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e-mobility: steel and aluminium in a smart material mix

Casting trends in the automotive industry will feature among the crucial focal themes of the world's leading foundry trade fair GIFA held as part of the Bright World of Metals in Düsseldorf from 12 to 16 June 2023.

Elon Musk with Tesla is a prominent example of e-mobility re-shuffling the cards in the automotive market. But experts doubt that newcomers will ring the death knell for established automakers. "The Chinese and Tesla are far from delivering the growth they promised. Well-established producers like VW, BMW, Mercedes and GM have been able to stand their ground very well on the markets," as Franz-Josef Wöstmann, Head of the VDI Conference "Casting Technology and e-Mobility" in Bremen in October noted with reference to current sales statistics. Wöstmann, Head of the Department for Early Detection and Exploitation of Technologies at Fraunhofer Institute for Manufacturing Technology and Applied Material Research – IFAM in Bremen, reminds us that back in 2019 Tesla still seemed the unrivalled No. 1 with 245,000 e-vehicles. Since then the e-vehicle pioneer has been able to multiply sales by a factor of 4 to some 936,200 vehicles in 2021, but over the same period VW has leapt from the middle ranges to almost first place by catapulting sales from 41,000 vehicles in 2019 to 762,000. "VW has multiplied its worldwide e-vehicle sales more than ten-fold within three years. Not even Tesla has succeeded in making such a quantum leap," adds Wöstmann providing food for thought. Other long-established players like BMW and Mercedes have also succeeded in massively increasing their output. And these established players – unlike the e-mobility newcomers – have done so while also keeping an eye on their standard production. But as the statistics of the past few years show, they have very good cards and are either massively catching up, or already overtaking sales of the new entrants.

Also interesting to follow are the developments of Chinese competitors. It is true that BYD managed to double its sales but fell back from 2nd to 3rd place nevertheless. BAIC even fell to near the bottom. "The Chinese were unable to leverage their pole position despite being located on the main e-

mobility market," says Wöstmann. By contrast, tradition-rich US brand GM, which did not even figure in the 2019 statistics, made it to the midfield in that short amount of time.

Growth outside of Europe

In the saturated markets Germany, Europe and USA the transition from internal combustion engines to e-mobility is developing without any notable change in the total volumes of registered cars. Growth is predominantly seen in Asia and above all China. Experts agree, as became clear at the Bremen casting technology conference, that by 2030 roughly half of all cars sold worldwide will be e-vehicles. Nevertheless, 2050 will also still see many IC-powered cars on the streets – for a wide variety of reasons as Fraunhofer researcher Wöstmann forecasts. Because even then many regions in Asia, Africa and Latin America will not have the supra-national infrastructure in place required for e-mobility. Add to this, the fact that in the fields of commercial vehicles, maritime shipping and aviation e-mobility cannot be the sole solution – which is why e-fuels and hydrogen will also play a key role in the energy mix of tomorrow's mobility.

From 2035 members of the European Union have decided that no more vehicles with IC engines are to be sold in the EU. Especially the light metal casters of aluminium and pressure-die cast aluminium for car bodies and drive trains are quietly optimistic about the trend towards e-mobility, even though the casting of large-volume IC engines is declining. "E-mobility means a multitude of new castings," explains Wöstmann; housings for e-motors, gearbox housings, battery boxes, cooling systems, housing and cooling components for power electronics as well as cast aluminium coils as an alternative replacing wound copper coils in future. The Fraunhofer researcher sees little change and definitely no growth for the cast iron segment. What might be expected, he thinks, is thin-walled steel casting in the motor housing segment especially for high-torque motors with built-in cooling. At present, however, no OEM is developing anything in this direction. Not forgetting lightweight construction, which is clearly a domain for aluminium and aluminium casting especially in e-mobility.

As for the components produced by pressure die casting in future, opinions split between established manufacturers and the new "kids on the block".

While Tesla and various Chinese producers intend to conquer the market with giga- and mega-casting machines featuring over 12,000 tons of clamping force, the long-established companies are rather reserved. Wöstmann views this approach to be quite positive especially because it demonstrates the potential of casting. However, he assumes, there will only be few suppliers penetrating this market. Instead, he feels a great deal of technology potential can be tapped into with clamping forces below 6,000 tons, which allows efficient manufacturing but has lower requirements in terms of logistics, quality assurance and production safety. “At the end of the day, technological expertise and know-how will outperform gigantomania for all sorts of product versions,” says a confident Wöstmann.

Lightweight construction: smart material mix with steel and aluminium

Steel – which is in any case the No. 1 material for the high-volume body market – will also be able to stand its ground and not only for the electrical steel strip, the indispensable “backbone material” for e-motors. Premium manufacturers are also aware of the strengths of new, high-strength steel, as demonstrated by Porsche with the mixed construction of its battery-powered sports car Taycan.

Hot-formed steel protects the passenger cell in A-column, B-column, roof frame and seat cross-beam. Considered a special highlight is the end wall cross beam in manganese-boron steel. Thanks to special manufacturing processes the tube-shaped component comes with varying cross-sections. This allows maximum strength to be attained at optimised weight. The strut mount, axle mount and rear side member are made of pressure die-cast aluminium. All of these are complex components with integral functionalities, meaning several components and/or component functions are combined in one part. The shock absorber mounts exposed to particularly high loads are made of forged aluminium. The front side member combines a sheet aluminium shell construction with extruded profiles. Just under 2 m long, the sills are made of a seven-chamber extruded profile. With this seven-chamber geometry the aluminium component complies with all the stiffness requirements for side crashes and prevents car bodies from twisting. Compared to a steel sill this structure reduces the number of components needed per side from fifteen to three

and the weight by some 3.4 kg by manufacturer's accounts. The complete external body is made of aluminium with the exception of the front and rear parts. For the Taycan the aluminium share totals approx. 37%. Its body is made by Thyssenkrupp Automotive Body Solutions, the car body building subsidiary of the Essen-based industrial group.

The efficiency of lightweight construction is decisively determined by the vehicle type. There is much more scope for using lightweight construction materials like aluminium and carbon-fibre reinforced plastic, which are more expensive than steel, in premium vehicles such as Audi, BMW or Mercedes than in the volume market of Volkswagen and Co. The self-supporting car shell design in steel is therefore the most frequently used car body construction type worldwide but it has come under pressure from aluminium for some years now. Sheet steel structures welded from several sheet steel blanks are increasingly replaced by one-piece die-cast aluminium parts. The benefits clearly lie in the process. In pressure die-casting even big castings with complex geometries such as strut domes can be produced efficiently in high numbers.

Trends towards larger pressure die-casting machines

According to Johannes Messer of the consulting company of the same name, there is a trend – both in business and technical terms – towards higher clamping forces, i.e. bigger die-casting machines for chassis and structural parts as well as e-mobility. Higher performing die-casting machines make for more efficient production of larger and more complex car parts.

Tesla boss Elon Musk claims he has rung in the latest trend in large-format die-cast components with mega or giga casting. The Giga Press type of die-casting machines used by Tesla for the first time are manufactured by the Italian company Idra; featuring clamping forces of 6,000 to 9,000 tons they form the molten aluminium into complete car front and rear parts. Musk even claims to hold a patent for complete car bodies from a single die-cast piece without heat treatment. By Musk's account, this mega casting already saves 300 robots on the assembly line today, thereby drastically reducing assembly times. At Tesla's factory in Grünheide every 45 minutes one body in raw rolls off the production line. By producing a complete vehicle in as

little as ten hours Tesla clearly outperforms such competitors as VW, where one vehicle takes around 30 hours to be completed. Idra was the first company with production orders for 9,000 ton machines suitable for SUV and small commercial vehicle markets. The company claims to have already sold 24 of its giga die-casting presses worldwide, predominantly to China and not only to the automotive sector.

As the US market research firm Ducker reports, Nio and Xpeng, two Chinese e-vehicle start-ups, have already followed Tesla's example and ordered die-casting machines with a clamping force of 12,000 tons from Idra's parent company, the Chinese LK Group. The "12,000 T Super Large Intelligent Die Casting Unit" by LK Technology was presented to the public in Shanghai for the first time in late September, in cooperation with the major Chinese foundry Guangdong Hongtu.

Ducker regards giga casting a serious trend for improving the profitability of e-vehicles. Volvo already announced investment in mega casting for aluminium body parts for the next generation of e-only vehicles at its Torslanda factory in Sweden. "Mega casting offers a series of advantages in view of sustainability, costs and performance during the lifetime of the vehicle," say Volvo. Casting big components of the vehicle's body structure as one-piece aluminium parts, they say, reduces the weight, which in turn improves the vehicle's energy efficiency and, hence its electrical range. In addition, Volvo explains the investment by saying that their designers can optimally use the available space in the cab and luggage compartment, thereby increasing the versatility of vehicles overall. Other benefits of mega casting include the reduced complexity of the manufacturing process. This in turn entails cost savings for materials and logistics, thereby reducing the complete carbon footprint in production and supply chain networks.

Volkswagen also voiced their interest in Tesla's production methods for its new factory planned for the e-model Trinity but have not announced an investment decision in favour of mega-casting yet.

Mega casting: development with a question mark

Despite all the optimism Ducker admits that mega casting still raises some questions. In terms of repairability, for example, a Tesla is not designed to

have its large cast parts straightened or simply replaced. If the structure is distorted or broken after a crash, the vehicle is most probably a write-off. So it can at least be doubted that Tesla-style mega casting will become the major gamechanger in automotive production. Foundry expert Wöstmann reports from the Bremen foundry conference: “The clear statement I heard from BMW for example is that our machinery is sufficient so we will not be entering the 6,000 or 8,000ton range.”

Prof. Dr.-Ing. Martin Fehlbier, Head of Foundry Technology at the Institute for Production Technology and Logistics of the Kassel University, however, does spot an international trend towards producing large castings with large casting cells – and not only in Asia. “Replacing up to 100 individual sheet steel parts by one single casting and thereby rendering many joining processes superfluous, is a very strong incentive to take a very close look at this new manufacturing technology,” says Fehlbier who also lists an up to 30% gain in production space, savings on the otherwise up to 100 individual moulds (dies) and many other reasons here.

Speaking against this technology in principle, he explains, is the open issue of repairability of large cast parts in the event of a crash. Apart from this, logistical problems have to be solved, such as the transport and changeover of the large moulding dies, or other key issues like the correct design and optimal die heating and, hence, the service life of these dies, which cost up to € 2 million and in part require well over 40 heating devices. Other issues to be addressed, he says, are the optimal die wash for these large surfaces, the ideal gating system for long flow paths, the required minimum wall thicknesses, and ideal casting alloys, to name but a few. “But in principle this is all feasible,” Fehlbier concludes.

Green steel for sustainable e-mobility

As steel producers move on their path towards climate neutrality steel is gaining an increasingly green image. This trend is supported by such automotive producers as BMW and Mercedes that are increasingly demanding climate-neutral steel. For instance, all leading steel producers – from ArcelorMittal, Salzgitter, Tata Steel and Thyssenkrupp to Voestalpine – not only have the first low-CO_2 to CO_2-neutral products in their portfolios. For steel-based lightweight construction for e-vehicles these

"industry heavyweights" are now also offering complete ranges with matching material concepts for both hot and cold forming. Take for instance the battery box: forming an integral part of the car bottom structure, the battery box is one of the most important components in e-vehicles and has so far been reserved to aluminium, pressure-die casting, sheet steel and profiles.

As e-mobility is ramped up and volumes rise, however, increasingly efficient solutions for battery boxes are in demand. This is why Thyssenkrupp Steel, for example, offers a crash-active and fire-safe lightweight battery box solution in high and ultra high-strength steel. Compared to aluminium as a reference, they confirm, the steel battery box has 50% lower production costs and emits 50% less CO_2-emissions over its entire lifecycle. The battery box complete with underride protection and lid boasts the highest fire protection possible thanks to steel and can fulfil all requirements in an almost weight-neutral way compared to aluminium. The frame of the battery box, a key safety feature, is assembled using low-cost roll-formed profiles of any length, thereby rendering superfluous elaborate deep-drawing dies for the production of the scalable battery box.

Author's note: Gerd Krause, Mediakonzept Düsseldorf

e-mobility: the demise of lightweight construction?
Whereas lightweight construction used to be the domain of IC engines, where a lower vehicle weight favours lower consumption, this topic also remains relevant with e-mobility. The Aachen-based automotive service provider fka contradicts the trend that lightweight construction will lose importance with e-mobility. While it is true that extreme and cost-intensive lightweight construction loses economic efficiency in e-vehicles with the possibility of energy recovery through recuperation and with falling battery prices, lightweight construction per se would by no means become superfluous. Lightweight construction can make a significant contribution to achieving the required ranges. A lower vehicle weight allows the installation of smaller and lighter batteries with the same range. The vehicle mass also decisively determines the driving dynamics.
Thus, lightweight construction not only has a positive effect on acceleration and handling but is also a significant safety aspect with regard to braking distance: in the event of unexpected emergency braking, for example, the vehicle should come to a halt in front of a truck at the end of a traffic jam rather than being stopped by it.

Press Contact:
Messe Düsseldorf GmbH
Larissa Browa

Tel.: +49 (0)211-4560 549
E-Mail: BrowaL@messe-duesseldorf.de

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