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# Aluminum die casting enters new dimensions – all mega or what?

**Tesla has shown the way, and other car manufacturers are following suit: they are using ever larger structural parts made of die-cast aluminum in vehicle production. By reducing the number of parts in the car, manufacturing costs are to be saved, while the reduced weight could increase the range of electric vehicles in particular. This trend, which is often referred to with the bold term megacasting or gigacasting, appears to be unstoppable. However, assessments of the possibilities and limits of this technology differ among experts.**

For decades, individual chassis, engine and body parts have been produced in automotive engineering using aluminum die casting. Then, after the usual well-orchestrated announcement by company founder Elon Musk, Tesla entered new dimensions: Since the beginning of 2021, the American company has been producing the entire rear floor assembly of its Model Y as a single, solid part in die-cast aluminum. This reduces the number of components, eliminates many of the joining steps that are usually carried out by robots and allows Tesla to produce one example of this vehicle type in just ten hours. With huge success: Model Y was the world's best-selling electric car in 2022 and the world's best-selling car ever in the first quarter of 2023. In the first three quarters of 2023, Tesla sold well over 1.3 million vehicles worldwide - more than in the entire year of 2022.

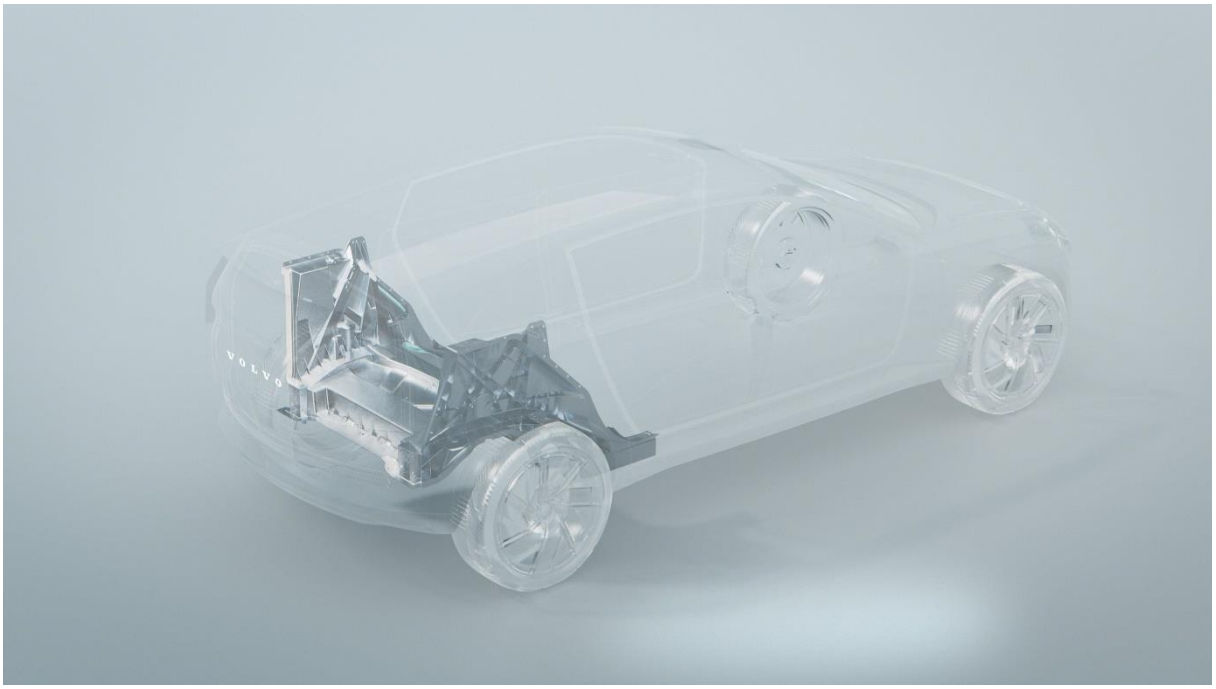
Professor Dr. Martin Fehlbier – Chair of Foundry Technology, University of Kassel

A development that has earned the respect of foundry technology experts: "Elon Musk has managed to draw attention to the highly innovative light metal die casting in an emotional way and to present its advantages to the public in an extremely effective way. Something like this has been missing until now and ultimately benefits the entire industry," says Professor Dr. Martin Fehlbier, Chair of Foundry Technology at the University of Kassel.

With the use of megacasting parts in the Model Y, the use of large and complex structures made of die-cast aluminum seems to have become established in the series production of vehicles. A development that even scientists could not have predicted just a few years ago. "I don't think anyone in the industry really expected this," says Professor Dr. Günther Schuh from RWTH Aachen University. The Chair of Production Systems has been dealing with issues of innovation and technology management and industrial production for over 30 years. As an entrepreneur - Schuh is CEO of e.Volution GmbH - he is driving the development of the world's first genuine circular economy vehicles. "The fact that we are seeing megacasting on this scale is surprising enough. But I find it particularly impressive to have turned it into a large-scale production process," he says.

## Technology is spreading

Tesla has shown the way, other OEMs are now jumping on the bandwagon. From 2025, Volvo - part of the Chinese Geely Group since 2010 - wants to use mega-casting at its main plant in Torslanda to produce electric cars. A considerable proportion of the vehicle floor is to be cast in a continuous process. Volvo project manager Mikael Fermér explained in 2022 that the introduction of mega-casting is the biggest technological change in car body construction for his company since the switch from wood to steel. The Swedes expect it to reduce weight by at least 15 percent and, thanks to the reduced complexity of the manufacturing process, also save on the use of materials and logistics, which should reduce the ecological footprint in the production and supply chain networks. Mega-casting offers advantages in terms of sustainability, costs and vehicle performance, according to the Swedes.



At Volvo in Torslanda, a considerable proportion of the rear vehicle floor is to be cast in one piece.

Other car manufacturers in China have now switched to casting large structural components for their vehicles. Recently, Toyota in Japan also introduced a new production technology with which a complete car body can be manufactured from just three parts in a short space of time. Japanese media report that the technology is to be used from 2026. VW also wants to use mega casting for the "Trinity" e-mobility project.

The large structural parts are cast using correspondingly large and powerful casting systems that have been newly developed in recent years. The OEMs are supplied by just a handful of machine manufacturers worldwide. These include the Swiss manufacturer Bühler, which calls its large models "Carat", Idra ("Gigapress") from Italy and the Chinese companies LK Technology Group ("Dreampress") and Yizumi ("Leap Series"). Weighing over 400 tons and measuring 20 meters long,

6 meters high and 6 meters wide, the machines currently enable car manufacturers such as Tesla to produce complex parts measuring around 1.50 meters square.

### What is technically feasable?

But this is by no means the end of the size development. While 9,000 tons of clamping force was previously the benchmark for an aluminium die-casting cell, 12,000-ton systems have already gone into operation in China, the world's first 16,000-ton machine was unveiled at the end of October 2023 and 20,000 tons are apparently being planned. Will it really be feasable one day to produce the body of a car from just a few parts, like a matchbox car? What is technically feasable?

"On paper, of course, you can design machines with ever greater clamping forces," says Martin Fehlbier. "In my opinion, what is missing are further scientific studies that show the problems that arise, especially with components with extremely long flow paths, for example when approaching a battery box that is almost 2x2 meters in size. Research still needs to be carried out into what happens to the metal after such long flow paths, how long the liquid melt remains in contact with the air or the mold, what oxide formation and porosity occur, what mechanical properties result, etc. In addition to fundamental investigations accompanying the large-scale casting process, there is a lack of correspondingly advanced innovative technologies and methods such as new mold temperature control, spraying and casting concepts, advanced simulation tools and new methods of process monitoring as well as AI and machine learning. Of course, every company will endeavor to acquire this expertise itself first and not publish it immediately, but these issues will inevitably come to the table the larger the parts become. This is not a sure-fire success, there is still a lot to do and evaluate in order to achieve good megacasting castings and sustainable processes."

Siegfried Heinrich, Managing Director of Schaufler Tooling in Laichingen, believes that the company's growth is far from complete. The internationally active company has been constructing megacasting moulds weighing up to 130 tons for customers in the automotive industry since 2021. This makes the mold making-specialist a pioneer in this technology. In the meantime, 20 molds have already been delivered and numbers 21 to 23 are currently under construction. "I think it is technically possible to produce the entire underbody for a compact vehicle in cast aluminum. But then we're looking at 20,000-ton machines," estimates Heinrich. However, he already sees a need for optimization in the current 6,000 to 9,000 tonne machine range. "There are already projects in series production in this range. And we can see that: Producing these parts with high productivity and with very robust processes every day in three-shift operation is a challenge."



## What makes sense economically?

In addition to the question of technological feasibility, the question of whether further growth in size makes sense must also be asked and answered. Not everything that is technically possible is also economically feasible: "Above a certain size, the challenge of designing the entire process economically increases," says Cornel Mendler, Managing Director Die Casting at Bühler. "The equipment in the die casting cell as well as the upstream and downstream processes must also be designed for these capacities and optimally coordinated to enable efficient production." Bühler also focused on these considerations when developing its own 9,000-ton Carat 920 machine - as the heart of the cell, the die casting machine must function in harmony with all peripheral equipment. Another challenge for Mendler is logistics: "When developing machines of this size, practical factors such as transportation must also be taken into account. The heaviest component must not be heavier than can still be transported on normal roads."

Cornel Mendler - Managing Director Die Casting, Bühler

Die casting machine, Carat 920 – Bühler

The globally positioned company maintains production capacities in Uzwil, Switzerland, as well as in plants in China and the USA. In 2022, Bühler was able to convince Volvo Cars of its technology: the Swedish premium manufacturer ordered two Carat 840 die-casting cells for its plant in Torslanda. Bühler currently has orders for 30 more megacasting solutions.

Die casting machine, Carat 840 – Bühler

"If a single cast part replaces 70 individual parts, some even talk about 100 individual parts, this is of course much less effort, also in terms of purchasing, individual tool planning and procurement and logistics. Many joining steps are eliminated, meaning that several hundred robots can be omitted from a line and up to 30 percent of the production area can be saved. On the other hand, casting on the Gigacasting machines is also very time-consuming," Martin Fehlbier points out in terms of economic efficiency. "It is difficult and expensive to transport very large structural parts, which is why it makes sense to manufacture them directly at the OEM. New production halls with large cranes of up to 150 tons and immense melting capacity are often required. There are often several production sites, so it may be necessary to build several foundries. In addition, redundant machines are needed if one of them stops. With this high investment, the question is, does it still pay off?"

The Kassel professor believes that the possibilities of smaller casting machines have not yet been exhausted: "There are very interesting approaches to producing large parts on casting cells in the 4,000 series, for example, by avoiding the maximum peak pressures or also using 3-plate technology with a smaller blast area.  The limits of what is possible on comparatively smaller machines have not yet been reached."

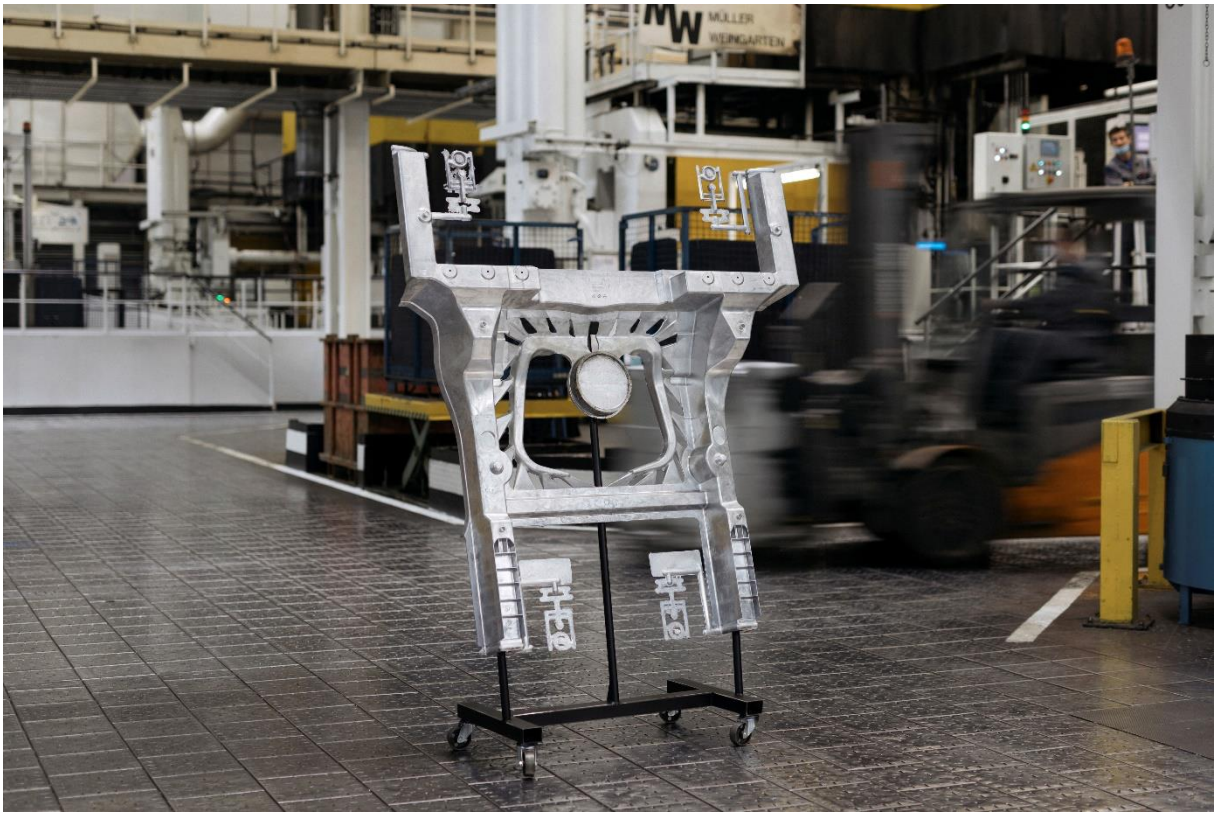
This is exactly the approach taken by VW. In contrast to the competition, the Volkswagen Group Components foundry in Kassel uses existing equipment such as presses, die casting machines and hot forming furnaces for more efficient production. It already has experience with structural parts – but not on the scale that has now been successfully implemented. A technological leap that was made possible by pooling all the know-how.

Mirco Wöllenstein – Head of foundry, VW plant Kassel

"We are currently working on the frame for the battery, where the cost savings potential is particularly high. For the rear end, 42 parts of conventional design have been replaced by just one. The front end was successfully installed in the ID.4 and crash-tested, with promising results," reports Mirco Wöllenstein, Head of Foundry at the VW plant in Kassel."

"The manufacturing process includes innovative steps such as the sprue in the middle for short flow paths and the prevention of overflows. Elements such as innovative venting valves prevent gas porosity during casting. The targeted inclined design of the mold helps to compensate for thermal distortion during the cooling process. After casting, the sprue area and the vent valves are punched off and melted down immediately," says Wöllenstein.

Over 1,000 rear carriages have already been cast under series production conditions in order to guarantee the cycle time and quality. Wöllenstein: "With an impressive cycle time of 130 seconds per part and one employee operating two machines, we have proven our efficiency. The time saving compared to conventional production is around 30 minutes per part and the company is aiming for a "10-hour car".



Rear end casting - Volkswagen_AG

In addition to part quality, Siegfried Heinrich from Schaufler Tooling considers the degree of machine utilization due to downtimes to be a key parameter for the economic efficiency of megacasting: "These are very complex processes and significant progress still needs to be made here to ensure that the predicted cost benefits can actually be realized." Professor Günther Schuh is generally skeptical about the trend towards ever larger parts: "Manufacturing ever larger parts from a single casting doesn't actually make technological sense. The base points of the A-pillar and C-pillar, for example, practically support the entire structure of the finished vehicle. Due to the limited tensile strength of aluminum, these junctions require a lot of material and correspondingly high pressure. Less pressure is required at other points of a large component. Nevertheless, the system must be designed for the highest necessary pressure. This means that some of the energy used is wasted. The size then becomes pointless if the span of the necessary pressure becomes too large." For him, megacasting therefore only makes sense in terms of the overall balance if this type of integral construction saves many other work and assembly steps.

## Greenfield-Approach at an adavantage

Experts agree that OEMs such as Tesla, which are building greenfield plants for new vehicle models, have an advantage over those who have well-established assembly lines with hundreds of forming presses and welding robots that they already use for their existing vehicle models.

Prof. Dr. Helena Wisbert - Department: Automotive Industry, Ostfalia University of Applied Sciences

"Megacasting will be used in particular to reduce production costs for electric cars. However, the advantages such as the massive reduction in components and the elimination of work steps and connection points are offset by high investments for the casting tools. For this reason, we currently see megacasting being used more by car manufacturers who are currently building new production plants than by car manufacturers who are transforming their existing plants for electric cars," says Professor Dr. Helena Wisbert, Director at the Duisburg CAR-Center Automotive Research and Professor of Automotive Economics at the Osfalia University of Applied Sciences in Wolfsburg.

If the application is to achieve the desired goal of cost savings, another issue takes center stage: the number of units produced. It is not only the megacasting machines that are large, but also the die-casting molds used. The molds, some of which weigh more than 100 tons, can only be changed with considerable effort and long downtimes - in contrast to tool changes in traditional sheet metal press shops, which take just a few minutes. This makes it uneconomical to produce many variants of a vehicle - with considerable effects on the product design of the cars.

Prof. Dr. Günther Schuh – Managing Director, e.Volution

Günther Schuh emphasizes a special feature of Tesla's model policy in this context: "Tesla basically only produces two car models in large numbers, which are also highly self-similar and have remained more or less the same for many years. Nobody in the car industry would have thought it is possible to become so boring and be so successful. This level of standardization is an example of the American art of scaling that the global auto industry never thought the market would support." Thanks to standardization, Tesla has more favourable production conditions than manufacturers with significantly more vehicle variants, who then only produce a model for four to five years. "If I produce not just 300,000 and 500,000, but a few million identical parts over the useful life of the plant, then the simplification advantage is naturally much greater."

Helena Wisbert believes that this aspect could possibly become less important with the development of electromobility: "Megacasting is associated with less flexibility in terms of the range of variants. However, as this is generally lower for e-cars, this disadvantage is no longer so significant."

## Effects on the foundry industry

An exciting question will be whether suppliers from the foundry industry can benefit from the trend towards the increased use of cast aluminum in the automotive industry - or whether, on the contrary, they could even be among the losers of the development. After all, Tesla casts the megacasting parts it uses itself and Volvo is also known to be planning to do so. An important argument here is the cost-effectiveness of transporting large parts over long distances.

Siegfried Heinrich – Managing Director, Schaufler Tooling

"Of course, logistics costs play a major role. That's why casting shouldn't take place far away from the body shop. But it won't be the case that every Megacast will be cast in-house at the OEM," Siegfried Heinrich is convinced. Experience with current projects in Asia has also shown this.

The Federal Association of the German Foundry Industry does not believe that the German die casting industry will rely on its own megacasting solutions across the board.

Dr. Achim Keidies - Speaker for NE-Metallguss, BDG

"Megacasting is really only something for OEMs in this country. The purchase of a megacasting machine costs several million euros and, due to its dimensions, it cannot usually be integrated into the existing infrastructure. They therefore need new halls and cranes with which they can move the large castings," explains Dr. Achim Keidies, consultant for non-ferrous metal casting at the BDG. In addition to the costs for the casting plant, there are also additional investments in the infrastructure, which is usually not feasible given the economic conditions. Keidies: "Die casters are medium-sized companies and therefore have real financing problems. Banks are reluctant to grant loans for automotive projects and interest rates are high."

## Chicken or egg?

As we all know, exceptions prove the rule: one company that sees itself in a position to make the challenging technological leap is the Handtmann Group. The family-run company, which will celebrate its 150th anniversary in 2023, has announced that it is entering the megacasting market - as the first tier-one supplier in Europe. A Bühler casting machine, a Carat 610 extended, will be purchased.

The structural conditions are currently being created at the company's headquarters in Biberach so that the large system can be installed, reports Dirk Seckler, Managing Director responsible for die casting within the group of companies. The machine is scheduled for delivery at the end of the 1st quarter of 2024. It will be used to cast complex structural parts such as battery trays for electric vehicles in both the car and truck sectors, as well as tailgates.

"It's true that the initial investment is high. However, the business case is quickly justified because, on the one hand, we have the opportunity to compete with suppliers in the extrusion and steel sectors. This means that we are tapping into potential that we were previously unable to exploit in aluminum casting with lower clamping forces. In addition, like an OEM, we also save process steps in joining, which would again entail a larger investment in machines and personnel, space allocation, etc.," explains Seckler.

"We believe that this technology will make us more competitive, in line with our company motto 'transformation through innovation'." Handtmann expects that the availability of the new megacasting offering will create additional demand. Seckler: "That's why we wanted to go ahead and solve this chicken-and-egg problem with our investment." He does not believe that Handtmann will purchase even larger machines. "The production of parts on 9,000- or 12,000-ton machines only makes sense if it is practically located directly next to a vehicle plant, because otherwise the logistics costs would be too high."

"It always takes people to lead the way," says Martin Fehlbier happily. The prospect of now entering new regions that did not previously exist in this form means additional business. But the foundry technology expert is also encouraging for die casting companies that do not take the plunge: "I believe that our die casting still has a lot of potential that is not being exploited today. You can still achieve a great deal with machine learning, AI, new temperature control concepts, multi-plate technology, etc. There are many areas in which conventional foundries can also develop further, so the industry is actually well positioned for the future."

## Positive eco-balance „not a sure-fire success"


And how big is the ecological footprint of megacasting? A lot of energy is used in aluminum production and, contrary to what one might think, replacing formed steel parts with castings made of the lighter aluminum - its density is around three times lower than that of steel - does not necessarily mean a weight saving for the car. Due to the size of the casting molds and the long distances that the liquid aluminum has to travel in them, comparatively thicker walls are required.

The fact that megacasting is nevertheless expected to have advantages in terms of sustainability, as is the case at Volvo, is due to the overall consideration of all processes: "It is estimated that around 30 percent$_{CO2}$ can be saved because many joining and post-processing steps are eliminated. But it's not a sure-fire success. We have to keep on developing new alloys or upgrading recycled alloys," Fehlbier believes.

On the other hand, the ease of repair must be taken into account when considering the ecological balance of megacasting. "The major disadvantage that a lot of energy has to be used for aluminum production could be offset by the fact that the aluminum remains in use for longer. But this will be less the case with large cast components," expects Professor Schuh. "Depending on the region of the world, a vehicle will suffer around 1.3 cases of moderate damage in its 12 to 20-year life. This kind of damage is not normally repairable in a large casting component. This means that we produce many more vehicles that have to be scrapped prematurely. I believe that for reasons of sustainability, developments in vehicle construction should be moving in the opposite direction. We would have to create bodies that last as long as the new electric drives. You could roughly halve the footprint of a car by making these vehicles last much longer. But then you would just build a chassis structure, in this case made of aluminum profiles, clad it, for example with plastic exterior parts, and then adapt this cladding again and again."

In terms of crash behavior, VW is pursuing approaches such as intelligent repair concepts in order to reduce the insurance rating. Areas that are not die-cast due to insurance regulations are replaced with more realistic solutions to ensure safety.

However, Schaufler Managing Director Siegfried Heinrich believes that the aspect of repairability could become less important in the future: "Driving assistance systems and autonomous driving will significantly reduce the number of accidents in the medium term. And we're not talking about a rear-end collision in a 30 km/h zone. A cast part is not going to break. But of course this is still an issue that needs to be resolved."

## Cast aluminium instead of formed sheet metal

What are the future prospects for large structural components made of die-cast aluminum? Will they be limited to the automotive industry or do the experts see further potential applications in other areas? "I believe in even greater growth in mega and giga casting outside of car manufacturing," is Günther Schuh's assessment. He considers its use in aircraft construction to be very promising. Handtmann is similarly optimistic:


Dirk Seckler – Managing Director, Handtmann

"In principle, there are many components that can be produced in just one process step using megacasting. Aluminum die casting will therefore not only be used in the automotive industry, but also in many other sectors such as aviation or telecommunications," Dirk Seckler also believes.

Competition between materials and processes could therefore intensify. The development is therefore being closely monitored by the steel industry, which could suffer from the further advance of aluminum casting. Foundry technology expert Martin Fehlbier finds it exciting: "There are still a lot of new things to learn and potential to discover in the field of large-scale casting. “You can only do that by getting involved and simply trying things out. And then there will certainly be ideas and

solutions for problems that are still there today, which we might not even be thinking about at the moment. So, I'm looking forward to this technology and I'm very excited to see how it goes."

**Don't miss any news about the die casting**