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Navigating the Evolving Landscape of EV Battery Pack Design

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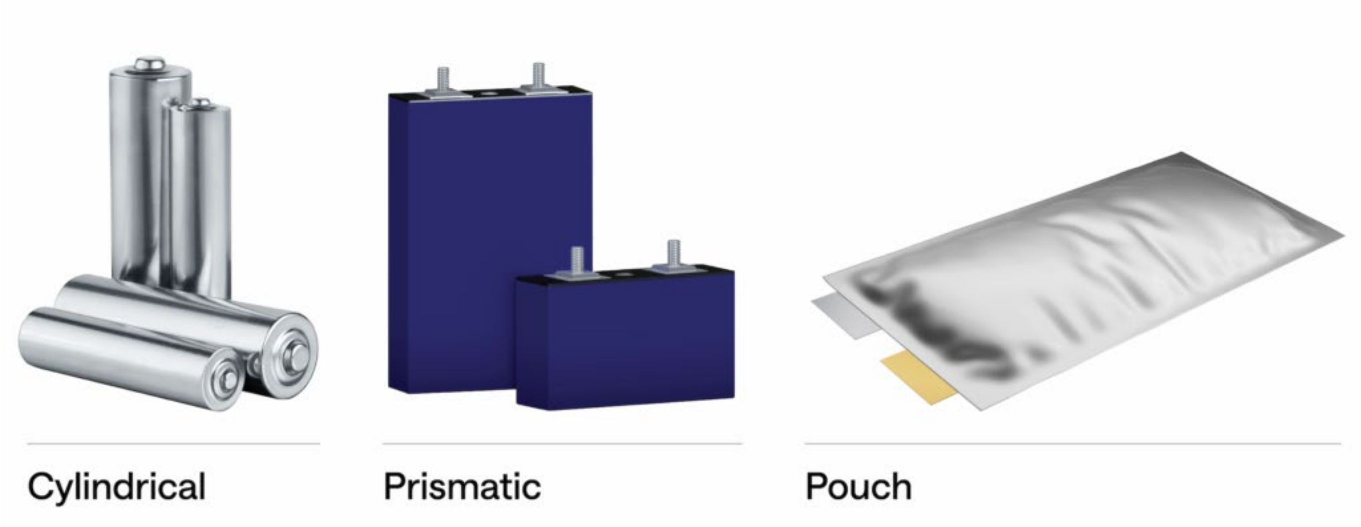

Figure 1. The electric vehicle (EV) industry is constantly advancing - with manufacturers continuously exploring innovative battery designs to increase energy density for better range, optimise space utilisation and reduce overall battery cost (which currently accounts for around 30% of the total cost of a car, according to Statista's estimations).

The following article looks at the dynamics influencing EV battery design, with a particular focus being placed on the transition from modular to cell-to-pack (CTP) configurations.
As of now, there is yet to be a predominant trend among original equipment manufacturers (OEMs) when it comes to CTP adoption or the uptake of cell-to-chassis (CTC) designs. Some OEMs adhere to traditional modular architectures, incorporating 16 or 32 modules within a pack. In contrast, others are moving away from the modular approach, gravitating towards CTP by reducing the number of constituent modules. Notably, certain OEM designs from China have recently fully embraced CTP.

Drawing comparisons between modular and CTP designs reveals a substantial increase in current density with CTP - a critical factor in enhancing overall EV performance. Of the 3 prevalent battery cell designs - namely prismatic, pouch and cylindrical - prismatic cells (mainly favoured in Far East) lag behind pouch ones in terms of current density. This difference has

driven Chinese OEMs towards adopting CTP designs - enabling them to remove the modular side walls, thus increasing energy density and shedding significant weight.
Despite the potential advantages of CTP, designs using the pouch format are yet to surface. The practical challenges of welding multiple pouches together have tied OEMs to the modular architecture. However, pouch designs are progressing, becoming larger and longer. In the cylindrical format, the inherent dead space between cells in CTP designs can be eliminated by using hexagon-shaped cells instead.

Innovations in battery interconnects

Initial current collector assembly (CCA) designs had a 1.2m span. Over time, such CCAs have been extended to 2.5m, exceeding the length of a typical car chassis. However, with increases in CCA length, maintaining precision and tolerance has become more challenging. The use of advanced stamping capabilities will mean that accuracy can still be assured - allowing seamless placement on top of thousands of cylindrical cells and facilitating welding without complications. A clip-on design for replacing welding has been conceptualised. This would align with the envisioned transition towards wireless battery management system (BMS) implementations.

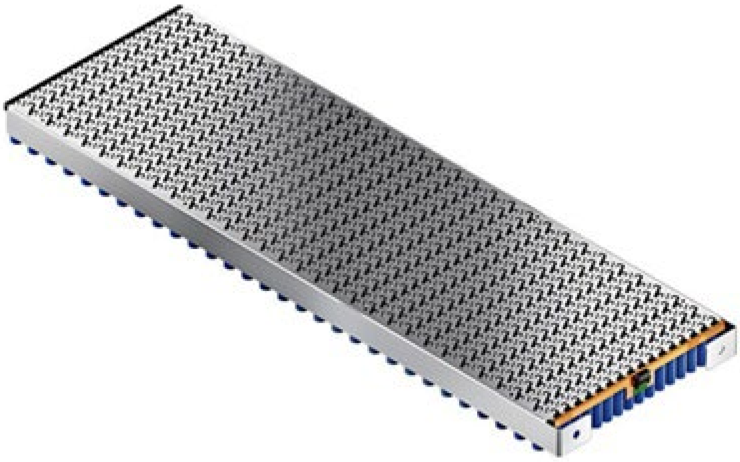

Figure 2. A 2.5m long CCA with ENNOVI's patented U-Turn arrangement for even current distribution

By equipping each cell with a wireless chip, OEMs can access granular charging data for predictive maintenance purposes. Unlike current welded battery connect technologies in modular and CTP designs, which necessitate destructive processes for cell replacement, clip-on interconnects would offer single-cell serviceability. This approach would enable OEMs to replace individual cells rather than entire battery packs, significantly reducing the associated costs - from as much as £15K for a battery pack to just £150 for a single cell replacement.
ENNOVI's recently introduced flexible die cut (FDC) capability complements the creation of longer CCAs. In contrast to the traditionally used flexible printed circuits (FPCs) in CCAs (which have a size limitation of 600mm x 600mm), FDC boasts the advantage of no length restrictions - as it can be manufactured reel-to-reel. Additionally, the die-cutting process allows for instant recycling of copper waste - a more sustainable practice in preference to chemical etching the copper traces, which takes a lot of energy to extract the copper from the chemicals.

By combining state-of-the-art stamping capabilities with FDC design, it is possible to provide CTP and CTC support to OEMs seeking to transition from the modular approach. Considering certain design restrictions of FDC - opting for 4 very long FDCs instead of 4 FPCs, for instance - could yield a cost benefit of 25%.

Challenges and considerations in transitioning to CTC

CTC represents the next evolution beyond CTP. Transitioning from a modular battery design to a CTC one involves the chassis itself protecting the battery cell - a matter of paramount safety. However, challenges arise in strengthening the chassis structure to prevent cells from bursting or combustion of cells occurring during a vehicle impact. Material considerations are crucial for OEMs contemplating a shift to CTC, in order to safeguard cells in such scenarios. For some CTP designs, switching from aluminium to stainless steel cans enhances structural integrity. However, this adds to the expense involved and the overall weight too.

From a production efficiency standpoint, considerations vary. CTP designs allow for offline pack production, meaning separate production lines for batteries and chassis. Conversely, CTC design necessitates finishing the chassis before integrating cells. Placing thousands of cells into a chassis individually poses production throughput concerns, especially for OEMs aiming to roll out an EV every 5 minutes.

Figure 3. ENNOVI's FDC technology integrated within a prismatic battery interconnect system

Transition from CTP to CTC is anticipated to be a gradual process, due to the inherent pros and cons - necessitating careful calculations of additional costs, strength considerations, plus the impact on the overall vehicle range.

Coexistence of different designs

While the decision to transition from modules to CTP might be comparatively straightforward, due to substantial weight reductions derived, the move is not without complexities. OEMs invested in production lines designed for smaller modules might face challenges when shifting to 2m-long modules, necessitating additional investments in manufacturing equipment.
The coexistence of modular, CTP and CTC designs alongside one another seems likely, with emerging entrants into the new energy vehicle (NEV) market more inclined towards CTP or

CTC designs. Newcomers are able to benefit from the absence of pre-existing production lines and equipment, offering greater flexibility when choosing their battery design approach.

With fewer components in EVs compared to traditional internal combustion engine (ICE) vehicles, the barrier to entry has lowered. Each essentially comprising a chassis, a battery and 4 electric motors, EVs eliminate the need for a gearbox and other mechanical elements, thus simplifying manufacturing. As a result, any entity with adequate funding and design capabilities can venture into producing affordable EVs with respectable ranges.

Autonomous driving and commercial adoption

In the realm of autonomous driving, commercial adoption is deemed more probable than personal use. The idea of relinquishing control to a self-driving vehicle can be difficult for consumers. Manufacturers focusing on fully autonomous operation are likely to be looking at incorporating such technology into commercial vehicles (e.g. trucks and robotaxis). The removal of human involvement or catering to consumers who lack driving skills forms an alternative strategic aspect of autonomous vehicle deployment. For instance, battery producers are introducing skateboard platforms, fully equipped for self-driving capabilities. These platforms will allow newcomers to the NEV market to concentrate on aesthetic design, infotainment systems and overall vehicle shape, streamlining the production process and reducing cost, so that the vehicle model appeals to consumers. This strategy aligns with traditional approaches from the ICE era, where manufacturers differentiated themselves through engine design and performance.

Differing strategies in battery technology

Within the EV space, divergent strategies are being employed by incumbent OEMs and emerging NEVs. Differentiating factors extend beyond the electric motor, as that technology is fairly mature. Instead, the emphasis is on the battery technology, encompassing current density and consumer-centric aspects like charging time and range. While some explore battery swapping strategies, others transition from 400V to 800V battery packs to increase charging speeds. Despite these endeavours, the desired 10min charging time benchmark remains elusive.

Figure 4. Larger cell groupings demand larger, robust CCAs with increased functionality

A future perspective

In conclusion, the EV battery pack design landscape is fluid. The migration from modular to CTP or CTC implementations reflects the industry's relentless pursuit of enhanced performance, increased energy density and efficient space utilisation. Coexistence of modular, CTP and CTC designs allows flexibility for OEMs, with new entrants leaning towards CTP or CTC for production efficiency. ENNOVI's innovations in battery interconnect designs, including the development of CCA and FDC, signify considerable strides toward cost-effective, sustainable, and serviceable battery architectures. As the industry contemplates transitioning from CTP to CTC, safety considerations, production efficiency challenges and material choices will all play pivotal roles in shaping the future of EV battery designs.

While the industry grapples with diverse strategies in battery technology, the focus remains on delivering affordable EVs with impressive ranges, shorter charging times and advanced driver assistance system (ADAS) features. As the automotive sector welcomes new entrants, the decisions made in relation to EV battery architectures will have huge bearing on the progression of sustainable transportation.

About the Author

Randy Tan is the Product Director at ENNOVI (formerly known as Interplex), a provider of interconnect solutions. He has over a decade of experience in the electrical and electronic manufacturing industry.
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