# Development of a methodology and tools for tolerances in vehicle electrification to meet future customer demand and ensure competitive advantage

## EnginSoft and Metasystem develop design validation, verification methodology for high-performance on-board chargers for electric vehicles

**By Enrico Boesso[1], Gabriele Codeluppi[2]**
1. EnginSoft - 2. Metasystem

Globally, the automotive industry is striving to reduce $CO_2$ emissions to meet increasingly stringent environmental protection standards. Car manufacturers are intensifying their research and development of hybrid and electric motors. These products require highly reliable, efficient subsystems to manage their electrical energy. The on-board charger (OBC) is one of the key components in the energy efficiency of these vehicles.

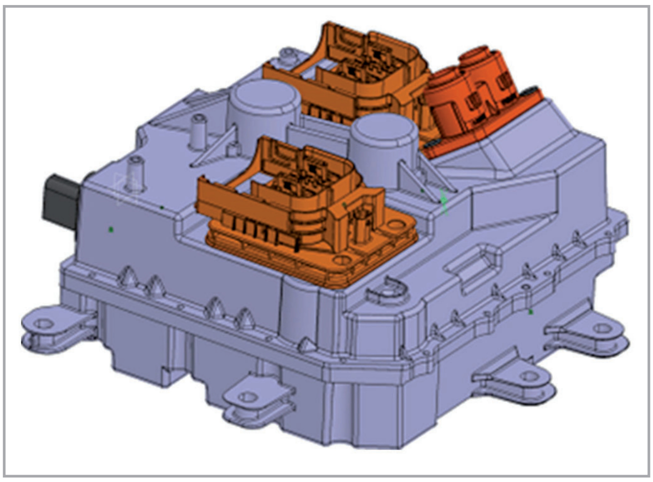
The OBC is a compact battery charger for electric vehicles that converts the alternate voltage supplied by the mains into the direct voltage used to charge the vehicle's high traction voltage battery. OBC Metasystems are products that take into account weight, costs, space, power density and efficiency and which must apply international standards and meet the functional safety requirements of ISO26262.

### Electro-mechanical integration and the role of tolerances in the product requirements

A complex product such as an OBC must meet various requirements, some relating to the mechanics involved and others to the electro-mechanical integration. These are explicitly requested by the customer who also requires visible compliance during the entire product development cycle.

To obtain high levels of efficiency, the weight and dimensions must be kept within pre-established limits. For the product, this leads to a high-density placement of electronic components inside and adjacent to the conductive structural elements, such as the aluminum housing, which dramatically increases the risk of discharges, short circuits, bridges, air creepage, etc. This can cause malfunctions, higher risk of fire, and lower efficiency which compromise the reliability of the system. To prevent these repercussions, designers identify, isolate and shield the areas at greatest risk, an approach known as the "insulation concept".

For the manufacturer, this demand for reduced dimensions increases the risk of interference during assembly which can cause an automatic assembly line to shut down, leading to loss of productivity,



supply delays and higher production costs. Furthermore, automotive manufacturing customers are placing increasing attention on any aspects that do not directly affect the final quality of the product supplied because wastage and reworking waste energy, increasing the car manufacturer's ecological footprint.

Tolerances play a fundamental role in meeting both these sets of requirements. However, as a direct consequence of their small size and the amplifying effects typical of the propagation of tolerances, component manufacturers cannot limit the verification of these requirements only to the design rating.

## The methodology developed

In complex products such as an OBC, the tolerances assigned to the individual parts propagate through the contacts and are amplified which can potentially impact heavily on the final product quality. It is, therefore, important to validate the design in advance and then verify it to pre-emptively predict their impact and mitigate the effects.

The term "design validation" in this context thus referred to the calculations of the propagation of tolerances created during the design phase to predict whether and how much the tolerances would affect the ability to meet the product requirements, prior to prototyping the first components. Armed with this information, the designers can intervene with corrective actions to improve the quality of the final product.

By nature, these calculations are complex and three-dimensional and require the use of dedicated software to obtain reliable results in a reasonable amount of time for industry. For these reasons, EnginSoft uses Cetol 6σ, developed by US-based Sigmetrix, to undertake these projects.

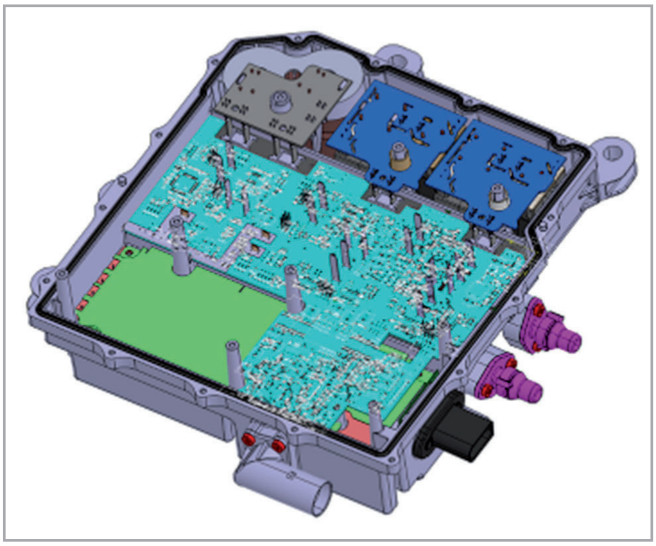
A further consideration that should not be underestimated is the geometric specification of the products: in recent years, the standards ISO 1101:2017, ISO 8015:2011, and ASME Y14.5-2018, which describe the geometric and dimensional variability of the tolerances represented in technical drawings, have been updated. The resulting geometric dimensioning and tolerancing (GD&T) language makes it possible to functionally describe components unambiguously. This is fundamental for tolerance propagation calculations that quantify quality because it enables the generation of unquestionable results. The use of this language is therefore integral to the methodology.

During "design verification", the real measurements of the prototype parts, produced from the models created during the "design validation" phase, were inserted into the software for the purposes of data reusability. This phase will enable designers to verify virtually (and therefore immediately), the impact of any aspect that is "out of tolerance" and quantify its effect on final quality. This will then enable informed decisions to be made about any corrective actions to be taken to avoid contestation of the supply by the customer.

The success of this phase is determined by the dimensional controls. In particular, the measurements must be taken in accordance with the project specifications. The use of the GD&T's standardized and unambiguous syntax also facilitates this, resulting in dimensional and geometric descriptions that are, by nature, suitable for evaluation with particular tools such as coordinate measuring machines (CMM), 3D optical scanners, or laser systems that accurately describe the surfaces by generating point clouds. Instrumentation then acquires these point clouds which are processed by the software, allowing the designer to "align" the scan of the actual part with its ideal model (a 3D CAD) to assess its compliance with the design tolerances.

## Results and conclusions

By applying the method developed and using the tools proposed, Metasystem was able to demonstrate the "robustness" of the project (defined as the low sensitivity of the requirements to the geometric and dimensional variations granted by the tolerances) to the customer and to fulfil all the requirements described.



This was achieved by interventions at the design phase, by making minor modifications to the nominal CAD geometries, and by working with the tolerances using GD&T standards-compliant dimensioning drawings.

The ultimate aim of the design validation phase is to table designs that, if respected, will guarantee the desired quality of the assembled product at the lowest possible cost based on the capability of the available production process.

It is highly likely that other customers will approach Metasystem with similar OBC design requirements, which would necessitate the repetition of these activities and calculations. Consequently, the consolidation of the methodology and the acquisition of suitable verification tools can be considered a competitive advantage for Metasystem: the project has allowed the company to acquire the know-how to satisfy future customer requests on the one hand, and to create projects that are as profitable as possible in terms of waste minimization, on the other hand.

For more information
Enrico Boesso - EnginSoft
e.boesso@enginsoft.com