to return to its original state even after substantial impacts below the yield threshold.

When impact loads exceed yield stress, Makrolon® transitions into controlled plastic deformation with exceptional ductility. This post-yield behavior is crucial for IK10 applications, as it allows systematic energy dissipation through material deformation rather than catastrophic failure. The combination of elastic recovery and controlled plastic flow makes polycarbonate ideal for repeated impact scenarios typical in public charging infrastructure.

However, polycarbonate can undergo **ductile-to-brittle** transition under certain stress states, particularly in the presence of sharp notches, stress concentrators, or multiaxial loading conditions. This sensitivity emphasizes the importance of careful design to avoid stress concentration points and maintain favorable stress distributions during impact events.

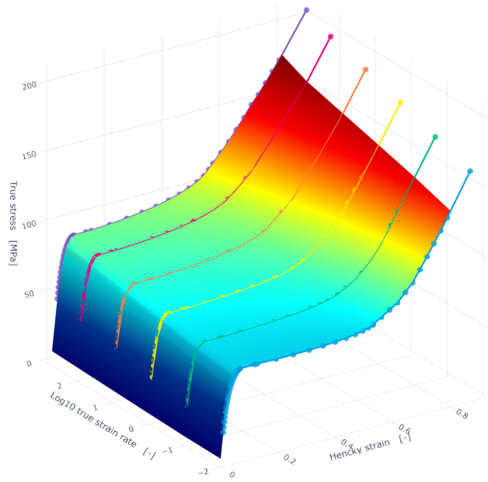

Figure 2: Rate-dependent true stress/strain data of Makrolon® 6487

Key performance characteristics include:

- Strain rate sensitivity: Impact loading (strain rates up to $10^4\,\mathrm{s}^{-1}$) significantly increases yield strength compared to quasi-static conditions, while strain at failure remains nearly constant (Figure 2)
- Temperature stability: Maintains ductility across operational temperature ranges ($-40°C$ to $+120°C$)
- Fatigue resistance: Repeated impact loading shows minimal degradation in energy absorption capacity

Design Philosophy: Design For Ductility

Successful IK10 housing design requires abandoning traditional "rigid protection" approaches in favor of controlled energy absorption strategies. The optimal design allows 10-15mm temporary deformation during impact while ensuring complete elastic recovery and maintaining all functional requirements. This philosophy manifests in several design principles:

- Wall Thickness Optimization: Base wall thickness of 3-4mm provides optimal balance between material efficiency and impact performance.
- Stress Flow Management: Internal features like screw bosses must guide stress distribution rather than create concentration points. Smooth transitions with minimum 0.5mm radii eliminate sharp stress risers that could initiate the transition to brittle failure behavior.

- Strategic Deformation Zones: Designated areas designed to absorb maximum energy through controlled plastic deformation, protecting critical regions through intelligent load redistribution.

FEA-Driven Design Validation

Finite Element Analysis using explicit dynamics solvers provides essential validation for IK10 designs before physical prototyping. The simulation approach requires careful attention to material modeling and time integration parameters to accurately predict impact behavior.

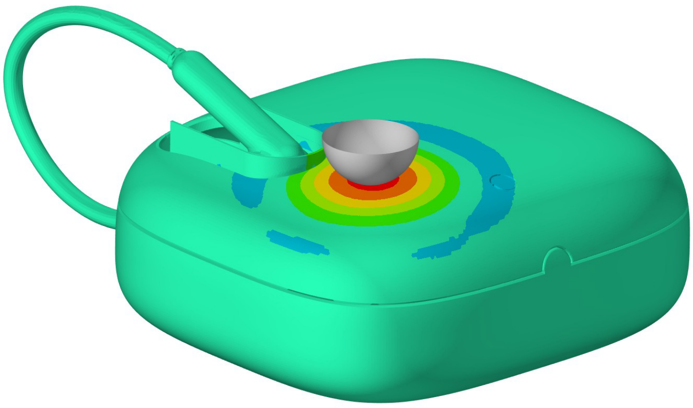

Figure 3: FEA - Deformation plot at maximum intrusion

Through FEA, engineers can rapidly iterate design concepts, optimize wall thickness distribution, and validate feature placement before expensive tooling commitments. Figure 3 illustrates the displacement field during maximum intrusion, demonstrating the controlled deformation behavior that enables effective energy absorption. Parametric studies reveal optimal configurations that minimize material usage while exceeding IK10 requirements, ultimately reducing development time and costs.

For complex applications and strategic projects, Covestro offers specialized simulation support, including validated material cards calibrated for impact simulation and technical consultation services. This expertise ensures accurate material property representation in FEA models, leading to reliable design predictions and optimized material selection.

Key simulation considerations include:

- Material modeling: Strain-rate dependent properties and failure criteria
- Time integration: Explicit solvers with appropriate time step control
- Mesh refinement: Adequate resolution in critical impact zones

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