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December 2022

Magna

eBeam™ Family for Truck and LVC Electrification

Michael Maten, General Motors

"We Don't Want to Make What We Call Half a Vehicle"

JJE

Advances Electromagnetic Clutch Technology to a New Level

Image source: General Motors

Dear reader,

Welcome to the 2022 issue of CTI Mag! After a two-year break, we are again providing you with content beyond our annual events. Like the CTI SYMPOSIUM, it reflects the rapid transformation of powertrain technology, where electrification is increasingly dominating the agenda.

The technical papers in this issue cover developments such as bi-stable electromagnetic clutches from JJE and ultra-compact differentials for e-drives from JTEKT. Magna reports on the versatile eBeam drive for electric trucks and light commercial vehicles, while the Technical University Darmstadt has developed a two-drive electric powertrain that promises outstanding efficiency in both electric and dedicated range extender operation. Marelli introduces an e-axle family that is intended to cover 90 % of the market.

We also report on last May's CTI Symposium USA, where one much-discussed question was: "What are our electrification strategies during the transition phase until 2030?" On the same topic, we interviewed Mike Maten to hear his company's viewpoint. GM, he says, has uncompromising electrification plans: "We don't want to make what we call half a vehicle."

Another game changer is the field of tomorrow's sensor technology and E/E architectures in electrified vehicles, plus the growing importance of in-vehicle smart devices. So to round off this issue, we held a short interview on the subject with our advisory board member Sven Beiker from Stanford University, California.

Our special thanks to everyone who helped make this issue of CTI Mag happen. We hope you enjoy it!

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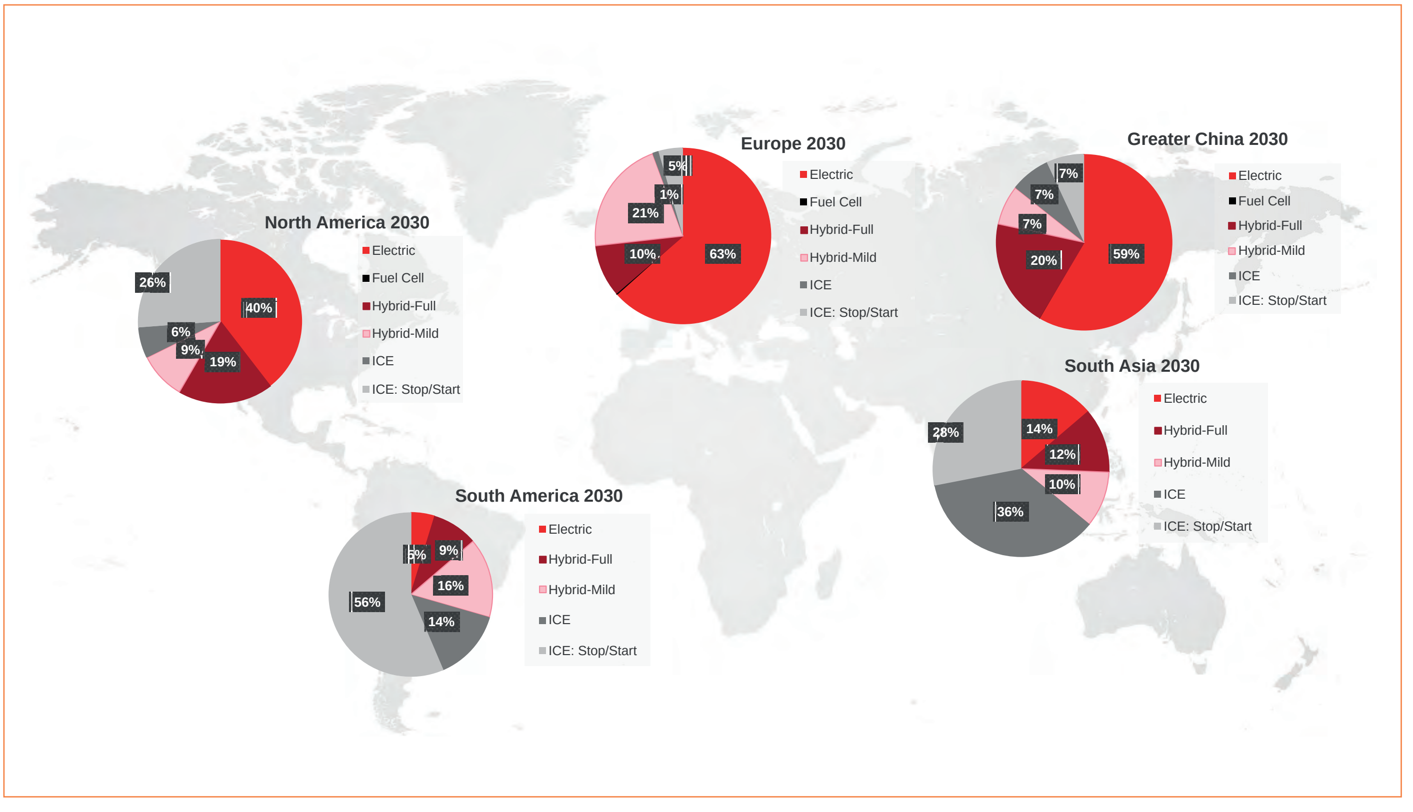
European Electrification Outlook to 2035

A. Saboor Imran and Romain Gillet, S&P Global Mobility (formerly IHS Markit | Automotive)

The fragmented situation around the world

The regional propulsion mix is a subject of multi-dimensional, complex, and interrelatedness with various sensitivities. It is based on factors such as compliance, regulations, policies, industry perspective, consumer behavior, and technology developments.

Propulsion strategies are now governed by an increasingly complex set of interactions and influences whose impacts vary across the regions. The aim is to speed up the transition to electric cars and fight climate change. To that end, three regions (EU28, Mainland China, USA) have adopted some stringent regulations for the years to come, leading to more rapid changes within the local powertrain trends. In order to comply, carmakers competing in these markets have to roll out specific product strategies relying essentially on electrification.



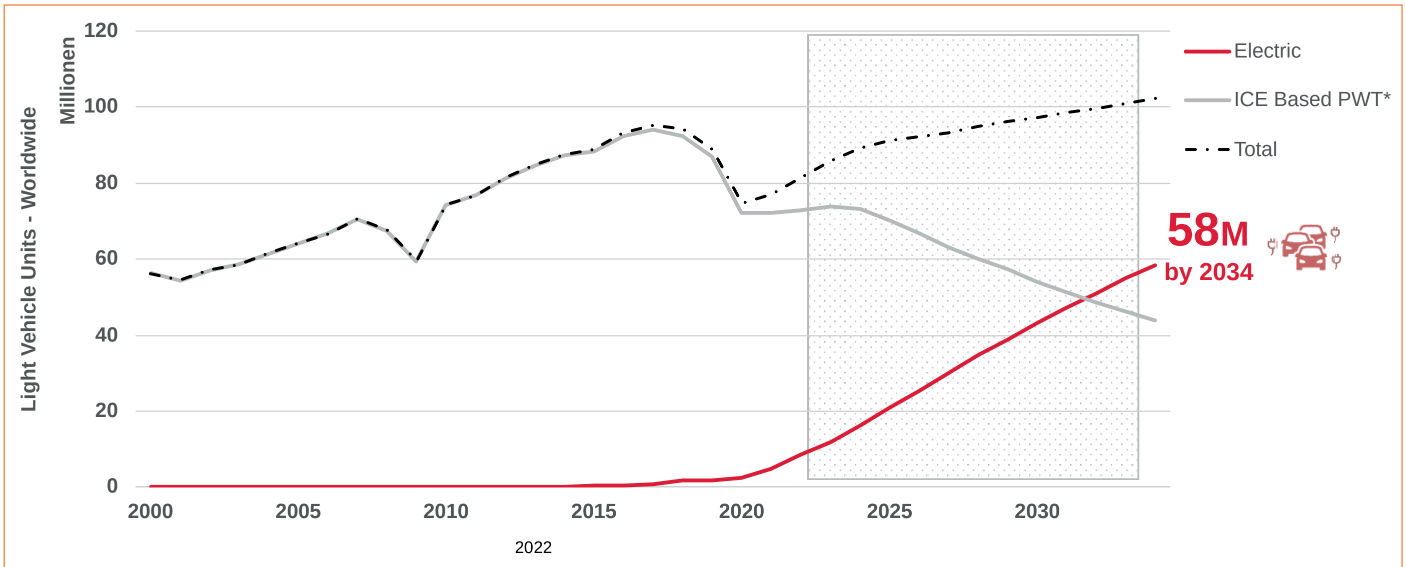
Source: S&P Global Powertrain forecast September 2022

The deviation of BEV across these regions is immensely different based on each local factor. By the end of this decade, the EU BEV rate is projected to reach more than 60%, whereas Greater China would be close to 50%. North America is also catching up with the pace of the EU and Greater China in electrification adoption. So far, the expected production share is around 40%. However, at the global level, we will likely observe a 2-speed electrification development, with those three regions being far ahead of the others due to the lack of stringent regulation elsewhere.

As a consequence, the latest volume projection anticipates more than half of the Global light vehicle production to be Electric cars as soon as the early years of the next decade.

Source: S&P Global Powertrain production forecast September 2022

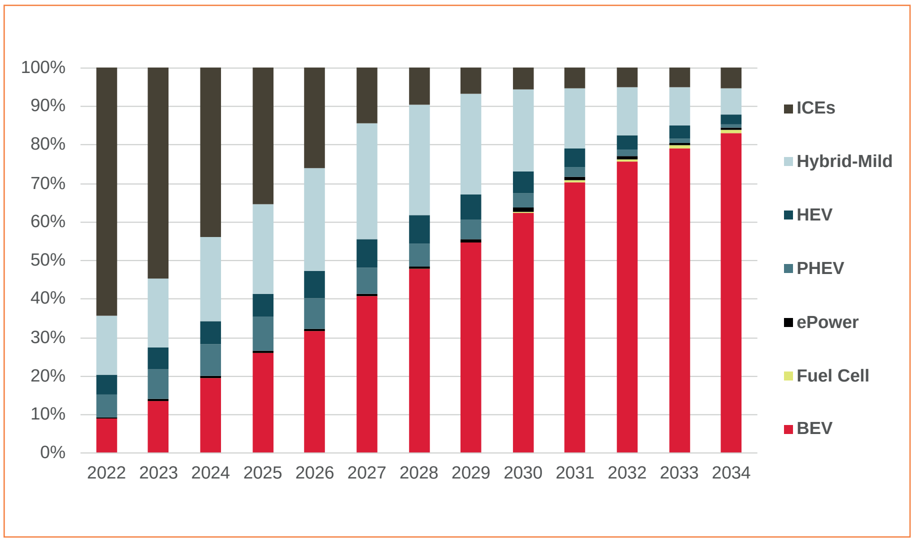
*ICE Based PWT = Internal Combustion Engine + Mild Hybrids + Full Hybrids



Focus on EU – The projected impact of the revised regulation outlook

In Europe, the predominant factor behind this massive shift is the regulatory framework. The European convergence towards electrified powertrains is the result of two types of legislation:

- CO_2 reduction, trajectory to mitigate climate change
- Pollutant Emission standards, to tackle the local pollution matters



Source: S&P Global Mobility Powertrain Production September 2022

Following the CAFE (Corporate Average Fuel Economy) CO_2 framework revision with the introduction of more stringent targets in 2020, each Carmaker will further see their specific targets being revised downwards again for 2025 and 2030 with -15% and -55%, respectively. Consequently, the powertrain strategies favor BEV adoption as it would not be possible for carmakers to comply without a high level of electric cars within their fleets. Furthermore, with the recent decision by the European Union that carmakers should achieve a 100% cut in their CO_2 emissions by 2035, there is no other way for the OEMs but to scaling-up on electric vehicles.

Zero-emission technologies to decarbonize mobility

From the projected production outlook, around one in four cars produced in 2025 will be electric before accelerating strongly in the second half of the decade to reach almost two in three by 2030 to provide enough BEVs to the relevant markets to comply with the CAFE targets. This massive volume growth will also be supported by a substantial ramp-up of dedicated BEV platforms to underpin these new vehicles. Therefore, this complete shift in the regional propulsion mix will materialize by a tipping point in 2029, where BEV will become the leading technology against all the other ICE-based configurations.

In order to reach zero-emission fleets by 2035, Fuel Cells (FCEV) could also be a viable alternative to BEVs, featuring tailpipe zero-emission as well. However, projected volumes are still minimal within the forecast horizon as certain challenges remain to scale the hydrogen powertrain properly. The critical drawback here is certainly the lack of existing infrastructure, and it would prove to be an immense challenge to have widespread H2 availability for passenger cars. Also, to contribute to the industry decarbonization path, mobility would need to get access to a low-carbon Hydrogen ecosystem that did not reach the required scale so far. That being said, it should not prevent some pilot programs from being launched (fueled by hydrogen produced by natural gas reforming), particularly in the light commercial vehicle area, which probably offers the best business case for FCEV at the moment in Europe.

As for eFuels, even if focusing a lot of attention recently, the current EU regulatory framework does not offer a clear route as it is not considered a zero-emission technology within the existing EU mandate. On top of that, other industries (aviation, MHCV, off-highway) will likely rely on these developments as part of their decarbonization roadmaps, eventually creating a certain form of competition leading to limited car availability. E-Fuels could anyway have a potential market in motorsport and accelerate the Vehicles-in-operation decarbonization in some markets.

Hybridized powertrains as bridging technologies alongside BEVs

While electric cars will represent most of the volumes in the future, the transition period will definitely require alternative options. In waiting for the EV era to reach its full maturity in becoming the mainstream technology, hybrid powertrains (from mild hybrid to plug-In hybrid) must spread heavily across all segments to bring some form of electrification to almost all vehicles.

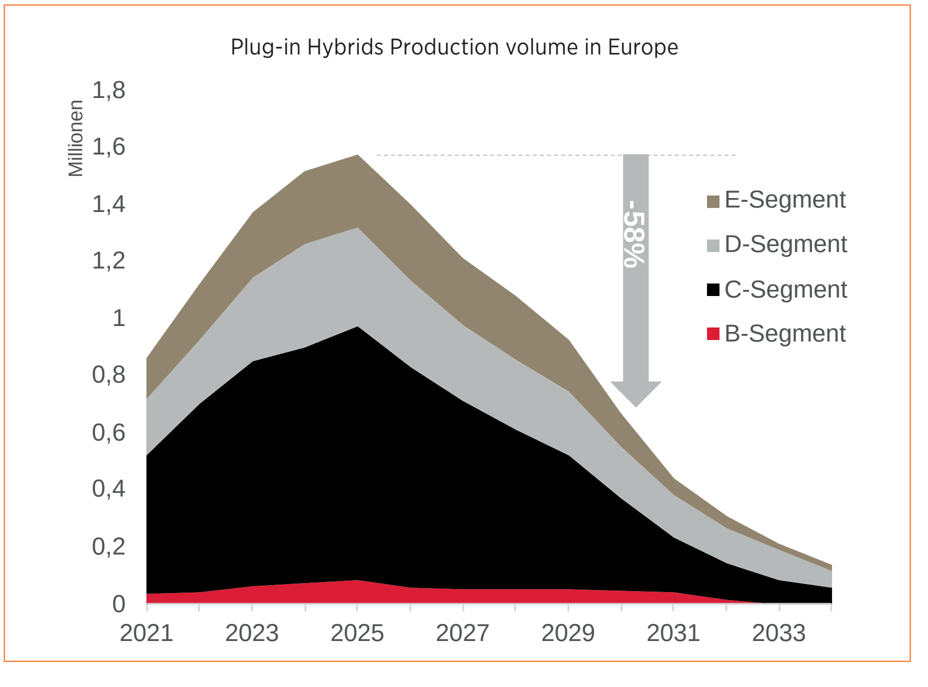
The hybrid powertrain portfolio will essentially consist of three different technologies – plug-In hybrid vehicles (PHEVs), full-hybrid vehicles (HEVs), and mild hybrid vehicles (MHEVs) – with various associated levels of cost and efficiency.

Once perceived as offering the best of both worlds, plug-in hybrids (PHEV) are now facing different headwinds that should eventually even question their availability on many nameplates. Indeed, while playing an essential short-term role as transition technology to bridge customers to the electric era, based on the latest developments, it appears that plug-in hybrids (PHEV) will eventually fall down quite shortly from 2025 onwards. The technology is expected to peak in the mid-decade before strongly ramping down. One of the reasons behind this quick demise is to remain competitive and comply with future regulations. Battery capacities must increase to achieve longer zero-emission ranges, driving additional costs.

Moreover, from the regulation point of view, the utility factor currently used for the homologation process must be revised around 2025 to reflect the real driving emission level better. Consequently, the certified CO_2 figure will undoubtedly be adjusted upwards, jeopardizing the current PHEV benefit within OEM portfolios. Volumes should then reduce, still focusing almost exclusively on higher segments.

On the other hand, some remaining conventional powertrain shares would remain almost flat from 2029 onwards, primarily driven by some Eastern European production activities (Russia, Uzbekistan, Turkey) and not being destined for EU markets. Indeed, as clear roadmaps for electrification do not exist yet in these markets and in light of the latest geopolitical developments, CIS operations will become more isolated, following its path, with foreseeable very limited electrified volumes within the next 15 years.

In general, in approaching the 2035 milestone, ICE volumes will eventually be phased out. As a result, the final set of ICE-based powertrains must be launched in the coming years in anticipation of the revised EU7 pollutant standards. However, during this transition period, most of these new engine programs would carry a certain level of electrification as part of hybrid architectures – either MHEV, HEV, or PHEV.

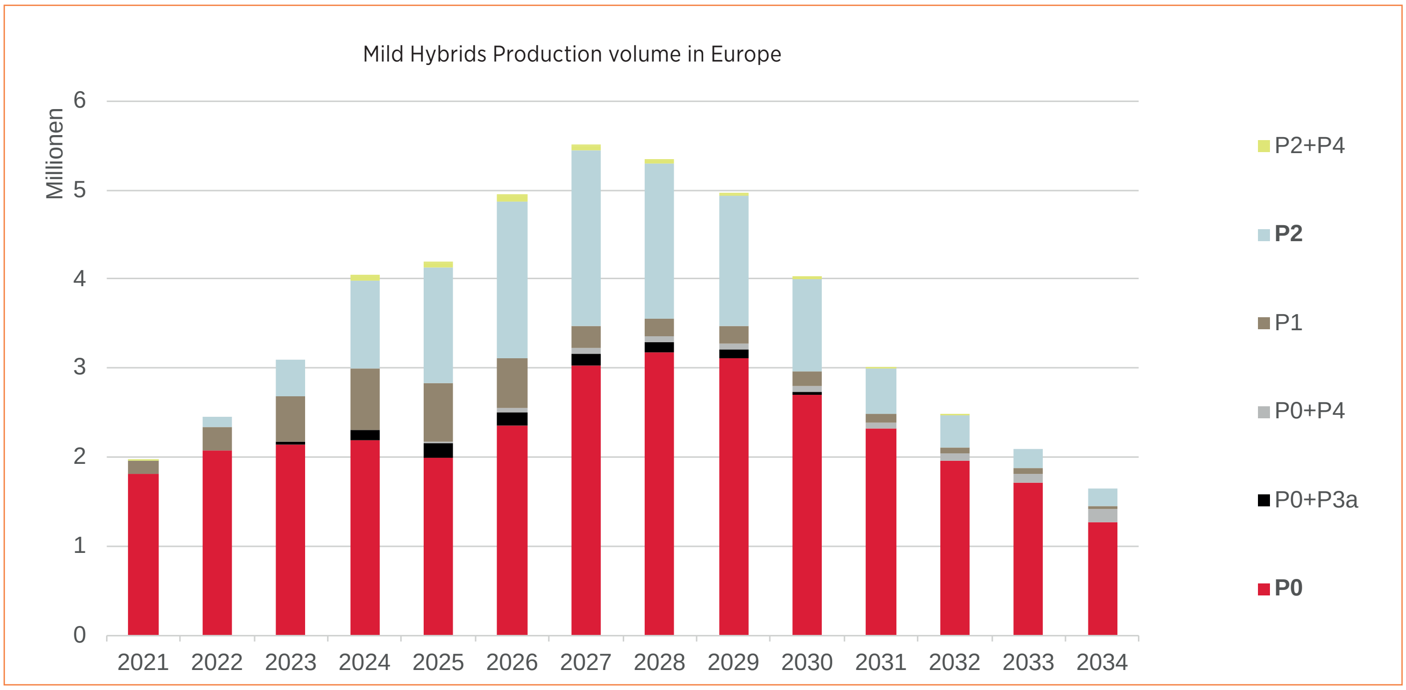


Source: S&P Global Powertrain Production forecast August 2022

In parallel, full-hybrid vehicles (HEV) will still represent an attractive technology for OEMs to reduce their average CO_2, especially in mainstream segments. While it was initially mainly developed by very few Asian OEMs, more carmakers now rely on this technology for the remaining markets, not transitioning to BEVs at the same cadence. There is also a potential for this technology in other markets (such as Asia and the U.S.A), offering some attractive product development synergies to better leverage the associated cost.

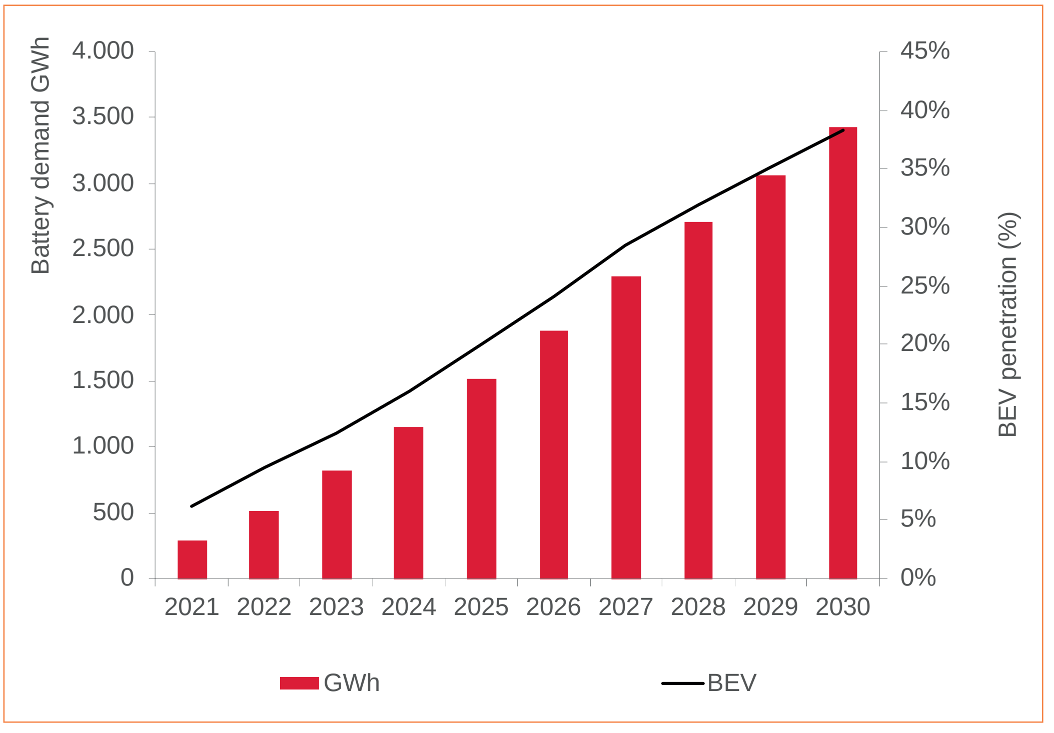
Last but not least, mild hybrid technologies provide a certain efficiency level with lower costs to ICEs. Therefore, it does offer opportunities for carmakers, suppliers, and customers before the complete death of ICE. While this technology alone would certainly not bring enough savings to comply with the new CO_2 targets, in covering different features thanks to the 48V electric machine, it helps anyway to reduce emissions slightly. It will progressively become almost standard in Europe. Furthermore, to deal with the extended boundary conditions of the RDE (Real Driving Emission) procedure as part of the EU7 pollutant standard, cold starts compliance might require EHC (Electric Heated Catalyst) device for some powertrains. Hence, 48V systems are likely to be installed to fulfill the power demand, simultaneously creating opportunities for mild hybrid architectures.

Different architectures coexist, but volumes will still be driven by P0 systems in the future. Most of the EU7-compliant engine families should feature such systems as standard. However, some OEMs like Stellantis or Volkswagen will adopt different technology routes with, respectively, P2 and P0+P3a rollover for some of their upcoming platforms and vehicles. Another significant development is the eAWD 48V systems. Installing a 48V drive module on the rear axle, it brings an attractive opportunity to offer an all-wheel drive option also on platforms that were initially not designed for mechanical AWD. Typically Renault and Stellantis are the two groups exploring this technology with their CMF and CMP platforms, with P0+P4 and P2+P4 layouts, respectively.



Source: S&P Global Powertrain Production forecast August 2022

A tremendous challenge to the battery ecosystem



Source: S&P Global Powertrain Production forecast August 2022

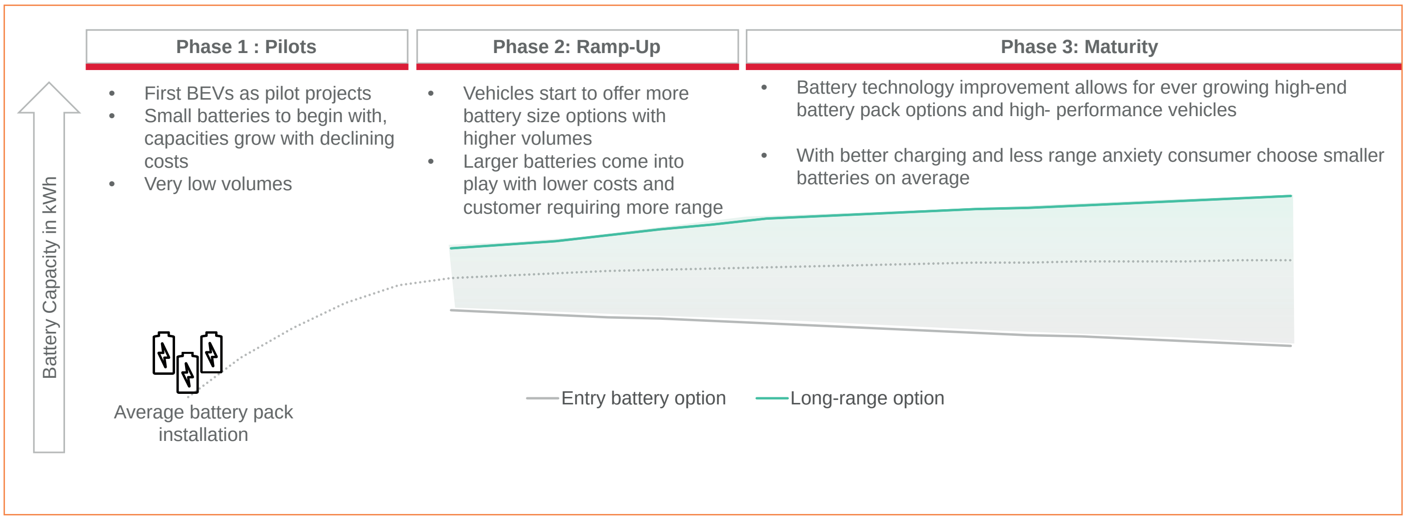
Batteries are a key technology to successfully achieving the targets for decarbonization. As manufacturers rapidly move towards the growing electrified industry, more resources are put in place to make batteries more affordable, efficient, and available. Collaborations play a vital role between carmakers, battery cell manufacturers, start-ups, the auto industry, and mobility providers to strengthen Europe's fully electric future further.

As there will be associated risks due to the raw material availability, the right battery pack sizing approach must be adopted to mitigate the shortage threat. As greater efficiencies are achieved (thanks to improvements to energy density, thermal management, optimized cell chemistries, and advanced battery management systems to extend battery lifetime or also with the vehicle platform design), the average battery capacity trendline will tend to stabilize.

However, in parallel, in order to cover all areas of the market and to maintain a certain level of affordability for some vehicles, the range of combinations offered will be extended to both the higher and lower end. Other improvements, such as high voltage architectures, would improve charging time, peak power, copper usage, and the vehicle's overall weight.

At the global level, this will lead to a battery demand exceeding 3TWh in 2030. Carmakers are therefore striking deals with battery suppliers to ensure they can fulfill their targets. Battery cell production must increase, and this scale-up has resulted in a number of new facilities being built or existing ones repurposed as 'Gigafactories'.

There are aspects of lithium-Ion batteries that must be considered and accounted for in the regulatory framework. As we move away from tailpipe emission monitoring towards a broader scope, it will be imperative that BEVs are adequately scrutinized. Concerns around mining emissions, lifetime energy usage and recyclability will likely be included in the new scope. These steps could help mitigate the geopolitical risks associated with the battery ecosystem.



Conclusions

For light vehicles, BEV will be the mainstream option to switch the EU market to zero-emission by 2035. Decarbonization roadmaps from various sectors require different solutions to fulfill each market constraints.

The transition period in Europe will be relatively short, a decade or thereabouts, this might take much longer in more cost-sensitive markets and where regulation is less severe. Although ICE-based powertrains will be phased-out rapidly in Europe, there is a potential to continue production for a considerable time, serving slower transitioning markets.

Europe aims to lead the transition towards net-zero mobility. Achieving these targets will be challenging for car manufacturers as this will require an optimized global carbon footprint based on a sustainable supply chain in operating markets. The fight against climate change is only possible with widespread renewable electricity to produce the components required for BEV proliferation and be circular on material utilization and waste.

Policy and associated financial risks have served as key market drivers for a low-carbon economy. They will continue to propel the automotive industry's decarbonization progress with additional sustainability frameworks.

Interview

“We Don’t Want to Make What We Call Half a Vehicle”

Michael Maten, General Motors

General Motors has been a pioneer in the area of range extender technology, but today it is focusing on all-electric vehicles. We spoke with Michael Maten, Director EV Policy and Regulatory Affairs at GM, about the company’s electrification path, and future development challenges in fields such as the production, transport, and storage of energy.

Mr. Maten, electrification is transforming the industry rapidly. At GM, which manufacturing and engineering fields are becoming less significant, and which more so?

I think both engineering and manufacturing competencies are becoming even more important. They are both necessary as we continue to electrify things. Electrical engineering and software engineering in particular are becoming more important. Mechanical engineering still plays an important role, but maybe a little less so. On the manufacturing side, it’s a really exciting time – to be right at the beginning of a new industry. Instead of just working around the margins to optimize things like the combustion engine, you truly get this ground floor, you’re building the foundations for the next hundred years of the auto industry. Many engineers who worked on ICE programs are now bringing that expertise to EV programs. And there’s another new aspect: In the past, manufacturing and engineering stopped at the factory doors, once that vehicle left the factory. Now our involvement doesn’t stop at the factory door, because we have over-the-air updates. We are constantly trying to optimize the vehicle, to add features to the vehicle.

What advantages does GM have in this transition, compared to newcomers in the market?

It starts with our size and scale and know-how. The fact that we can quickly bring things to an enormous scale, brings the cost down, to improve the technology, I think that's a huge advantage. Our modular Ultium platform, which I was involved in planning back in 2017, can be used for a wide range of vehicles. It can adapt to different battery formats and chemistries. It can really be the foundational element for several generations of General Motors vehicles. We are actually building the vehicle around the platform, around the battery, instead of trying to shove a battery into an existing vehicle architecture. I would add that we think we're the best in the business at generating efficiency throughout the supply chain. Taking what we've done in optimizing the supply chain over the last hundred years of ICE development, bringing that level of knowledge, that level of rigor, the level of process to the lithium-ion battery space. It's still very much what I call a cost-plus industry and not optimized. But we have the experience to handle that.

Your Silverado is a genuine e-truck. How do you ensure sufficient range for a vehicle that's often used for towing trailers or transporting heavy loads?

Well, we're designing it not only for 300 miles, but with a 400 miles range in mind to address some of those concerns. We know there are some challenges when you're towing, and some challenges with temperature variation. We are trying to address all of those with the technology we are putting in the truck. We're still figuring out, especially for the American consumer, what their kind of crossover point is. I think everyone feels that 300 miles will get most people into an electric vehicle. But there are certain people, in Wyoming or Montana or elsewhere, who say man, I really need 400. But we are committed to the transformation, we think the battery cost curve is coming down. We think the battery technology is getting to a place where we can effectively offer those types of products. I should also say it's not just about battery chemistry. We are taking an overall vehicle approach. How can we efficiently heat and cool the cabin, things like this. There are many important factors in the overall equation of the range capabilities of the vehicle.

In North America, temperature extremes are much greater than in Central Europe. What are the solutions for reducing negative impacts on range – e.g. through air conditioning and heating?

Certainly, heating is almost a bit of a forgotten area. But we're focusing on it from a research perspective, whether it's conductive surfaces like conductive door panels, armrests, or dashboards. I'm not saying this is technology that's coming out tomorrow in vehicles. But you just have to look at it as a whole system. And how are we doing this? In an internal combustion engine, you're generating a lot of waste heat that can be used. So now we're just beginning to explore the capabilities of BEVs and how those all work. Preconditioning is going to play a large part. You know, you're plugged into an energy source. And when you're charging, that can be used to precondition the cabin and the battery, you can program when you leave in the morning. I think it's going to be a key technology, particularly in colder climates. We see in Norway that people in colder climates can adapt to EVs. So you just have to figure out what it is for the American consumer that will cause them to do that. Extreme temperatures are something that a lot of research is going into how to handle that.

What opportunities do you see for hydrogen and e-fuels in the area of passenger cars and light trucks?

I think there are going to be applications in the future that will be the last to adopt electrification. E-fuels could potentially play a role in some of those. Quite frankly, we don't see hydrogen playing a large role in passenger cars and trucks. But it will play an important role in the overall decarbonized economy, for stationary storage, potentially for medium and heavy-duty vehicles. At GM we have our Hydrotec fuel cell. We have a commercial agreement with Navistar to provide those. But green hydrogen, I always have to preface that, is another area where we need technical and cost improvement. However, in a decarbonized economy, in the passenger car and truck case, we see a potential role for stationary energy storage to support infrastructure. In other words, for somewhere where you can't quite get all of the energy for 350 kW charging, you may put a hydrogen fuel cell storage unit there, or maybe a large stationary storage battery. This is one of the most important questions: How do we store and transport energy? In America, the middle of the country is rich in renewable energy, wind and solar energy. You can generate a lot there. But unfortunately, the use for most of that energy is on the coast. I think batteries can play a massive role in the stationary storage of energy. Some people don't quite understand the amount of energy in it. You know, the Hummer EV can power a home for a week.

GM has been a PHEV pioneer, even if the Volt was originally intended as an E-REV. What future do you still see for PHEVs?

We made the decision that we want to accelerate the EV transition, and we felt even hybrids – PHEVs but especially hybrids – are transition technology. If we had $1 billion to spend, we didn't want to spend it on a technology that might be going out after one generation. Yes, we were a leader in plug-in hybrids or E-REVs, but for a couple of reasons it was a difficult value proposition for customers to understand. Engineers understand the operation, but the customer now had to manage two energy sources and we never quite got the demand that we thought was there. Another aspect is the regulatory angle. We never quite got the regulatory treatment we felt we deserved for PHEVs, especially the E-REV, as 90% of its operation was in electric mode. Again, everything is regulations in the EU and the US, as you know. But primarily it was just a 100% focus on electric vehicles and what we would take to get there.

To what extent will small, affordable vehicles still be available as electrification moves forward?

We plan an offering of a wide range of vehicles. But we do not plan an offering of lower-range vehicles that have less utility, just to hit a certain price point. These vehicles are not going to have as much utility to a customer. We believe these longer-range BEVs are the way to go, and yes, it is a challenging price point to hit. We've committed to an Equinox starting at $30,000 next year. And we have the Bolt EV out there, the 2023 range starting from just $26,595. So we think we're covering most price points. I think we've also made allusions to future developments of more affordable vehicles. We are a full-line manufacturer, and we plan to continue that into the BEV space. And that includes being committed to that lower end of the market. What we don't want to do is make what we call half a vehicle.

Interview: Gernot Goppelt

Magna's eBeam™ Family for Truck and LCV Electrification

Although light trucks and light commercial vehicles are used for different purposes, the requirements are similar in terms of robustness, performance, package compatibility, etc. The Magna eBeam™ family offers a flexible electrification solution that covers class 1 to 6 trucks as well as LCVs up to 7,5 tons.

Introduction

The electrification of pickup trucks has recently become a major topic, especially in North America. Solutions are needed that do not compromise on robustness, payload, or towing capacity. In Europe, these trucks have been playing a comparatively minor role so far. However, there is a big market for electrified light commercial vehicles (LCV) and small commercial trucks. These may not have major requirements regarding off-road capability, but the expectations for payload capacity are similar.

The Magna eBeam™ product family, is compatible with class 1 to 6 trucks, which compares to a gross vehicle weight of up to 11.793 kg or 26.000 lbs respectively. Regarding LCV and truck classes in Europe, classes are typically differentiated into 4,25 tons and up to 7,5 tons, the latter requiring a special driver's license. Like in American trucks, there are many different requirements as to robustness, power, package, and weight. The new Magna eBeam™ product family addresses these through several variants, which can be seamlessly integrated into existing vehicle platforms.

Rear axle requirements for trucks and LCVs

Pickups are used for work and transport. They should be able to carry large loads and serve as towing vehicles, for example for boat or equipment trailers. At the same time, they are being used in daily traffic situations, requiring high comfort in terms of suspension, NVH, etc.

LCVs, although their purpose is quite different, have similar requirements. Typical applications are delivery services, logistic companies, vehicles being used by craftsmen, installation services, etc. Especially in terms of the load on the driven axle, requirements are similar to light trucks, sometimes even higher.

Based on customer surveys, Magna developed the new eBeam™ product for all these kinds of private and commercial use. There were several objectives: Firstly, an electric rear axle must not have any disadvantages compared with ICE-based powertrains and drivetrains. Secondly, a cost-effective solution was crucial. Thirdly, the new technology should enable full electrification within the typical ladder frame of existing vehicle platforms.

Suspension architectures for heavy-duty applications

Traditionally, light trucks and some LCVs have often been designed with a beam axle, which has proven to be particularly robust in practice. One main characteristic of the beam axle is its continuous lateral structure for high rigidity. Starting its development project, Magna also investigated De Dion axles and independent suspensions, which are common in passenger cars and SUVs, (Fig. 1). The following characteristics were compared: cost, weight, shaft angle, packaging, towing, and payload capacity.

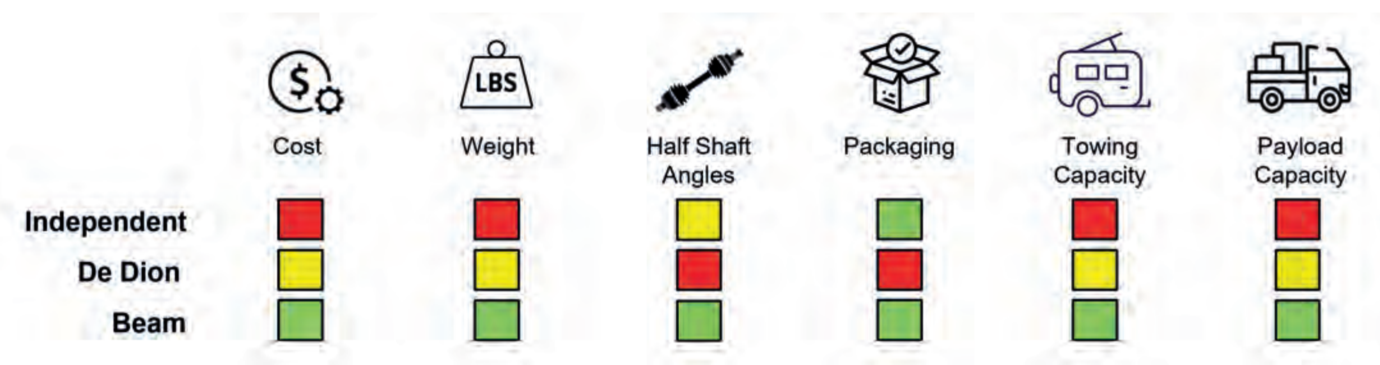


Figure 1

In comparison, the independent suspension is disadvantageous in terms of cost and weight, but also regarding payload and towing capacity. The De Dion axle showed disadvantages in terms of towing, cost, weight, and payload. Moreover, it is significantly inferior regarding packaging and half-shaft angles, the latter being crucial in off-road driving. In all the areas mentioned, the beam axle proved to be superior for the target applications mentioned.

One potential disadvantage of the beam axle is that it has a higher unsprung mass compared to an independent suspension. The independent suspension, on the other hand, would require a sub-frame system, increasing the sprung mass, and compromising payload as well as towing capacity. Investigations and simulations of typical use cases have proven that the unsprung masses do not result in any noticeable ride comfort disadvantages. The decision was therefore taken to develop a whole family of structure-oriented electric beam axles with different application-dependent design options.

Variants for different applications

The two critical performance factors for the vehicle classes we are looking at are continuous power and peak torque. They are primarily influenced by the GVWR, which by definition stands for the gross vehicle weight rating over both axles.

	Coaxial-design			Offset-design			
FHWA Vehicle Weight Class	Class1	Class 2a	Class 2b	Class 3	Class 4	Class 5	Class 6
GVWR	0 - 2.722 kg 0 - 6.000 lbs	2.723 - 3.856 kg 6.001 - 8.500 lbs	3.857 - 4.536 kg 8.501 - 10.000 lbs	4.537 - 6.350 kg 10.001 - 14.000 lbs	6.351 - 7.257 kg 14.001 - 16.000 lbs	7.258 - 8.845 kg 16.001 -19.500 lbs	8.846 - 11.793 kg 19.501 - 26.000 lbs
GCW [kg]	5,897	9,072	15,876	22,680			
GCW [lbs]	13,000	20,000	35,000	50,000			
Structural Requirement GAWR [kg]	1,750 (SRW)	2,000 (SRW)	3,250 (SRW)	3,500 (SRW) 5,000 (DRW)	7,250 (DRW)		7,850 (DRW)

Figure 2

Besides these, there are two more essential requirements defining the drive and beam architecture. One is the package: For example, possible obtrusion of the e-motor into z-direction can be an issue, especially for LCVs with the target to keep a low loading height. Another aspect is rigidity: It can be said that from 3500 to 4500 kg GVWR (~ 8000-10.000 lbs) upwards, the rigidity of the horizontal eBeam™ structure must meet higher demands, (Fig. 2).

The eBeam™ family includes both coaxial architecture for lighter applications and an offset architecture for Class 3 and above, (Fig. 3). In the coaxial architecture, the eDrive is part of the weight-bearing structure, whereas the offset architecture is mounted to a solid beam structure. The e-motor is installed coaxially, with the gearbox close to the center. All mounting points to the frame correspond to those of conventional suspensions, complying with OEM specifications. The coaxial architecture ensures a similarly compact package as a conventional beam axle. As a result, practically no vehicle-side modifications must be made in terms of package, spring mounting, wheel end, etc.

Figure 3

For applications above – 3250 kg gross axle weight rating (GAWR) an offset architecture of the eBeam™ is available. The offset mounting of the e-motor enables a higher structural rigidity for applications with very high payload and towing requirements. Whereas GVWR defines continuous power and peak torque, GAWR is the defining factor for the axle structure. This is why, depending on the application, the Magna eBeam™ flexible family approach includes both coaxial and offset solutions. For example, depending on the OEMs model alignment, class 3 truck architectures may be based on either coax or offset architectures.

Apart from these two basic design variants, there are some further options: a one-speed version with two e-motors and a two-speed product with one e-motor, as well as an electric locking differential, disconnect system, and a park lock. Especially for certain off-road applications, there is also a steerable eBeam™ for front use available.

Electrification opportunities

The trend towards truck electrification in North America is evident and being pursued by all major OEMs in the US. There are especially two approaches that set the Magna solution from others: One is the modularity and scalability of torque, power, and architecture, which covers all classes of trucks and light commercial vehicles. Secondly, Magna offers the in-house expertise to provide advanced traction and driving dynamics add-on value. For example, this includes dedicated trailer-tow, off-road, rain/snow, and city/highway modes, which distribute the e-motor torque between the front and rear axle for best efficiency, traction, and driving safety under any driving conditions.

As to LCVs, the eBeam™ offers similar benefits. LCV applications may have another purpose, but the requirements regarding power, torque, rigidity, package, etc. are very similar. The eBeam™ family offers the capability to tailor these while relying on standard products of the Magna eDrive family. This makes it a promising and versatile product for the growing field of emission-free delivery traffic.

Development of "JTEKT Ultra Compact Diff." for eDrive system

Contribution to further eAxle compactness and higher power density

Makoto NISHIJI, Senior General Manager / Chief Engineer,
Driveline CE Department, Automotive Business Unit, JTEKT Corporation

In response to the strong expansion of the battery electric vehicle (BEV) market, JTEKT has developed and just announced "Ultra Compact" product series, JTEKT Ultra Compact Bearing™, JTEKT Ultra Compact Seal™ and JTEKT Ultra Compact Diff.™ aiming for e-axle size and weight reduction. (Fig. 1)

"JTEKT Ultra Compact Diff.™ (hereafter referred to as JUCD™)", is new differential proposal for BEV e-axle using very unique/patented differential gearing. JUCD™ is extremely small compared with traditional two pinion – one piece housing bevel gear type differential for the same strength.*JTEKT Ultra Compact Diff. and JUCD are registered trademarks of JTEKT.

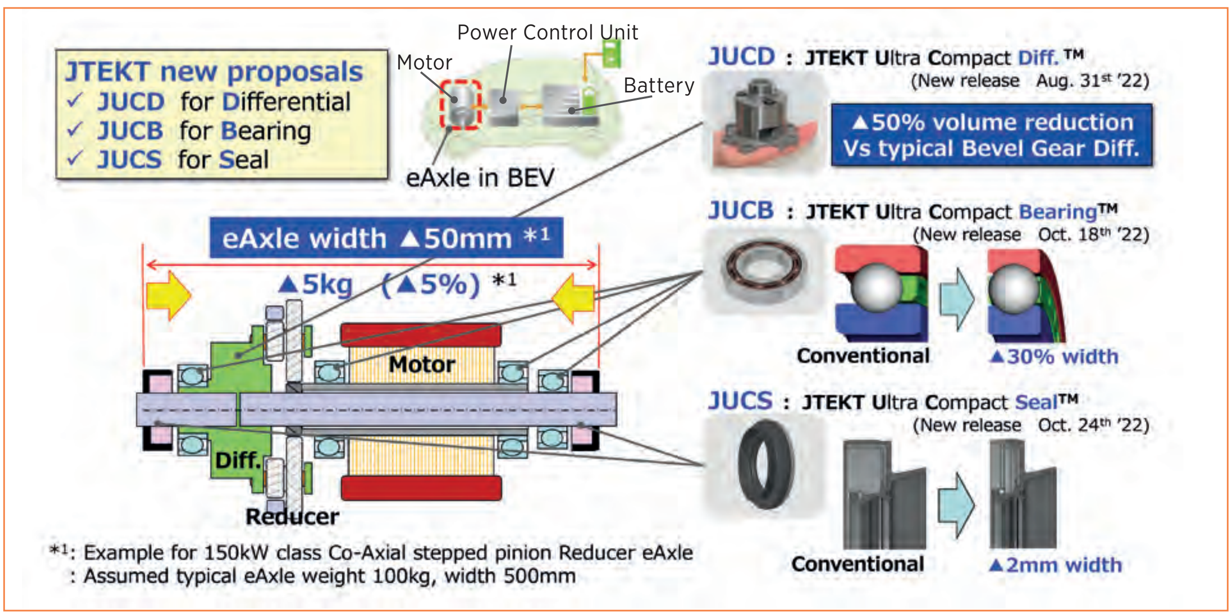


Figure 1: JTEKT Ultra Compact products for eAxle

Needs for eAxle compactness

Following with automotive electrification growth trend and also high ratio of 4 Wheel Drive BEV trend, development and production of eAxle is growing rapidly worldwide. e-axle is the heart of the eDrive system, and integrated inverter, motor, and reducer including differential. In order to develop a better BEV keeping enough battery capacity installation space, the e-axle is required to be smaller and should have much higher power density (power/weight ratio) in future. In response to this market need, demand of very compact differential for e-axle is expected to grow, and will replace the typical bevel gear type differential widely used for traditional vehicles.

JUCD Background

JTEKT has developed a very compact size and highly durable differential as “JTEKT Ultra Compact Diff.”, which is suitable for BEV e-axle. A differential is a device that absorbs the rotational speed difference between the left and right wheels that occurs in cornering, and transfer the torque between the drive power source to both wheels.

We have further evolved our “No.1 & Only One” product, the Torsen LSD technology, which is a high-performance differential suitable for high power 4WD/sports vehicles, by adding new knowledge of gear design and machining technologies. Introducing smaller gear module geometry into the unique composite planet gear set, we have made it smaller in radial and axial directions, and reborn as “JUCD” general-purpose differential for wide range of eAxles.
* LSD: Limited Slip Differential

JUCD Features and Advantages

› High torque density and durability.
› Wide range of torque capacity.

Compared to the bevel gear type differential, JUCD has an increased mesh quantity and wider mesh width at larger diameter between planet gear and side gear. This is possible by using smaller diameter parallel axis planet gears which are directly supported by the housing bore similar with journal bearing structure. (Fig. 3) As a result, for the same differential gearing functional volume, the ultimate strength is more than doubled. Consequently, for the same ultimate strength, the required volume is less than half for JUCD. (Fig. 2)

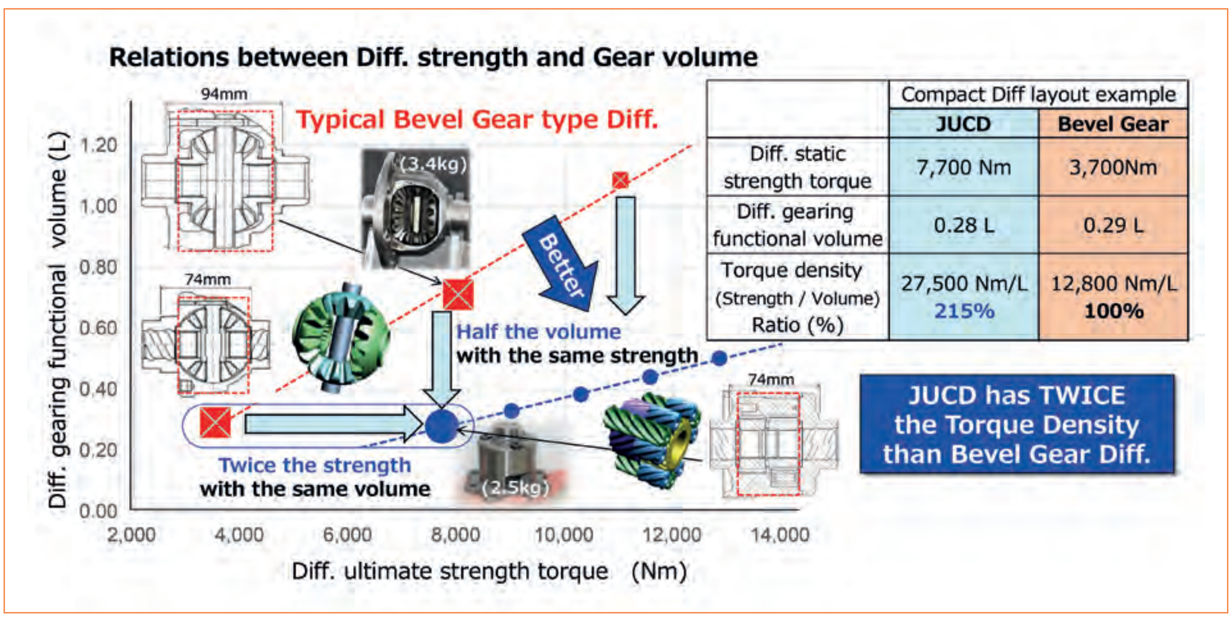


Figure 2: Bevel Diff. Vs JUCD: Torque density

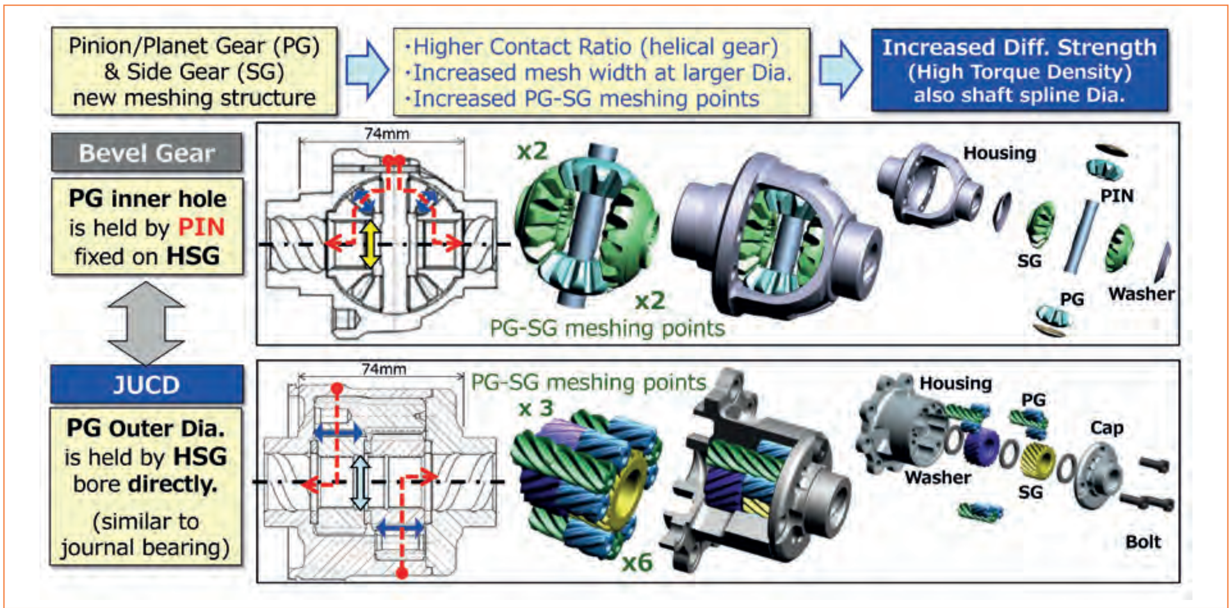


Figure 3: Bevel Diff. Vs JUCD Diff. Structure

In addition, high durability is ensured by reducing each load of the sliding surfaces between planet gears outside diameter to housing bore, compared with the bevel gear type differential pinion gear hole to drive pin. (Fig. 4)

JUCD can support wide range of torque capacity requirement, by selecting the number of side gear teeth and the size of differential outer diameter and/or additional planet gear set, while keeping the common planet gear sets and differential width. (Fig. 5) With these, JTEKT can now propose the optimum ultra compact differential for various eAxle reducer structures and torque requirements. JUCD contributes to the further eAxle compactness and higher power density, and also improves flexibility of the eAxle mountability to the vehicle.

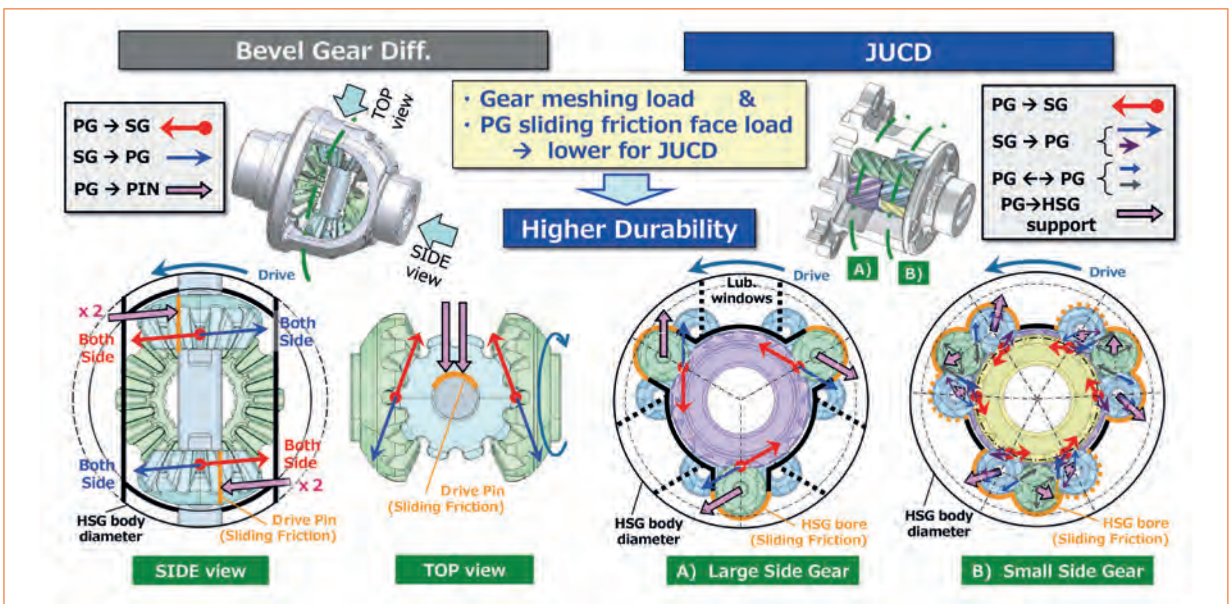
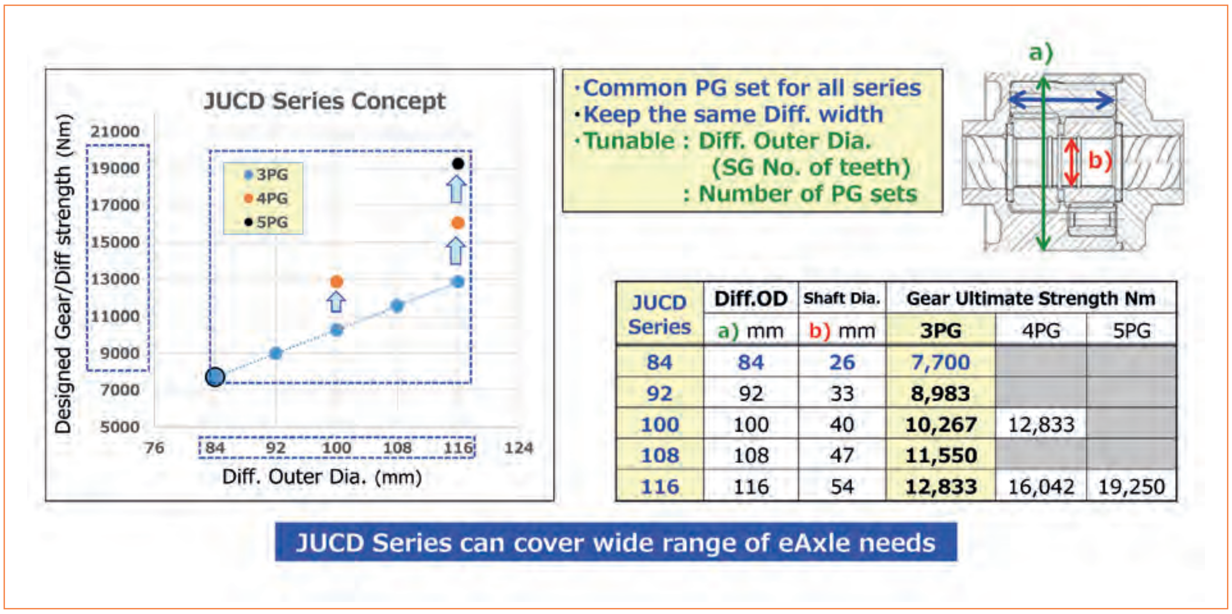


Figure 4: Bevel Diff. Vs JUCD: Load comparison

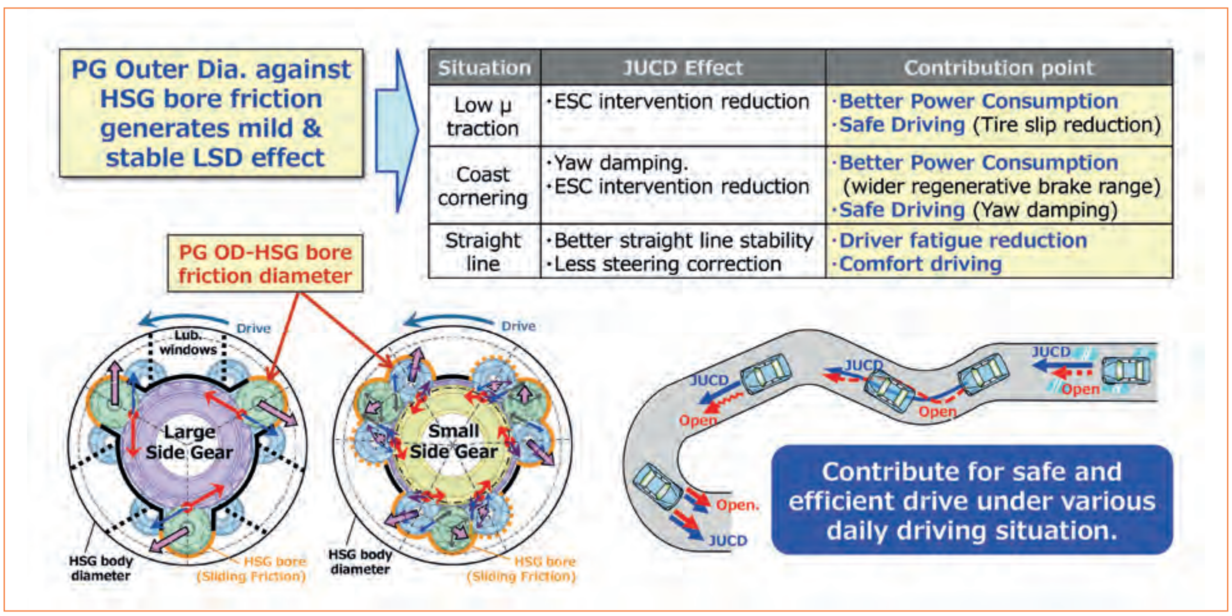


JUCD Series	Diff.OD a) mm	Shaft Dia. b) mm	Gear Ultimate Strength Nm 3PG	4PG	5PG
84	84	26	7,700		
92	92	33	8,983		
100	100	40	10,267	12,833	
108	108	47	11,550		
116	116	54	12,833	16,042	19,250

Figure 5: JUCD Series Concept

Improve electricity power consumption and safety performance

JUCD also has mild and stable torque biasing LSD characteristics derived from its unique structure, mainly by planet gears outside diameter to housing bore friction as journal bearing structure. This feature contributes to reducing the vehicle wheel friction brake load that intervenes when the tire slips at vehicle start on slippery road surface or climbing a hill. It also contributes to expand the range of regenerative braking situations by stabilizing vehicle behavior during deceleration. These effects are expected to improve electricity power consumption. In addition, these characteristics also contribute to improve straight-line stability, which will reduce continuous steering wheel angle adjustment during steady straight-line driving, contributing to reduce driver's fatigue and improve ride comfort. (Fig. 6)



Situation	JUCD Effect	Contribution point
Low μ traction	·ESC intervention reduction	·Better Power Consumption ·Safe Driving (Tire slip reduction)
Coast cornering	·Yaw damping. ·ESC intervention reduction	·Better Power Consumption (wider regenerative brake range) ·Safe Driving (Yaw damping)
Straight line	·Better straight line stability ·Less steering correction	·Driver fatigue reduction ·Comfort driving

Figure 6: BEV Power Consumption & Safe Driving

For more detail

JTEKT Ultra Compact Diff.™: www.jtekt.co.jp/e/news/2022/220831.html
JTEKT Ultra Compact Bearing™: www.jtekt.co.jp/e/news/2022/221018.html
JTEKT Ultra Compact Seal™: www.jtekt.co.jp/e/news/2022/221024_3.html

With a global focus on sustainability and zero-carbon targets, our aim is to deliver energy solutions that fuel progress in a responsible manner.

Guided by our four sustainability lenses – which are aligned with the United Nations' Sustainable Development Goals 2030 – our commitment is to conduct and grow business in ways that contributes positively to wider society and the environment.

As part of this evolution, PETRONAS Lubricants International launched PETRONAS Iona in 2019. Fluids under the PETRONAS Iona brand are developed specifically by our experts for latest generation EVs that answer to the demand of the ever-increasing market.

Together we move the world.

The future of our planet lies in all of our hands. **We all have a part to play.**

PETRONAS aspires to achieve net **zero carbon emissions by 2050**, delivering **clean energy** and **low carbon solutions** to people globally.

PETRONAS Iona is here to help accelerate the world towards a zero-carbon future by **optimising energy efficiency**, **safety and performance** with advanced fluid solutions tailored for its partners.

INTEGRATED DRIVELINE SYSTEM

- Energy efficiency due to low viscosity and friction reduction
- Long-life gear box performance and lifetime wear prevention
- An extra smooth ride and gear shifting

JJE Advances Electromagnetic Clutch Technology to a New Level

JJE DirectFlux^{TM} Mono-stable and Bi-stable Electromagnetic Clutches for Disconnect and Differential Locker Applications

Jing-Jin Electric (JJE) has been developing electromagnetic clutches for various electric drive applications over a decade. Instead of using "reluctance" magnetic force, JJE electromagnetic clutches utilize direct magnetic force – flux in the same direction as the magnetic force – which is named "DirectFlux^{TM}". A mono-stable clutch is engaged by actuation current, and disengaged by spring force when the current is off. A bi-stable clutch will only change its state when there's an affirmative pulse of command current; otherwise, it will hold its state. Earlier this year, JJE launched industry's first bi-stable electromagnetic clutch for automotive applications.

Both mono-stable and bi-stable clutches can serve applications such as disconnect, differential locker, transmission shift clutch, or hybrid mode-management clutch. When used for disconnect, differential locker and transmission shift, bi-stable clutch is functionally safer than mono-stable clutch, and is more energy efficient as it does not require any holding current. However, when electromagnetic clutch is used as a mode-management clutch in a series-parallel hybrid, mono-stable is desired as the system needs to fall back to series mode in the event of clutch failure

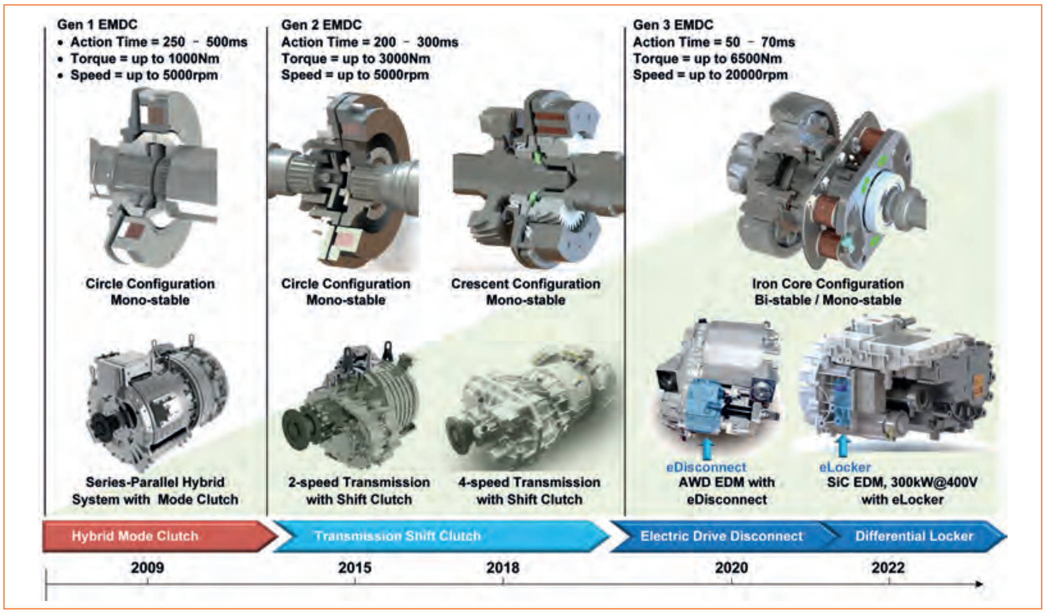


Figure 1: JJE's EMDC Development

The technology roadmap for developing an electromagnetic dog clutch (EMDC) plays a key role in the product's developing stage. Back to 2009, JJE started to develop the electromagnetic clutch in "DirectFlux™" concept. The first generation (Gen 1) EMDC product is a circle configuration, mainly applied on hybrid systems as a hybrid mode clutch, which was very successful in China's commercial market.

In 2017, the 2nd generation (Gen 2) EMDC product was launched, and expanded its application to transmission shifting after optimization over mechanical design. The "crescent" configuration was developed and added in the JJE's EMDC family.

In early 2019, JJE began the development of 3rd generation (Gen 3) EMDC. The third generation (Gen 3) EMDC features further innovations. It has both mono-stable and bi-stable options. It overcame some limitations of the existing design. Coils evolved to smaller solenoids, and magnetic circuit are further optimized to reduce flux leakage. The Gen 3 EMDC is more capable, faster, functionally safer, and more energy efficient.

DirectFlux™ Electromagnetic Clutch

JJE's DirectFlux™ mono-stable electromagnetic clutch has several advantages because of its unique magnetic circuit design and mechanical structure. Compared to the more conventional reluctance flux magnetic circuit design, the DirectFlux™ design greatly reduces flux leakage, therefore it utilizes the magnetic flux to generate force more effectively. The reluctance flux design cannot avoid magnetization of parts near flux circuit, or "flux leakage", which cause less effective utilization of the magnetic flux.

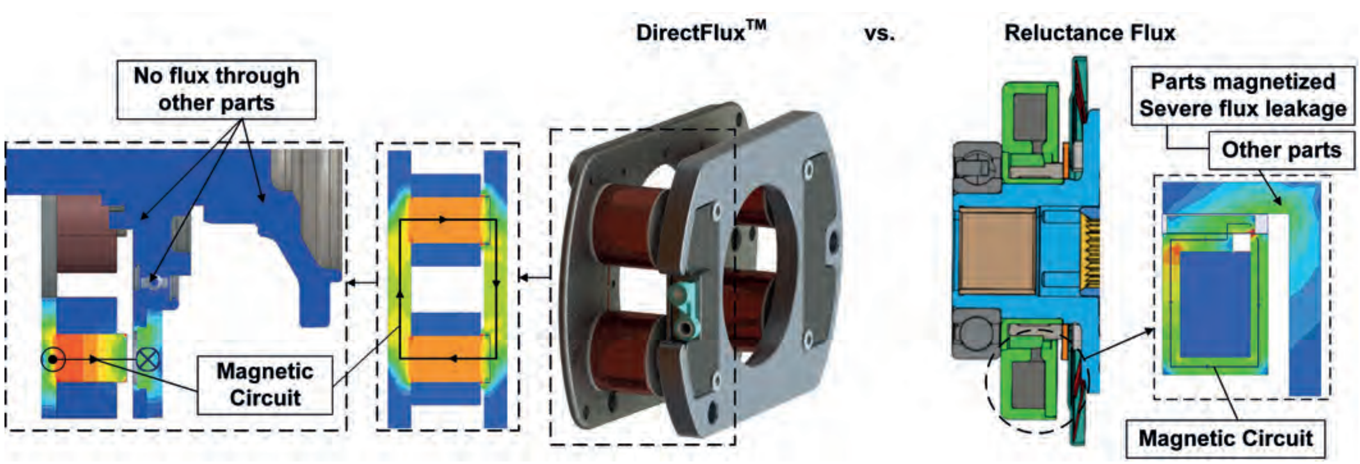


Figure 2: DirectFlux™ vs. Reluctance Flux Clutch

Because of the more effective flux utilization, the DirectFlux™ clutch has much higher electromagnetic force than reluctance flux clutch, therefore it acts 2-3 times faster, as shown in the charts.

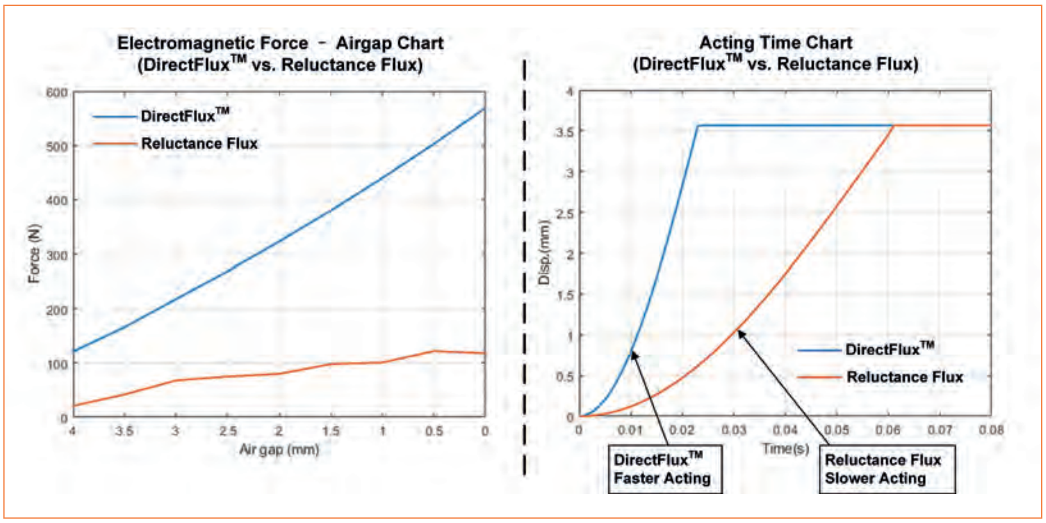


Figure 3: Performance Difference, DirectFluxTM vs. Reluctance Flux Clutch

Bi-stable Electromagnetic Clutch

The bi-stable electromagnetic clutch – still based on JJE's DirectFlux^{TM} electromagnetics – is an innovation beyond JJE's mono-stable electromagnetic clutch. It uses permanent magnets to hold the clutch in its engaged position, while still allowing the electromagnetic coil to "push" the clutch plate away while disengaging. As the clutch can self-hold at both engaged and disengaged positions, there is no need for holding current as the mono-stable clutch does. The operation current curve exactly illustrates the difference between the mono-stable and bi-stable. For bi-stable clutch, the operation only needs to provide a current pulse to switch the clutch's state (see Fig.).

The bi-stable clutch is inherently fail-safe as it won't change state in the event of loss of holding current. This feature brings the bi-stable clutch a higher safety level than mono-stable clutch for disconnect, differential locker, and transmission shift applications. As far as energy consumption, the bi-stable clutch's feature of "zero holding current" achieves the zero consumption.

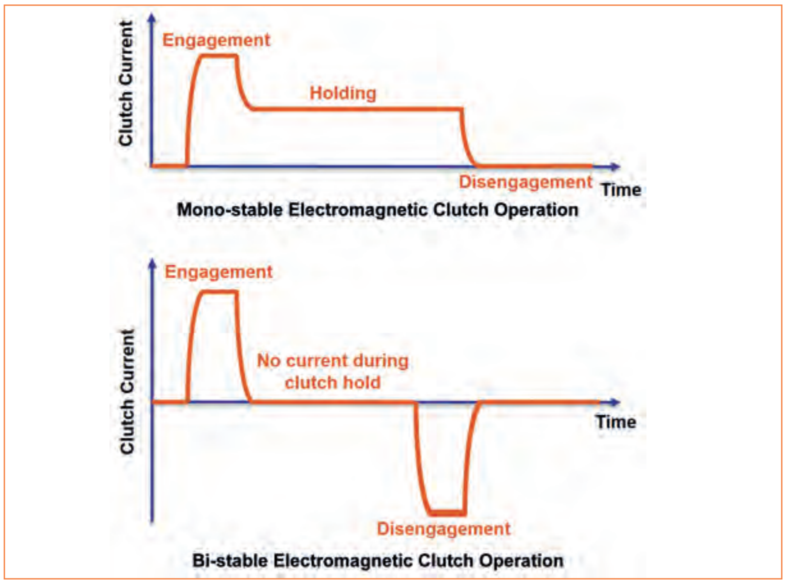


Figure 4: Operation Comparison Between Mono-stable and Bi-stable Clutch

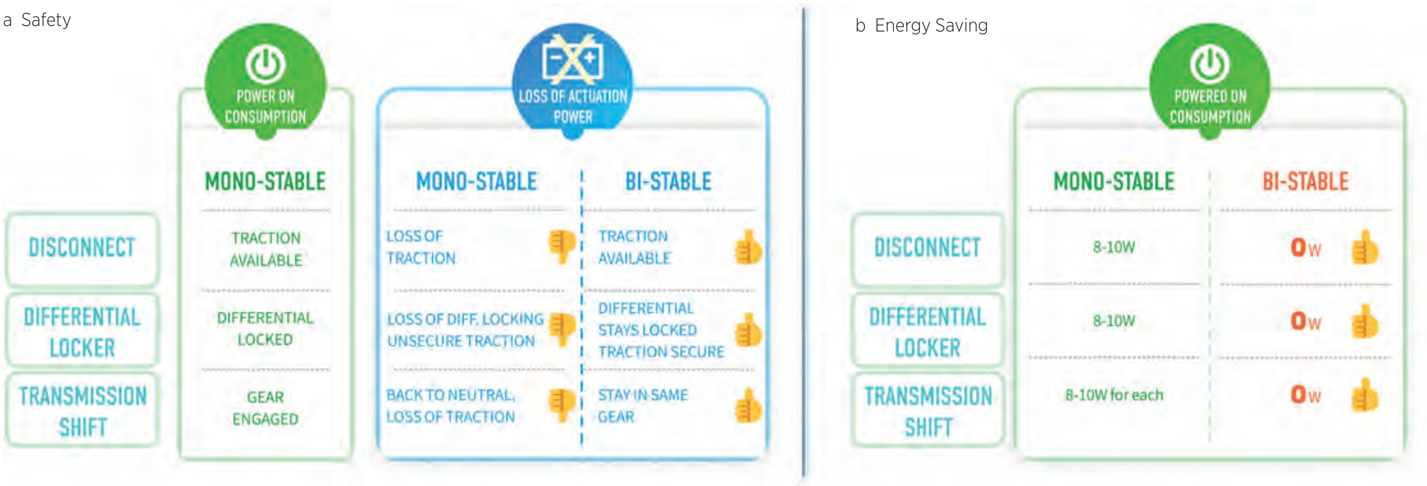


Figure 5: Advantages of Bi-stable Electromagnetic Clutch

Disconnect

JJE's mono-stable clutch has already been successfully applied on electric drive disconnect. In an offset, layshaft reduction gearbox, the disconnect clutch is on the output and is integrated with differential. Compared with disconnect on the input shaft or on the layshaft, the output shaft disconnect cuts out most mechanical losses.

JJE is also introducing bi-stable electromagnetic clutch to disconnect application. There is no holding current or power consumption when the clutch is engaged. It is mechanically fail-safe in the event of critical electrical or control fault. When the vehicle is in AWD state, all-wheel power will be maintained for consistency; when the vehicle is in the 2WD state – or secondary axle disconnected – the secondary axle won't be suddenly engaged, which would cause big jerk, or even wheel lockup at low traction.

DirectFlux™ bi-stable clutch has a great performance on the action time. The differential locker and disconnect driven by DirectFlux™ bi-stable EMDC have been tested on JJE's Dynamometer. The average action time is less than 70ms, and only current pulses are needed for engagement and disengagement.

With JJE's disconnect clutch, the drag loss reduction is remarkable. In a typical 200kW electric drive unit with permanent magnet motor, at 150km/h vehicle speed, the drag loss reduction is greater than 90%, or from nearly 8kW to less than 500W.

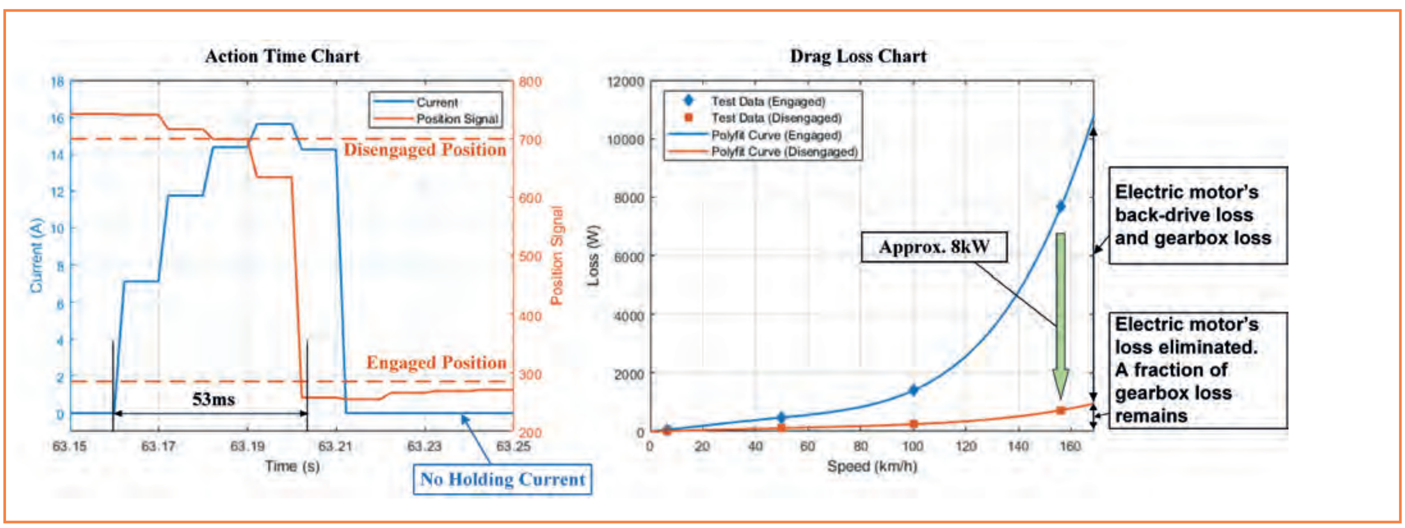


Figure 6: Performance and Benefit of Bi-stable Electromagnetic Disconnect

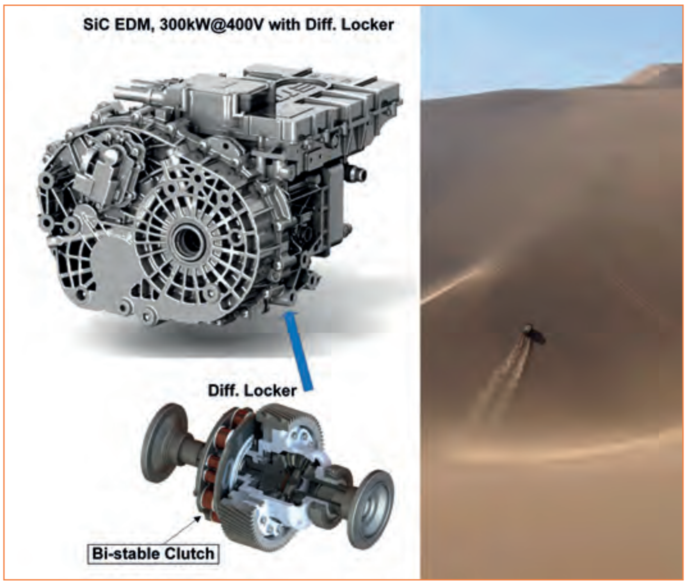


Figure 7: Electromagnetic Differential Locker for EDM

Differential Locker

JJE debuted industry's first electromagnetic bi-stable differential locker at 2022 CTI US. Bi-stable's greatest advantage is still fail-safe – in the event of critical electrical or control fault, this bi-stable feature can prevent sudden locker release and dangerous loss of traction

This bi-stable DirectFlux™ differential locker will be used in high capability pick-up trucks, SUVs and off-road vehicles in independent electric drive module (EDM) or eBeam axles. It will be launched into production in 2023 in JJE's newest 6000Nm, 300kW Silicon Carbide EDM for a high-end 4x4 SUV by a leading OEM, which features over 100% gradeability.

"JJE has been developing and producing electromagnetic clutch for over a decade", says Ping Yu, JJE's Chairman and Chief Engineer, "we have pioneered electromagnetic dog clutch's application in many areas and generated multiple global patents. The introduction of the bi-stable clutch technology is more exciting – it brings security like a mechanical sleeve clutch while maintaining or even improving all other great aspects of an electromagnetic clutch. It will further reinforce our leadership in electric drive technology".

Performance Cars to LCVs – Marelli's eAxle Family Strategy

Rahul Plavullathil, Marelli Europe S.p.A., Head of e-Axle Mechatronics Department, Electric Powertrain

Matthieu Rihn, Marelli Electric Powertrain Strasbourg, Head of Component Kit Design

Cyrille Bridier, Punch Powerglide Strasbourg, Senior Analysis and Design Engineer

1 Method overview: how to build a e-axle family strategy

1.1 Definition of a e-axle variant

Marelli's goal is to define an electric axle family strategy to cover 90% of the market. To do this, it is necessary to draw inspiration from what was generally done in the world of automotive gearboxes. A unique concept based on a given architecture must be defined. This concept will be declined in several variants, each of which will adapt to different torque ranges that will segment the market. The variants will differ from each other simply in the size of the mechanical components transmitting the torque. In each variant, a certain flexibility will be allowed, especially for the gears. In fact, several sets of gears will be available in order to realize different speed ratios, the number and value of which will be determined by a market analysis. Finally, additional systems with a design common to all variants will be available at the customer's request: parking system, cooling or forced lubrication with an electric pump, or even a two-speed system.

Each variant will be derived for several applications, i.e. for vehicles with different characteristics. It will therefore be necessary to adapt certain systems according to the maximum speeds and maximum torques to be achieved at the wheel. In this respect, the motor, inverter and gears will be defined specifically for each application, in order to comply with the torque and power requirements. However, some elements such as bearings or shafts will be common to all applications of the same variant. They will have to be calculated for the damage and stress envelope of all applications forming the variant. For some of the applications, they will therefore be oversized, but this will allow economies of scale and avoid the multiplication of part numbers within the same variant. It should be noted that Marelli will however keep a certain flexibility for its customers, and that each of these parts can be readjusted on demand, if more ambitious performance and efficiency targets have to be reached. Finally, standard interfaces will be defined for all parts or systems that are interchangeable from one application to another, such as the coupling between the rotor shaft and the input shaft of the gearbox.

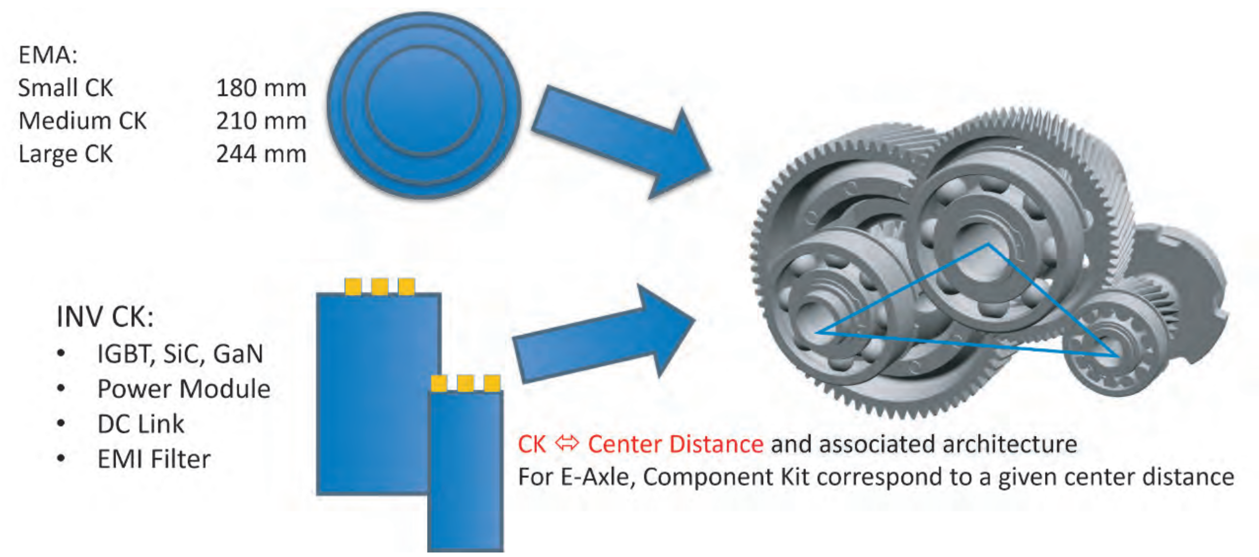
1.2 Definition of a component kit

Marelli's strategy to offer modular and interchangeable sub-assemblies is to base the 3 main components (electric motor, inverter and gear-box) on an assembly of component kits.

This component-kit approach is based on adaptable modular solutions: key design parameters are variable over a given range and can be adapted to meet customer requirements. It is also based on common technical solutions shared across different projects and application-specific components to meet unique needs. This should allow for cost reductions in first instance, owing to reduction in development time and costs, improved Bill of Material costs through scale, and Flexible Manufacturing (multiple projects on the same assembly line).

1.3 Component kit methodology applied to the gearbox of the e-axle

The electric motors available from Marelli for the current and future generation are based on individual components of 3 different diameters (stator outer diameter): 180 mm (Small Component Kit), 210 mm (Medium Component Kit), and 244 mm (Large Component Kit). Regarding the inverters, several voltage levels are available, as well as several power module technologies (IGBT, SiC, GaN). They will also vary by the choice of DC-Link, Power Module, or EMI-filter.



Picture 1: Component kit strategy for E-Motors, Inverters and Gearboxes

It remains now to define a strategy of components kit for the gearboxes. Gearboxes for electric axles can be of two types: layshaft configuration, or planetary gearsets. Still following what is commonly accepted for the definition of gearbox strategies, especially for transverse layshaft gearboxes, it will be assumed that a variant is characterized by its center distances. Therefore a unique architecture will be defined, on which a homothety will be carried out to obtain two, three or four variants of different sizes based on the same concept.

2 Application analysis based on IHS data processing

In order to define the right market segmentation for the different variants, a study of the existing and future market has been carried out based on the data provided by IHS.

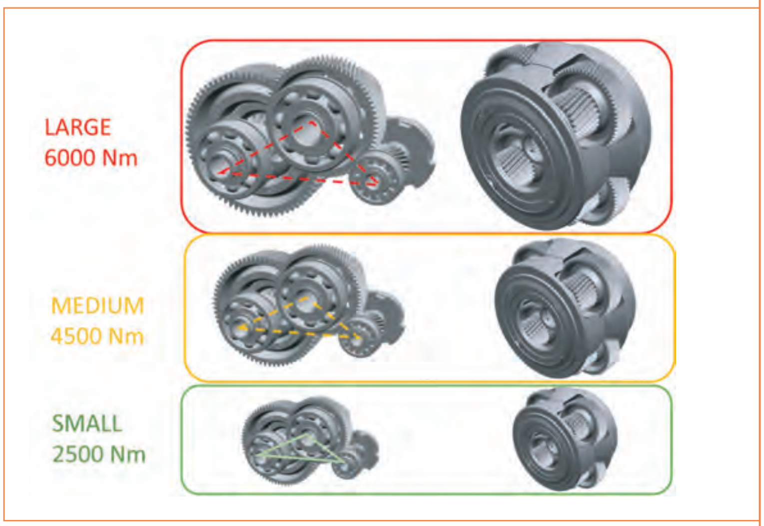
Although these data are extremely detailed and almost exhaustive, they do not include certain elements that are absolutely necessary for the sizing of the electric axles: top speed of the vehicle, Gross Vehicle Weight (GVW), ratio of the electric axle. This missing information has been completed by Marelli with the best engineering judgement possible.

3 Family strategy definition for layshaft architectures

In order to explain the method, let us first focus on the case of layshaft configuration.

3.1 Delimitation of the torque ranges for the variants

The first step is to estimate the torque limits between the different variants. The considered torque for sizing the gearboxes is the torque at the output of the electric axle. The study of the expected production volumes from today to 2027 leads us to define a small variant for torques up to 2500 Nm, a medium variant for torques up to 4500 Nm, and a large variant for torques up to 6000 Nm.



Picture 2: Gearbox variants definition

3.2 Selection of the ratios

The next target is then to pre-select several gear ratios per variant, with a double objective: firstly, to have some ratios „on the shelf", with a number of teeth for the gears that will be selected later; secondly, to define representative applications that will allow durability calculations to be carried out on elements such as gears and bearings.

For the small and medium variants, the multiplicity of available gears leads to the selection of four ratios each time (7.5, 9.5, 10.5 and 12). For the large variant, however, only two representative ratios are chosen (short gears being much more anecdotal for these very powerful applications).

In reality, Marelli will remain flexible with its customers and that any specific ratio will be possible to optimize performance and efficiency.

3.3 Association to E-Motors

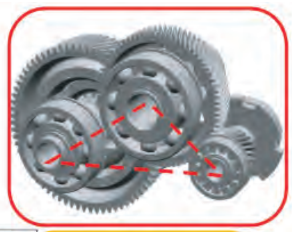
The production volumes of the addressable market from 2023 to 2027 are distributed in a matrix indicating in addition the peak torque required for the electric motor. This matrix will finally allow to allocate the different motors coming from Marelli's component kits. However, before choosing motors from these component kits, packaging constraints must also be taken into account.

Indeed, in a layshaft configuration the external diameter of the motor may interfere with the differential, which would lead to reduce the motor diameter for smaller variants. However, for planetary configurations, it is advisable to choose large diameter motor components, in order to have enough space available to pass one of the wheel shafts in the center of the motor rotor, which is the principle of a coaxial architecture.

These boundaries led Marelli to consider the following distribution of electric motors for the layshaft electric axles. Concretely, the small variant would ideally be equipped with small diameter motors (180mm). The medium variant would be equipped with 180mm or 210mm motors. And finally the big variant with 210mm or 244mm motors. The length of these motors would be adjusted each time to deliver the required torque without excess.

	Gearset Small				Gearset Medium				Gearset Large	
Variante	L	L	L	L	M	M	M	M	H	H
Output torque envelope (Nm)	2500	2500	2500	2500	4500	4500	4500	4500	6000	6000
Vmax envelope (rpm)	2133	1684	1524	1333	2133	1684	1391	1280	2133	1684
Ratio	7,5	9,5	10,5	12	7,5	9,5	11,5	12,5	7,5	9,5
LSL ratio range	7,5	8,5	10	11,5	7	8	10	12	7,5	8,5
USL ratio range	8	9,5	11	14,5	8	9,5	11,5	14,5	8	14,5

EM torque (Nm)	Volume [2023 - 2027]										Total
50	-	-	23 318	2 523	-	-	-	-	-	-	25 841
100	3 185	180 mm / 150 Nm	074	1 111 182	-	-	-	-	-	-	1 418 441
150	4 579 776	152 407	933 373	3 108 077	-	-	-	-	-	-	8 773 633
200	4 924 817	1 484 388	2 645 684	4 072 380	180 mm / 250 Nm	-	-	-	-	-	13 127 269
250	920 617	3 282 794	4 665 794	1 107 546	-	-	-	988 034	-	-	10 964 785
300	6 375 557	3 762 812	-	180 mm / 350 Nm	-	-	6 436 823	1 032 084	-	-	17 607 276
350	5 972 059	-	-	-	-	3 354 905	6 341 103	807 788	-	124	16 475 979
400	-	-	-	-	7 194 404	2 614 543	1 950 087 / 210 mm / 450 Nm	246 738	-	6 744	12 012 516
450	-	-	-	-	1 908 122	3 005 404	937 927	-	-	178 550	6 030 003
500	-	-	-	-	10 100 574	1 785 744	210 mm / 550 Nm	-	-	373 469	12 259 787
550	-	-	-	-	5 162 358	2 302 463	-	-	-	466 808	7 931 629
600	-	-	-	-	3 582 303	210 mm / 650 Nm	-	-	244 mm / 650 Nm	918 105	4 500 408
650	-	-	-	-	-	-	-	-	126 545	164 108	290 653
700	-	-	-	-	-	-	-	-	92 855	918 561	1 011 416
750	-	-	-	-	-	-	-	-	244 mm / 800 Nm	113	267 813
800	-	-	-	-	-	-	-	-	120 048	33 087	153 135
Total	22 776 011	8 682 401	8 572 243	9 401 708	27 947 761	13 063 059	15 665 940	3 074 644	491 148	3 175 669	112 850 584



Picture 3: Allocation of E-Motors for layshaft e-axles

The same work has been done for the coaxial configurations with planetary gears. In this case, only 244mm diameter motors are taken into account, for packaging reasons.

3.4 Association to Inverters

In the same way, inverters must now be allocated. The selection of an inverter is primarily based on the required voltage and power. Other considerations and factors may come into play, and it goes without saying that the inverter application matrix can be further refined.

Marelli has defined the technology roadmap based on several power module technologies (IGBT, SiC, GaN) and voltage levels (400V, 800V and 900V). For applications operating at 400V, IGBT inverters for low power and SiC inverters for higher power can be applied. It should be noted that IG-BTs may be replaced by GaN when the technology is validated.

For 800V applications, IGBT technology is no longer considered, and the applications will be covered by SiC or GaN inverters.

3.5 Gearboxes design: gears and bearings

Once these foundations have been laid, it is now time to dive into the concrete design and define the dimensions for the center distances, the number of teeth and modules for the gears and the dimensions for the bearings.

Variante	Small	Small
Output torque envelope (Nm)	**2500**	**2500**
Overall ratio	**7,803**	**8,236**
EM torque (Nm)	**327**	**310**
Center distance stage 1	73	73
Center distance stage 2	125	125
Center distance in/out min	**165**	**165**
Center distance in/out max	198	198

Stage 1 gears	PG1 / WG1	PG1 / WG1
Ratio:	1.862 (54/29)	1.966 (57/29)
Normal module (mm)	1,62729	1,57052
Normal pressure angle: (deg)	19	19
Helix angle: (deg)	23	23
Working center distance: (mm)	73.000 (Input) (calculated = 73.000)	73.000 (Input) (calculated = 73.000)

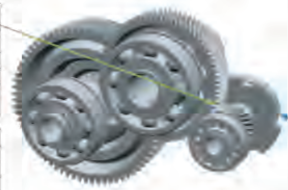
Gear:	PG1	PG1
Number of teeth:	29	29
Face width: (mm)	32,6	32,6
Effective face width:(mm)	32,6	32,6
Tip diameter: (mm)	55.800 (Input)	53.800 (Input)

Gear:	WG1	WG1
Number of teeth:	54	57
Face width: (mm)	29	29
Effective face width:(mm)	29	29
Tip diameter: (mm)	98.650 (Input)	100.200 (Input)

PG1 / WG1 Transverse contact ratio	1,79	1,751
PG1 / WG1 Overlap contact ratio	2,216	2,297

PG1 / WG1 contact stress under peak torque (MPa)	1482	1499
PG1 root stress under peak torque (MPa)	800	821
WG1 root stress under peak torque (MPa)	808	821

Example of stage1 gears and input roller bearing for 2 ratios of the small variant.



Variante	Small	Small
Output torque envelope (Nm)	**2500**	**2500**
Overall ratio	**7,803**	**8,236**
EM torque (Nm)	**327**	**310**
Center distance stage 1	73	73
Center distance stage 2	125	125
Center distance in/out min	**165**	**165**
Center distance in/out max	198	198

Bearing B1 reference	6306	6306
Type	DGBB	DGBB
Dimensions	30 x 72 x 19	30 x 72 x 19
Location	input axis @ housing side	input axis @ housing side
Dynamic load rating (N)	26700	26700
Static load rating (N)	15000	15000
Mass (kg)	0,346	0,346
ISO76 static safety factor (peak torque motor mode)	*2,227*	*2,264*
ISO76 static safety factor (peak torque regen. mode)	*1,807*	*1,846*

Picture 4: Gearbox design

The choice of the number of teeth to obtain a given ratio is guided mainly by NVH criteria which aim to avoid the superposition of the mesh orders with the harmonics of the frequencies generated by the electric motor and the inverter. These criteria will not be detailed here, but picture 4 gives examples of the number of teeth chosen to obtain the desired ratios. First, care should be taken to choose numbers of teeth that allow realistic modules and are compatible with the expected stress levels. These stress levels and the safety factors will then be calculated more precisely with the Romax software.

In the same way, a first choice of bearings allowing to obtain contact pressure values lower than 3200 Mpa at peak torque is made.

4 Conclusion

In conclusion, Marelli Electric Powertrain Strasbourg has laid the foundations for architectures that meet all market demands, while taking into consideration the constraints of family strategy that will allow a certain standardization of products.

This study has been carried out for both layshaft and planetary gear architectures.

The next steps in defining the component kits will be to structure the ancillary systems offered on demand, such as parking systems and pressure lubrication systems.

5 Marelli Electric Powertrain Strasbourg

As an innovative and high tech company with an integrated approach to vehicle energy management, Marelli has developed a complete, modular portfolio of leading edge technologies to control, manage and optimize the energy balance in electric vehicles.

Leveraging its combined competencies in e-powertrain and thermal solutions, the company offers a full selection of single components, as well as subsystems, up to solutions for the management of complete integrated vehicle energy management system.

E-axles is one of the key systems of electric vehicles.

Marelli and PUNCH, a supplier for the development, integration and manufacturing of driveline and powertrain solutions, have a joint venture focused on a system approach for optimized integrated e-axle solutions.

The Joint Venture Marelli Electric Powertrain Strasbourg will develop and assemble e-axle systems and be targeted specifically toward the markets in Europe and the Americas. The company will have a facility for production, prototyping and testing on-site in Strasbourg.

Marelli Electric Powertrain Strasbourg is growing organization with start-up mindset and solid foundation in design, development and manufacturing of gearsets, inverters and electric motors. It leverages Marelli's partnership approach to customers and strong integration with parent companies to deliver fully optimized e-axle systems.

Development of a Multi-Speed Two-Drive-Powertrain

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An electric Two-Drive-Powertrain using two electric machines is presented, which allows a highly efficient over all usage. The multi-motor approach achieves a downsizing effect, when one motor is deactivated during moderate driving. The novel features of the powertrain are its electric synchronized dog clutches and its two highly overloadable electric machines, each connected to a two-speed sub transmission providing a total of four different electric speeds. This arrangement enables full torque support during shifting processes. In addition, the waste heat from the inverters and the electric machines is used for heating the transmission oil under cold environmental conditions, thus increasing efficiency. Furthermore, the possibility and advantages of adding an internal combustion engine mechanically linked to both sub transmissions and its realization in a public founded project is addressed.

Keywords: multi speed, two drives, DRT, TDT, oil-conditioning, mode shift map

Introduction

Increasing efficiency is a major target in the development of electric drivetrains. In parallel to established BEVs with one electric motor and a fixed transmission ratio, multi-speed [1, 2] and multi-motor [3, 4, 5] concepts are gaining importance. At the IMS of the TU Darmstadt, research is focused on multi-motor and multi-speed drives called TDT („Two-Drive-Transmission“). These electric drives combine high efficiency and performance by using a downsizing effect, according to which a highly utilized electric drive can be operated more efficiently than a large one in its corresponding partial load.

The conceptual benefits of an all-electric concept with two small electric machines with two speeds each, called TDT22, have already been outlined in [6]. Efficiency advantages of up to 8.3% were identified for urban use compared to a benchmark fixed speed BEV. For short and slow driving, there is almost no alternative to a BEV from an ecological point of view. When it comes to long range, [7] stated that it is currently not reasonable to realize high ranges by using larger and heavier batteries. The battery capacity of BEVs capable of reliably reaching distances greater than 500 km increases to more than 100 kWh. A current P2 hybrid concept with optimized energy storage sizes and propulsion machines shows potential to reduce the CO_2 footprint from cradle to grave because of its smaller battery. To achieve this, however, it must be charged regularly and driven mainly electrical. In addition, there are user benefits such as rapid refueling e.g., using renewable fuels in the future if an even longer distance is to be covered.

With these potentials in perspective, this paper will focus on the development of a hybrid version of a TDT22 already mentioned in [8]; a TDT4LR („Two-Drive-Transmission for Long Range“). This concept is based on a DRT (Dedicated Range-Extender Transmission) and is currently being developed and built in the public funded Project DE4LoRa for a dedicated use case.

1. Development

The vehicle being developed in DE4LoRa is designed for a typical German average user and leaves a minimal environmental footprint. According to the “Kraftfahrt-Bundesamt” [9] the 101-110 kW power class contained in 2020 by far the most new-registrations in one of the discrete subdivisions. This number was only topped by the open-ended category of more than 151 kW. At the same time, the most frequently registered class was the rather unspecific one of SUVs, closely followed by the C-segment [10]. As the former is not suited for an ecological vehicle, the focus is on the latter. According to a study from the Federal Ministry for Digital and Transport called “Mobility in Germany” surveyed in 2017 [11], approx. 80% of passenger car trips covered less than 20 km, with only approx. 30% of the total mileage of a vehicle reached on short distances of less than 20 km in total. Therefore, the development of the drivetrain was focused on this use case (e.g., daily commute to work and twice a year a long trip on vacation).

A BEV designed for this user profile needs a large and heavy battery, barely using its full capacity. In contrast, the DE4LoRa concept was developed to cover ranges of up to 100 km electric combined with the high efficiency benefits of a TDT22. To reduce complexity, two identical electric machines have been designed, each realizing a continuous power of at least 40 kW to enable highly efficient driving with one EM during moderate cycles like the WLTC. Furthermore, they can jointly provide 120 kW peak power for short sporty driving. To enable shifting without interrupting traction even at high accelerations, both electric motors are able to provide 120 kW each for the very short duration of a shifting process. The development of these permanent magnet synchronous machine is further described in [12].

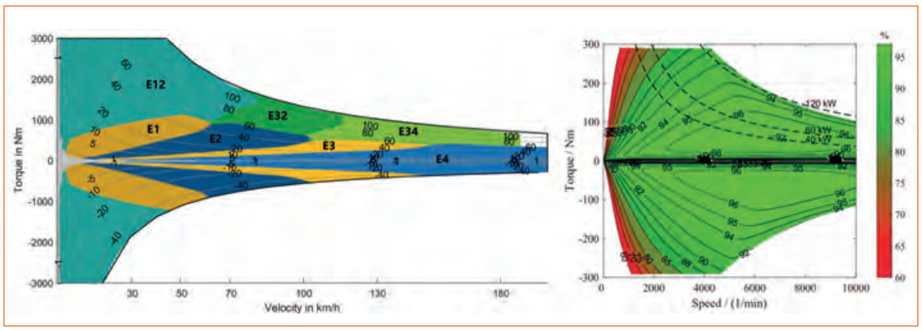

Figure 1: Mode shifting map for different vehicle speeds and torques at the wheels (l); Simulated efficiency map of the PSM designed for the DE4LoRa-Project [12] (r)

Assuming constant transmission efficiencies, as well as a constant battery voltage and temperatures, a simple heuristic operating strategy for electric modes can be created. The resulting shifting map for this TDT22 is shown in Figure 1. The advantages of four different electric gears compared to a non-shiftable transmission are described in more detail in [6].

In an overall assessment of the electric consumption, the relatively low transmission losses cause a significant proportion of the total losses due to the high efficiency of power electronics, electric machines, and batteries. Therefore, electrically synchronized dog clutches were chosen to avoid friction losses which would occur in mechanical synchronization units. Furthermore, the losses of a transmission increase with higher viscosity of the transmission oil e.g., at low temperatures. To keep the efficiency as high as possible after a frequently expected cold start in winter, it can be beneficial to use the waste heat from the electrical components for conditioning the transmission oil. To further increase electrical efficiency, DE4LoRa also uses a rather high voltage level up to 820 V. Since the efficiency drops with the voltage over the state of charge of a battery, the latter should be kept as high as possible. In this concept, the electrical consumption in the WLTC increases by approx. 5% if started at an SOC of 25% compared to 90%.

For the use case described above, highly efficient short-range electric driving alone is insufficient. To improve the concept for occasional long-distance, a monovalent methane gas engine is added. This engine can be connected to both sub-transmissions with different gear ratios, as shown in Figure 2, enabling multiple parallel and serial hybrid modes. This integration combined with the high dynamics and performance of the electric drive allowes the gas motor to be operated in a phlegmatized manner, thus minimizing emissions and maximizing its efficiency. In addition, methane provides a high energy density per carbon atom, can be produced synthetically more efficiently than liquid synthetic fuels, and, unlike hydrogen, is easy to store and benefits from an existing infrastructure. Optimizing the gear ratios of this transmission involves a compromise between highly efficient electric and SOC-neutral hybrid modes, with SOC-neutral consumption being more sensitive to changes. It has been shown that an electric overdrive provides efficiency benefits, resulting in a top speed of 180 km/h in SOC-neutral operation in the third, not fourth gear.

2. Oil-Conditioning

During optimization constant transmission efficiencies were assumed between 96.9 and 97.8% for each mode-dependent combination of two spur gears. In real applications, these efficiencies depend not only on the acting speeds and torques but also on the viscosity of the gear oil and thus its temperature. With lower temperatures, the transmission losses increase disproportionately. The inverter and electric machine generate usually unused waste heat. If the lubrication concept of the transmission already uses an oil pump, the heat can be used for conditioning the oil by adding a heat exchanger.

The potential depends on several parameters like the current efficiencies, the water flow rate, and the oil used. To investigate the possibilities for this project, an analytical transmission loss model was created, which includes the viscosity of the gear oil in its calculations of churning losses, meshing losses, sealing losses, and bearing losses. Not only the load-carrying elements but also all co-rotating parts for every mode are considered. This model is supplemented by a lumped-element thermal model of all transmission components. All loss effected transmission parts as well as a water-oil heat exchanger and 30% of the losses of the electric machine at the input shafts are implemented as heat sources. Thus, both the self-heating of the gearbox and the heat transfer from an external water circuit is represented.

Two different transmission oils and two different scenarios were considered, using only modes with one EM for simplification. First, a common rather more viscous transmission oil was modeled corresponding to a SAE 80W90. Figures 3 and 4 show the simulation results for a cold start in the Artemis Urban cycle with 0 °C ambient temperature.

The efficiency changes of the transmission are shown in Figure 4; in blue without using the heat exchanger, in red with a water flow rate of 1 l/min. In addition, the efficiency with an oil temperature of 60 °C at the beginning is shown as a benchmark in gray. Figure 5 shows the most relevant results of the simulations. The heat exchanger in this configuration enables an efficiency advantage of 1.3% which is noticeable, but significantly lower than the efficiency with already warm oil. If the gear layout and the acting surface pressures allow the use of an oil with (very) low viscosity, much higher total savings are possible. On the other hand, the benefits of conditioning are hardly noticeable with this lubricant. Finally, the potential in a WLTC at 20 °C ambient temperature is evaluated, whereby the heat exchanger leads to an 0.6% lower energy consumption. Prospectively, the usage of additional

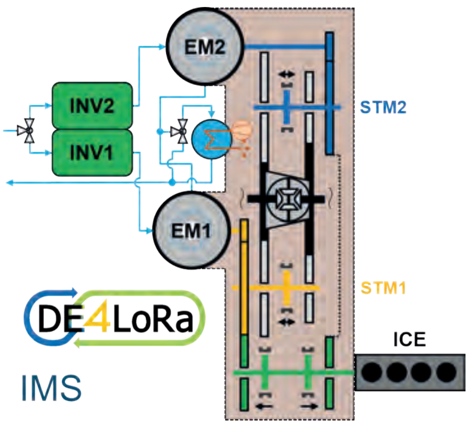

Figure 2:
Sematic layout of the powertrain designed in DE4LoRa with oil-conditioning (l) and visualization of the gear set (m: front, r: right)

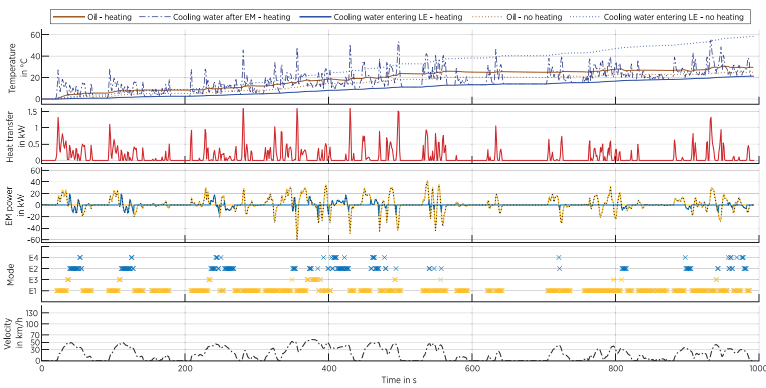

Figure 3:
Simulation of the Artemis Urban cycle with a cold start, SAE 80W90 transmission oil and 0 °C ambient temperature.

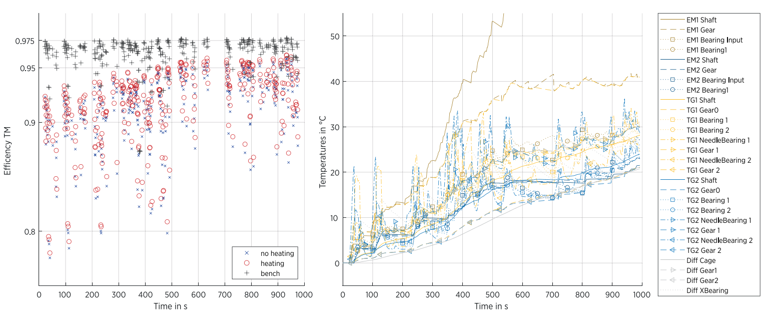

Figure 4:
Simulation results with 80W90 in Artemis Urban at 0 °C ambient temperature: Efficiencies of the transmission (l); Temperatures in the transmission with active heat exchanger (r)

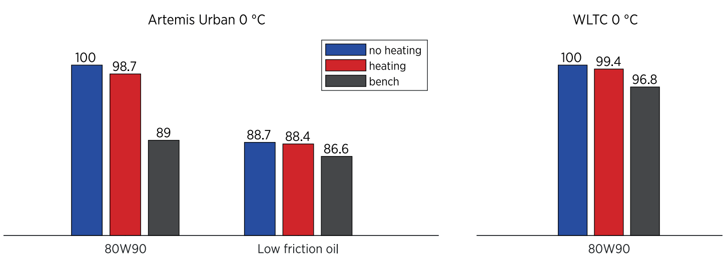

Figure 5:
Normalized efficiency comparison of simulation results

waste heat by other consumers, such as an internal combustion engine, could achieve greater improvements. Furthermore, the effect could be improved by further optimizing the flow rates and quantity of water and oil.

Conclusion

The concept idea for a hybrid TDT22, the development process as well as the results achieved in the DE4LoRa project so far were stated. It is tailored to fulfill the requirements of an average German driver with minimized ecological footprint. It covers short distances in highly efficient electric driving due to the advantages of four speeds, uses a comparatively small and thus light battery, a high voltage level, and supplementary oil conditioning. To maximize efficiency, it is recommended to keep the SOC as high as possible. In addition, the effect of transmission oil conditioning was examined in more detail, and in summary, the loss reduction potential depends primarily on the oil used. If a conventional transmission oil is used, there can be considerable efficiency benefits for short trips and cold ambient temperatures – 1.3% in this example. However, if the design or maintenance strategy allows using a low-viscosity oil, the effect if an oil conditioning decreases significantly and combined with longer driving distances and higher ambient temperatures, becomes unnoticeable small.

Gratification

We want to thank Max Clauer, Zhihong Liu, and Arved Eßer for theirhelpful feedback and advice.

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Electrification in Times of Scarce Resources

Electrification is taking off: there are more EVs to choose from; platform concepts are becoming more important, and competition among e-drives is lively. The first e-trucks are arriving on the US market – and the jury is still out on how long ICEs have left to live. And which energy forms are reliably available in the future? At this year's CTI Symposium Novi, 18 – 19 May 2022, these were just some of the topics up for discussion.

Live again at last! In May 2022, after two years of online CTI Symposia USA due to Covid, drivetrain experts got together in Novi to discuss the latest industry developments and outlooks. A lot has certainly happened in those two years. As chairman Hamid Vahabzadeh put it in his introduction: “We are witnessing an unprecedented change in the industry… just a few years back, we were wondering how long transmissions would still be around.
Now everything is about electrification.”

Electrification has now also entered series production in the pickup trucks in the US market. Examples include Ford's F-150 Lightning that just went into production, or the Chevrolet Silverado – and that's just the beginning. All the more reason to devote a separate panel discussion to the topic, entitled: What does it take for EV trucks to go mainstream? Moderated by Ulrich Walter, this entertaining discussion on day Two of the symposium featured Brett Smith from the Center for Automotive Research (CAR), David Schankin, General Motors, Thomas McCarthy, Ford, and Alexander Edwards, Strategic Vision.

How do you sell electric trucks to customers?

The demands placed on trucks are different and often higher than those for other cars. Trucks are utility-oriented and must be able to transport heavy loads and tow trailers. As Alexander Edwards put it: “A truck needs to be a truck first; it must get the job done. Customers will not pay for a compromise.” Thomas McCarthy believes it's not enough for e-trucks to tick all the usual boxes – they need to tick a few more as well. On the one hand, he said, you have the early adopters, who expect up-to-the-minute connectivity. On the other, you have classic truck customers such as farmers, who see them as tools. During the discussion, participants also cited the e-trucks' ability to provide backup power for homes as a potential add-on benefit, for example during blackouts in winter etc.

Naturally, range issues crop up right away with trucks. David Schankin said trucks need a range of 200 to 300 miles, even when towing a trailer. But on average, that trailer reduces range by roughly half – and cold weather takes a further 30 percent. That fueled a discussion on how best to address this drawback: larger batteries, or more fast charging opportunities? Brett Smith said the latter was probably more important; there was no adequate infrastructure at the moment. McCarthy brought up another possibility: Range Prediction. This feature helps users make better use of their available range, and is already in series production.

Smith added another intriguing thought: From reading e-truck reviews, it's clear that they tow better and drive better… yet there are still cynics who only see the downsides, like lower range etc. All the same, he remains upbeat: “It's just getting started.”

After this roundup of the panel discussion on pickup trucks, a brief look at the ten plenary lectures reveals that they were roughly split into three fields:
OEM electrified drive solutions, resources and infrastructure, and current developments in electric motors.

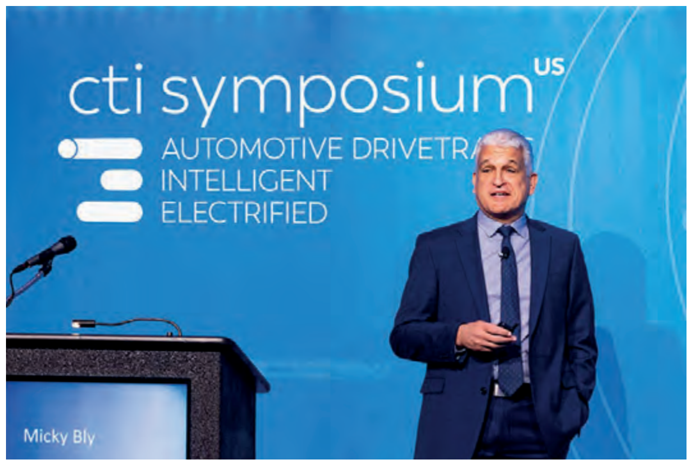
Kent Helfrich, President GM Ventures

How OEMs are electrifying their vehicles

General Motors is already in the midst of its electrification process, as Kent Helfrich, President GM Ventures, explained in his plenary lecture. Our path to zero crashes, zero emissions, and zero congestion. For GM Ventures, he said, one task involved making GM a platform provider, via suitable investments in new technologies. Helfrich presented two solutions – ‚Ultium' and 'Ultify'. ‚Ultium' is a platform concept that includes the battery, power electronics, and all electrical drivetrain components. The batteries are designed for maximum flexibility in all aspects, including battery module counts, spatial configurations and cell types; you can even retrofit modern cells throughout the life cycle. The second solution, ‚Ultify', is a software platform designed to enable functional scalability, again throughout the vehicle's life cycle. Helfrich made a clear statement: GM is striving for zero tailpipe emissions by 2035, and carbon neutrality across all company processes by 2040.

Dave Filipe, Vice President Vehicle Hardware Modules, Ford, spoke on How fast, how far, which flavors – the transition from ICE to electrification. Besides the trend toward BEVs, he still sees a need for HEVs, saying not all customers wish to, or can, move to BEV. Interestingly, Ford uses multiple architectures for its HEVs: the Ford Maverick pickup, for example, has a power-split hybrid drive; other models are parallel hybrids. Ford has recently launched its pure-electric F-150 Lightning truck and is following a 'scalable platform' strategy. Felipe also pointed out the considerable synergies between control strategies in BEVs and power-split HEVs, saying the software architecture was basically the same and was functionally adaptable. Since Ford was still committed to HEVs, however, he 'feared' that ICEs would need further improvement work too.

Micky Bly, Senior Vice President Global Propulsion Systems, Stellantis, also sees an initial need for different levels of drive electrification, as explained in his presentation (e)volution – leading the way the world moves. He said Stellantis expects to sell about 50% BEVs in the US and 100% in Europe by 2030. Stellantis is also adopting a flexible platform concept for BEVs, with the following categories:
Small (City Mobility), Medium (Premium), Large (AWD Performance & American Muscle) and Frame (Capability & Practicality), with electric ranges of either 300 or 500 miles. Depending on the application, Bly said, Stellantis plans three electric drives from 70 to 330 kW with either 400 or 800 V. The company also plans to market solid-state batteries as early as 2026, and would offer around 10,000 fuel cell delivery trucks per year from 2024 onward in the EU. Stellantis aims to launch its Ram 1500 BEV e-truck in 2024, and will deliver a fuller portfolio of technology with more range, power, productivity and convenience".



Kent Helfrich, President GM Ventures

As Alexander Dolpp, Head of Powertrain, Mercedes Benz R&D North America, made clear, his company has a strict EV-first approach. In his presentation How Mercedes-Benz uses software to ensure the best electric drive experience, he explained that Mercedes plans to make the transition to BEV-only by 2030. By 2025 every model will be available as a BEV version, and Dolpp expects 50% of all vehicles sold will have a plug. PHEVs would also still be on offer; in the 4th generation, defining features include an electric range of around 100 km. Dolpp noted that Mercedes was focusing increasingly on partner-ships: The company was cooperating with Geely on ICEs, and had tasked Magna with the production of small dual-clutch transmissions, with a new generation due to launch in 2025. Mercedes will build its new, scalable 'ultra-high-performance axial flux e-motors' at the Berlin plant, using technology acquired from Yasa Ltd. Looking forward, Dolpp said that using software developed in-house, Mercedes would be able to give electric drives bespoke characteristics. Besides Driving & Charging, the MB OS also covers Infotainment, Automated Driving and Body & Comfort. So even when hardware was shared, sub-brands such as Maybach or AMG would still retain their individual characters.

Dave Filipe, Vice President Vehicle Hardware Modules, Ford

Resource and infrastructure challenges

Discussion with the Plenary Speaker of 18 May 2022 (from left to right): Chairman Hamid Vahabzadeh (AVL), Uwe Dieter Grebe (AVL), Don Hillebrand (DoE), Kent Helfrich (General Motors), Micky Bly (Stellantis), Dave Filipe (Ford)

The ability to electrify is at least as important as the will to electrify. Don Hillebrand, Division Director of Argonne National Laboratory, began his talk DOE transportation decarbonization pathways by saying: "It's important to talk about which resources we have". He showed that China currently produces around two-thirds of battery components, while the United States is consistently in the single-digit percentage range. The US Bipartisan Infrastructure Law foresees investments of around $7 billion to promote battery materials processing, manufacturing, and recycling. A further 7.5 billion are earmarked for developing the charging infrastructure, and car manufacturers have committed to investing 71.5 billion dollars in electrified drives by 2030. In March 2022, the USA signed a battery alliance with the EU. Hillebrand said that meeting the net-zero CO_2 target by 2050 would call for tremendous effort and societal collaboration. This included creating a 'pull effect' in the market by offering reliable, affordable products that customers really want to buy.

In his plenary lecture, Uwe Dieter Grebe spoke on Reaching net-zero CO_2 with tailored regional strategies while also addressing the topic of energy security against the current political backdrop. Grebe pointed out that we should take a global view of emissions. Since CO_2 emissions from Asian manufacturers were high, for example, Europe was considering putting a price tag on those emissions downstream. The speaker also addressed the dilemma whereby the regions best placed to generate renewable electricity are often those that need it least, and viceversa. This is why he believes x-fuels are also justified. Like many of his colleagues in the industry, Grebe thinks BEVs are best suited for small vehicles through to vans, with hydrogen for long-distance applications and e- and biofuels for focus industries such as shipping and air transport. Running combustion engines on hydrogen could also make sense, in conjunction with modified DHTs that would optimize NO_X emissions in transient operation. In general, Grebe noted, the global potential for producing regenerative energy exceeds demand.

Besides BEVs, Hyundai is also clearly committed to FCEVs, as Jerome Gregeois, Director Commercial Vehicles Development at Hyundai Kia Technical Center America, explained in his speech Hyundai Motor Group commercial vehicles mass electrification.

While Hyundai was already backing BEV applications for city buses in Korea, it has also set up a dedicated business unit called HTWO to advance fuel cell technology – not just in cars, but in air taxis, generators, airplanes and ships as well. By 2030, the company planned to produce 700,000 fuel cells annually, 500,000 of them for FCEVs. Series applications for heavy-duty trucks already existed in Switzerland, where Hyundai would deliver 1,600 vehicles to customers by 2025. And starting in 2023, thirty Class 8 Xcient Fuel Cell Trucks would be entering service in Oakland, California. Why the commitment to fuel cell? Because it takes just 8 to 10 minutes to refuel a heavy-duty truck, Gregeois said. That equates to around 500 miles for a 6x4 tractor, or 250 miles for 4x2 cargo. Regarding Los Angeles for example, he cited 7-8 miles per charging minute for fuel cell, compared to 2 miles for BEV. He expects to see at least 15 miles per minute soon and added that, unlike BEV, fuel cells were not significantly affected by low ambient temperatures.

Mayank Agochiya, Director FEV Consulting, spoke on CO_2 regulations for the heavy-duty sector and potential compliance approaches. For the US market, he said, product planners had three factors to consider: CO_2 regulations, pollutant regulations, and local regulations. Agochiya then made an interesting comparison about the best way to meet regulations up to 2027. Was it better to invest more in improved ICEs, or in BEVs? If I want to save one percent on fuel or energy, what are my additional costs per vehicle? In his comparison, BEV came out on top across all applications with an additional per-vehicle cost of 627 dollars, compared to 1017 dollars for ICE. But as the speaker noted, these figures also depend on which credit multipliers legislators foresee for BEVs – a regular discussion topic in the USA. Nevertheless, Agochiya concluded, as of 2027 there would be a focus on BEVs in heavy commercial vehicles too, while FCEVs would only play a bigger role from 2030 on. This would increasingly be supplemented by measures such as adapting vehicle architectures and aerodynamics.

Electric motor trends

Whether for BEVs, FCEVs, or even xHEVs, competition is rife among electric motors. At the moment 95% of traction motors use rare earth magnets, as Ali Emadi, Founder and President of Enedym Inc. pointed out in his lecture entitled Next-generation electric drive modules for BEVs: rare-earth free electric motors and state-of-the-art power electronics. Emadi said the price of neodymium had risen by 292% within two years. Switch reluctance machines (SRM) could cut costs by about half, but were not

Discussion with the Plenary Speaker 19 May 2022 (from left to right): Dr Hamid Vahabzadeh (Chairman), Ali Emady (Enedym), Craig Renneker (AAM), Alexander Dolpp (Mercedes Benz), Mayank Agochiya (FEV Consulting), Jerome Gregeois (Hyundai)

The participants of this year's symposium had the opportunity to try and test several vehicles, namely the AAM Light Duty BET, AAM Jaguar I-Pace, Stellantis Wrangler 4xe, Stellantis Grand Cherokee 4xe, Sigma Powertrain Ford Raptor and the Sigma Powertrain Sprinter Van. Moreover, the Corvette Stingray, Ford Mach-E GT and the brand new Ford F-150 Lightning were showcased in the exhibition.

easy to master acoustically – especially given the trend towards high-speed engines. During motor development, he said Enedym relied on two factors: mechanical simplification, and increasingly digitized system design. This approach permitted early development iterations which, in turn, enabled optimal SRM motor configurations, faster prototype validation, and shorter time-to-market. Enedym promised development times of just six months, as opposed to the 'traditional' one to two years. As to power electronics, Emadi concluded, the trends were "Integration, integration, integration".
Craig Renneker, Vice President Driveline Product Engineering, talked about specific electric motor development work at AAM.

As his title Increasing electric drive unit power density with high-speed motors and next level integration suggested, the speaker foresees electric motors that can run at 10,000 rpm and higher. For him, the question is: "How small can we make electric motors?" High rpm, for example, could put a strain on seals. The solution? "Don't put any seals on a high-speed shaft – no seals, no problems". As another example, Renneker cited the so-called bearing load balance. By distributing load between two opposing gears that mesh with one shaft, you could reduce radial forces – and take rpm higher still. Renneker said AAM also used direct oil cooling for the stator, thus eliminating the need for internal seals and a 'bulky' water jacket. Another interesting approach was the use of discrete components for inverters, which enabled AAM to use a compact ring inverter design. Renneker said these and other measures had enabled a whole row of industry benchmarks: a 10% advantage in mass and losses, and 40% higher volumetric efficiency and power density.

How do you deal with the messy middle?

Finally, here are some insights from the Day One expert discussion, which anticipated many of the issues that the conference subsequently examined. The discussion title was Messy Middle: What is the strategy between now and 2030? The participants were Michael Maten from GM, Charles Poon from Ford, Abbas Nazri from Wayne State University, and Jay Hwang, S&P Global Mobility. The moderator was Ulrich Walter once again.

The question of how long ICEs still have to live popped up straight away. Michael Maten said we need to switch to BEVs quickly, while Abbas Nazri thought it depends on what infrastructure(s) would be available.

Jay Wang expects further ICE applications for the same reason, saying some markets would not be able to handle an EV infrastructure. For Charles Poon, the effects of different air temperatures on electric drive performance are another major challenge. Despite his pro-EV stance, Maten believes there is far too little renewable energy to power EVs in a clean way, saying much more investment is needed. For Poon, 'time anxiety' is another thing we will need to address at some point – by providing sufficient fast-charging capacity.

Issues around raw materials and resources also recurred in the discussion. Maten said GM was very committed to recycling, but in the long term industry and society would need to become independent of today's sources, such as China. Jay Hwang noted that battery prices were currently 'going crazy'. Normally, economies of scale would push prices down; at the moment the opposite was happening.

So should we go with FCEVs or PHEVs instead? Hwang believes a good balance between EVs and PHEVs is important, while Nazri believes ICEs will also play a role into the next decade. As for fuel cells, Michael Maten spoke of 'certain geometry issues' in passenger car applications but conceded that fuel cells made sense above this segment.

See you in Berlin and Novi!

The podium discussion in a sense anticipated what the plenary lectures confirmed later on, namely that there is no easy answer to the question of which drive is best, and that ultimately it's about more than drive concepts alone. As Corona, the ensuing supply chain restrictions, and the Ukraine war have made painfully clear, further steps will depend on which energies and raw materials will be available. That said, the will to replace fossil fuels with regenerative energies has never been stronger. This is why all stakeholders in society need to work together – an insight that was expressed repeatedly.

Despite these big challenges, after two years of restricted attendance, it was a great experience for the experts at CTI Symposium Novi 2022 to be able to exchange ideas in person again. They could experience 10 plenary speeches, meet 35 international exhibitors and sponsors and experience several technology demonstration vehicles.

The next CTI Symposium Novi is already scheduled for May 2023, and we cordially invite you to attend this year's symposium in Berlin (5 – 6 December) too.

Interview

“We Need Decentralized Intelligent Sensors but High-Level Centralization”

Dr Sven Beiker, Silicon Valley Mobility | Stanford Graduate School of Business

Accompanying vehicle electrification, new E/E architectures, intelligent sensors, smart devices in cars etc. change the way vehicles and user interfaces are developed. We held a short interview on this with our advisory board member Sven Beiker from Stanford University, California.

Dr Beiker, there is an idea that sensors can become ‘smart’, thus improving ADAS and autonomous driving functionalities. What are the advantages of this decentralized approach?

For one thing, it’s a matter of managing the sheer data volume. Especially with tomorrow’s sensors, laser systems etcetera, you need to handle enormous amounts of data, either via the CAN bus – if it can handle it at all – or through Flexray for example. Now if you sort the data where it originates and accumulates, and focus only on the important content, you can design much more elegantly and with less complexity. But that means sensors need to be smarter so they can distinguish between important information, and sheer quantity. Another point is simply to enable more modularity, and to exchange information only via standardized interfaces.

At first glance, the trend towards reducing the number of ECUs and centralizing functions in software domains seems to be heading in the opposite direction. Would that conflict with these distributed sensors?

To handle a very complex modular system, you need high-level centralization. If you had 100 control units in a vehicle, 100 black boxes if you will, that would be a tremendous level of complexity. That's why we need precisely defined interfaces and very clear task assignments, with a centralized system for implementation and final decision-making. However – and this is not a contradiction – the provision of information through sensors can be decentralized, because we have so many different specific requirements. With autonomous driving you're going to have a laser, cameras, or radar – all with their different tasks. With electromobility you're going to have voltages, current flows, moments, and temperatures. But to really deliver standardized information, these sensors will need to be intelligent. In a way, it's similar to ourselves: human beings have many ways to gather information, via our senses. But the decisions are made centrally, in our brain.

Another trend is the way smartphones are taking over in-car functionalities – for instance, when Google Maps uses vehicle sensors. To what extent do you think smart devices will replace car functionalities?

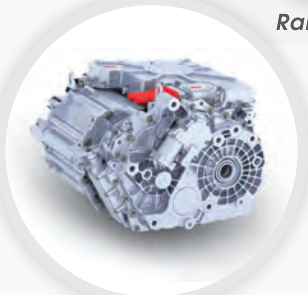
Many things are possible, as long as they are not safety-relevant. But tasks like steering or braking, controlling the powertrain and so on will definitely not be left to consumer electronics, no matter how capable they are. The requirements for tablets or smartphones are just too different. But in non- safety-critical areas it's a different story. A lot will happen there. Apple, for example, showed where things are going at their developer conference this summer. It‘s no longer just about the center console as a display for navigation, MP3 and so on. It will also be about what we see on the instrument panel behind the wheel: things like speedometer, range etcetera. So the smartphone takes information from the vehicle, for example road speed or battery status, then sends it to the display that replaces the OEM‘s instrument panel. This is where providers like Apple want to come in. They want to offer an integrated customer experience, a customer journey that no longer comes from the car manufacturer, but is provided via a smart device.

driving the next

Electric Motor

Range Extender
Generator

Inverter, IGBT and SiC
MOSFET 400V & 800V



eDrive Assembly
Layshaft Offset

Commercial Vehicle
Hybrid System

eDrive Assembly
Planetary Co-axial

LD & MD Commercial
Vehicle eDrive
System, Longitudinal

Electromagnetic
Disconnect
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