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Implementing Better Busbar Construction for Next Generation Vehicles

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The emergence of electric vehicles (EVs) is bringing about a transformation within the automotive landscape. Many of the largest car manufacturers have announced plans to have completed their migration to solely EV-centric production by the start of the next decade. Widespread vehicle electrification will have clear environmental plus points (such as dramatically reducing air pollution), but what are the implications of this from an interconnect perspective?

While for gas-run cars it was generally specifications like acceleration and horsepower that set particular models apart from one another, with EVs it is now the powertrain/battery where the real focus on differentiation is being placed. Moving forwards, the attributes proving of most value are going to be:

1. Making EV powertrains as efficient as possible.
2. Keeping down the overall weight of all the constituent hardware.

Both of these will allow EVs to cover greater mileage before they need to be recharged. The upshot of this is that the ‘range anxiety’ concerns that still currently put some people off buying EVs can be alleviated, and unit shipments will ramp up.

In order to raise EV efficiency levels, automobile makers and their tier 1 suppliers are implementing heightened powertrain voltages. The 400V previously used is in the process of being superseded by 800V systems - featuring high performance power components based on gallium nitride (GaN) and silicon carbide (SiC) technologies. The result is that more effective high-density systems with minimal power losses can be realized. These systems are also helping to achieve the desired weight reductions too.

With more compact and lightweight elements being incorporated into EV powertrains (including the inverters, on-board chargers, batteries and traction motors) the way in which electrical interconnection is approached needs to change. Automobile manufacturers are looking to replace conventional wiring arrangements in favor of the latest busbar options.

Advantages that busbars offer

Through use of busbars, rather than conventional wiring, it is possible for electrical performance parameters to be significantly augmented. In addition to this, assembly procedures can be significantly simplified. For example, cable dimensions alter (due to bending), but busbars have fixed dimensions. Things like this are highly beneficial when it comes to automated assembly -

resulting in increased production output and greater profitability for vehicle manufacturers. Busbars also offer greater power capacity and heat dissipation compared to traditional wires/cabling.

Selecting the right busbar materials

Busbars will usually feature either copper or aluminum conductors. If there are likely to be elevated temperatures and space constraints involved, then the attributes that copper possesses will usually make it the preferred choice. Copper conductors have greater conductivity, so they can be physically smaller. Their superior thermal characteristics mean they are better able to dissipate heat. Where system weight reduction and curbing bill-of-materials costs are the prime objectives, use of aluminum conductors will be advisable. This is a much lower density material, leading to conductors based on it being approximately 50% lighter than their copper counterparts. It should be noted that it is also substantially cheaper.

Numerous different fill materials can be employed for busbar isolation purposes - such as polyphenylene sulfide (PPS), polyethylene terephthalate (PET), polybutylene terephthalate (PBT) and polyphthalamide (PPA). In situations where high currents need to be dealt with, the insulation that PPS can achieve will prove preferential. If high voltages are going to be present, then PPA will usually be utilized (because of its greater dielectric breakdown value).

Another key consideration is coefficient of thermal expansion (CTE) variation between the different materials being incorporated into busbar designs. If there are mismatches, then contraction/expansion stresses will occur within the busbar assembly as the temperature fluctuates. Selecting materials with similar CTE values will mean that such stresses are mitigated and the longevity of the busbar assembly increased.

Changes to the market pricing of materials, particularly the conductor metals utilized, can impact on the overall busbar costs, but this is unavoidable. Though wanting to minimize the cost of other elements (like the fill materials) is understandable, it must be appreciated that selecting cheaper options can result in shortened operational lifespan, and the expense of having to replace busbar components earlier. This is why making judgements from a total cost of ownership (TCO) standpoint is going to be a much better strategy.

Mechanical considerations

Automotive application environments are uncompromising. Temperature cycling can cause the formation of oxidation layers on busbars' aluminum and copper conductors. These oxidation layers will increase resistance and this will impinge on interconnect performance. It may cut the working life too. The application of tin, nickel or silver to a copper conductor surface allows oxidation effects to be lessened.

Next, there is addressing the effect of vibrational forces. Exposure to ongoing vibrations can impact on the long-term functional integrity of interconnects. This is why the stress relief aspect cannot be overlooked. Flexible busbars can often be the most suitable way of solving the problem. These comprise thin high-conductivity copper foil lamels that have been bonded together at the mounting areas through molecular diffusion welding. The lamels are able to slide against each other - so that the connection is sustained regardless of exposure to even very intense vibrations.

Figure 1. Flexible busbars consist of multiple lamels bonded together at their ends

To facilitate assembly procedures, and avoid the prospect of production hold-ups, it is also essential that acceptable tolerances are incorporated into busbar designs. This will give automated equipment enough operational flexibility when assembly activities are being conducted.

Attaining adequate insulation

The need to incorporate coatings and materials with high dielectric strengths and a strong comparative tracking index (CTI) values must be accompanied by resilience to extreme temperature levels. Under some circumstances, a busbar's internal temperature may exceed the surrounding ambient temperature. This can consequently cause issues in relation to the dielectrics in direct contact with the busbar conductors. Polyester coatings may show themselves to be applicable here.

Having good creepage and clearance values is vital, to make certain that safe operation is maintained. This is becoming even more important since the voltages supported are rising and busbar assemblies are becoming smaller. By adding supplementary layers of insulation foil into the assembly, creepage/clearance distances may be extended.

With busbar implementations needing to take up less space, there are also technical challenges in relation to their attachment. As busbars are being subject to acute space restrictions, the bolting, welding, or clamping of connections to them is becoming impractical. Soldering is not a viable route either - since it means another manufacturing stage needs to be added. This will take up precious time, complicate what are otherwise fully-automated workflows with unwanted manual involvement and lead to potential errors occurring. On top of this, components within the sub-system will have to be exposed to heat (and the risk of being damaged as a result). Solder may also affect busbar assemblies' CTE compatibility. All these issues can be dodged by using a solderless busbar connection methodology.

There is scope for even more space to be saved via the integration of further system level functionality. Electromagnetic interference (EMI) filters and current sensor concentrators are just a couple of examples of the useful items that can be built into busbar designs.

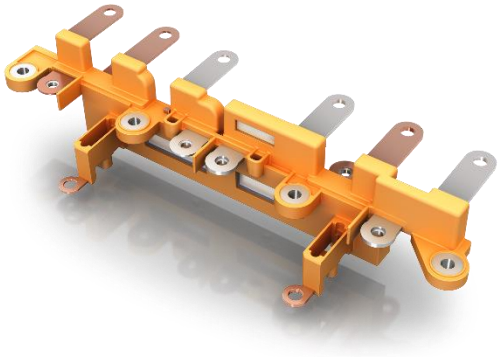

Figure 2: ***One of the numerous*** *complex busbars available via ENNOVI (formerly known as Interplex)*

Automobile manufacturers now need access to complex molded busbars that enable space and weight reductions to be delivered. These busbars must also be optimized for the high-volume manufacturing procedures that the automotive industry mandates - enabling accelerated assembly times and preventing costly mistakes being made.

Conclusion

Automotive designs are radically evolving, as a new epoch begins. Operational demands, alongside the need to reduce bill-of-materials (BoM) costs and save space, mean that end-to-end fully-integrated systems are being implemented, instead of discrete interconnected subsystems. The new breed of complex multi-layer molded busbars now emerging are bringing major benefits to the automotive industry. They are presenting vehicle manufacturers with advanced interconnect solutions that have smaller dimensions, augmented performance and assured reliability, as well as being attractive in terms of TCO.

About the Author

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