

Die Casting or Sheet Metal Forming: A Comparison of Car Body Manufacturing in Times of the "Giga Press"

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Abstract: Die casting as an alternative for sheet metal structures in car body design has been around for a few years. While the application of die cast body components by legacy automakers is rather limited, especially for mass market products, Tesla bases their mass-produced cars on a few extremely big die cast structure parts. The impact of this strategy makes it necessary to rethink car body manufacturing. In this study, published information and expert interviews are used to evaluate the strengths and weaknesses of the competing philosophies of car body manufacturing.

Keywords: car body manufacturing; large-scale die casting; sheet metal construction

1 INTRODUCTION

The motivation behind this work lies in the continuous development of manufacturing technologies for vehicle bodies in the automotive industry. Regarding mass production, two main technologies play a decisive role: the increasingly important large die-casting technology and the sheet metal shell construction method. As part of this research work, the aim is to make a comprehensive comparison between these two manufacturing processes.

The automotive industry faces constant challenges, ranging from increasing efficiency and cost savings to meeting stricter environmental regulations. Choosing the right manufacturing technology can have a significant impact on the overall performance and competitiveness of an automotive manufacturer. It is therefore crucial to fully understand the advantages and disadvantages of large die casting technology compared to the established sheet metal shell construction method.

2 STATE OF THE ART

2.1 Car Body Manufacturing with Sheet Metal

The sheet metal shell construction or self-supporting shell construction (see Fig. 1) is used in the automotive industry in body construction and represents the current standard for the construction of passenger cars with steel construction [1]. This is a chassis construction method in which steel or aluminium half-shells are connected and there is no longer a distinction between the chassis and the body of the vehicle. Individual areas such as the roof, floor or side walls consist of large sheet metal areas and take on load-bearing tasks as part of the body. With this construction method, it is possible to build complex 3-dimensional structures and to achieve targeted lightweight construction by integrating almost all components. The sheet metal shell design also enables a high degree of automation in the systems and is suitable for the production of high quantities at low cost. Due to the high acquisition costs of the production tools required for forming the sheet metal,

customization and a high number of variants are not economically viable. [2]



Figure 1 Body with self-supporting shell construction ([3], p.18)

2.2 Car Body Manufacturing with Die Casting (Mega or Giga Casting)

The term mega-casting is a die casting process that is also referred to as large-scale casting [3], large-scale die casting or more general high performance die casting. The process has initiated a change in the automotive industry. Compared to the established die-casting processes, the main difference is the size of the systems [4].

For vehicle production, these new processes mean the possibility of reducing the complexity of joining and automation technology as well as cycle time and space requirements due to the lower number of components. However, the challenge to reproducible quality, which is due to the lack of knowledge and experience regarding the highly complex die casting process, must be addressed in the future [5]. Large-scale die casting also has an impact on the car body as a product and offers manufacturers the opportunity to further optimize the lightweight construction potential. Accordingly, it means that joints can be reduced and at the same time it is possible to integrate connection points directly into the components. This integration facilitates the connection of add-on parts. Compared to current processes, however, the body can only be adapted or modified to a limited extent. In 2022, the authors stated that problems with component quality, pore formation and the possibility of reparability still need to be solved in car body series [5].

The changes to the body are illustrated in Fig. 2 using a model of a Tesla Model Y body as an example. By using large die casting, the number of individual components can be significantly reduced. In the left-hand image, 171 components are marked, which can be replaced in the right-hand image by the two components marked in colour.



Figure 2 Change of car body parts due to large die casting a Tesla Model Y [6]

2.3 Brownfield versus Greenfield

The term Brownfield refers to an approach that provides for planning based on existing buildings and infrastructure. In this case, the planners of new industrial plants must plan with the existing structures and take these into account when implementing new technologies, production facilities or processes. The given conditions of the existing facilities, both the existing buildings and the processes envisaged in the original planning, limit flexibility and lead to compromises during implementation. Accordingly, the planners are faced with the challenge of realizing the planning objective despite various restrictions. The counterpart to the Brownfield approach is the term Greenfield. This refers to an approach that provides for planning on an open, undeveloped area. The planners of the plants have maximum freedom in the planning and design of the industrial plants, which are only limited by the capacities desired by the client and the financial specifications. This makes it possible to plan and build a factory that meets the latest standards. The freedom in the planning of production processes, material flow but also energy use makes it possible to design the facilities uncompromisingly for efficient processes without being restricted by existing structures. [7]

3 METHODOLOGY

The expert interview was conducted in a quantitative way. As a first step a target group was identified on internet professional platforms using keywords corresponding to die casting. For this sample group a questionnaire was provided. The sample size of 24 complete expert questionnaires was used to compile a quantitative analysis of the current status of large die casting versus sheet metal shell design.

The sample group was set up as shown in Fig. 3.

Most of the experts in the sample group were long time employed in the casting industry, with 8 out of 24 with over 20 years of experience in the field. Fig. 4 displays the duration of relevant employment of the interviewed.

The questionnaire for the sample group compared both car body manufacturing technologies in 14 criteria (Tab. 1).



Figure 3 Expert sample group composition

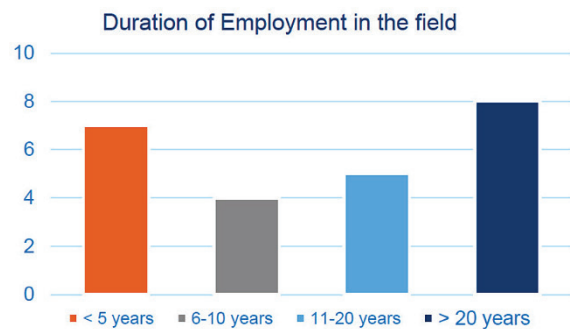


Figure 4 Expert sample group Working Experience.

Table 1 Questionnaire comparison criteria

Product Criteria	Process Criteria
Product Safety	Manual Labour Savings
Leight Weight Potential	Production Time Savings
Energy Consumption	Scalability
CO ₂ Emission	Investment Costs
Repairability	Maintenance Savings
Stiffness	Suitable for E-Mobility
Quality and Tolerances	Space Savings

Which production process makes it easier to achieve the **safety requirements** in car body construction?

1 2 3 4 5

High Performance Die Casting Sheet Metal Shell Construction

Figure 5 Example question of the expert interview

All questions were displayed as a direct comparison between Sheet metal design and die casting with five different options to answer, as shown in the example in Fig. 5. Option "1" would be strongly in favour of die casting, whereas option "5" is strongly in favour of sheet metal. "3" would be the neutral option. All comparison questions were set up in the same way, so lower numbers favour die casting and high numbers sheet metal design.

All questions were based on the premise, that we have a complete Greenfield approach, so no preliminary conditions for the comparison were defined.

4 RESULTS

The results of the expert interview show a sizeable variation within the answers of the experts, but nevertheless give a consistent picture in most of the categories.

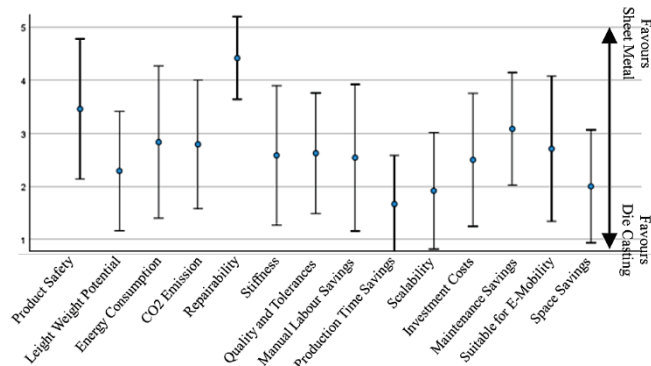


Figure 6 Results of Expert Interview Questionnaire

In 11 out of 14 categories the experts considered large-scale die casting as advantageous. While some of these criteria were almost even, six criteria were evaluated with a very clear outcome. Two indisputable advantages of the sheet metal design, according to the interviewed, were product safety and repairability.

Large-scale die casting was rated superior in light weight potential, production time savings, scalability and space savings.

4.1 Discussion

4.1.1 Product Safety

Even though crash ratings of Tesla Model Y and 3 using large die casting parts for the car body have been very good in comparison, one problem of large-scale die casting processes is the quality of the parts. At the current state of the art lunkers and other casting errors are not completely avoidable for parts with the weight of 50 kg and above.

4.1.2 Light Weight Potential

Although some experts were convinced, that the same or even better results could be achieved by sheet metal forming, most of the experts saw an advantage in die casting, with the two main reasons being the lower specific weight of aluminium compared to steel and the lack of multiple joining or bonding surfaces.

4.1.3 Energy Consumption and CO₂ Emission

Both technologies were rated pretty similar in that regard. When reviewing the specific energy consumption of the base materials sheet metal forming using steel should be the more sustainable solution, with some compensation in the life cycle because of a little higher vehicle weight. In CO₂

emission in most cases steel would also be lower and therefore preferable to aluminium, but this is highly dependable on the energy source used for aluminium production. Overall aluminium production has a path to almost Zero emissions by using exclusively renewable energy, whereas economical Steel production is still relying on coal.

4.1.4 Repairability

Building a car structure out of big casting parts has a great disadvantage when it comes to repairability. If the car structure is damaged by an accident, even just a small local deformation or crack, there is currently no comparable way to repair this, as it can be done with sheet metal, as welding is not possible without altering the material properties. As the parts are pretty much unremovable without taking apart the whole car, a damage of the car structure often time means a total loss of the vehicle.

4.1.5 Stiffness

The flexibility in design of large Casting Parts can give the structure a greater area moment of inertia. Together with less joining points this can make up for the lower Youngs Modulus of Aluminium compared to Steel. Nevertheless, this is highly depending on the design of the structure, so there is no clear advantage with any of the two technologies.

4.1.6 Quality and Tolerances

As mentioned in 4.1.1 big casting parts have issues with lunkers and other casting errors. Additionally, the dimensional accuracy of big castings is not on the same level as sheet metal parts. The reduction of joining points can compensate for that.

4.1.7 Manual Labour Savings

Both technologies offer the opportunity of an almost complete automation. Although more manual quality checks or deburring may be needed for the casting parts, the lower number of parts gives the die casting process a slight edge.

4.1.8 Production Time Savings

According to the experts the major advantage of the large-scale die casting technology is the lower time needed for the production of the car body. Although the big casting parts have a significantly higher cycle time than any sheet metal part, the reduction of parts and joining operations means a significant time saving.

4.1.9 Scalability

Various automobile manufacturers prove that a sheet metal shell design is suitable for lot sizes in the millions, so in principle this technology scales up very well. The better perceived scalability by the experts originates in the lesser parts needed for a die casting structure, so essentially scaling up the lot size is setting up more die casting machines. For a

more complex sheet metal structure changing lot size would result in more complex planning.

4.1.10 Investment Costs

Die casting machines are expensive investment goods, but press lines are as well. The small edge of the large-scale die casting process in this regard may result from the reduction of subsequent process steps for joining and assembly.

4.1.11 Maintenance Savings

In regard of maintenance sheet metal design has a slight advantage. Again, the reduction of parts also reduces the number of tools, that need to be maintained, but deep drawing processes are known to be very reliable at high output with relatively low amount of maintenance needed. Die casting tools on the other hand are not only burdened with high pressures, but also high temperatures and aggressive liquid aluminium. This results in a significantly shorter time of these tools before they need to be serviced.

4.1.11 Suitable for E-Mobility

The biggest difference between an internal combustion engine car (ICE) and a battery electric vehicle (BEV) is the heavy battery pack. The design flexibility of large-scale die casting structures allows a high functional integration of the battery into the car body structure. Mechanical mounting and connections for temperature control of the battery can be directly included in the casting design.

4.1.12 Space Savings

The footprint of the high performance die casting machines is smaller than the footprints of a press line, the necessary tools and all the subsequent assembly operations. According to expert information sheet metal car body manufacturing needs approximately double the footprint of large-scale die casting.

Finally, when asked for the future potential of large-scale die casting the answers were almost unanimously in favour of the die casting process (Fig. 7).

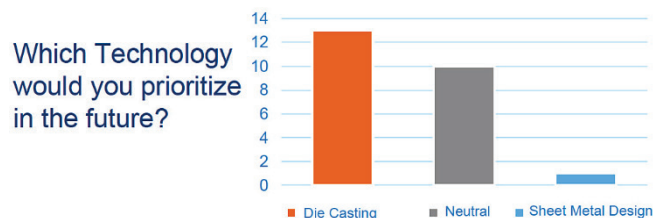


Figure 7 Future Technology Preference of the interviewed

5 SUMMARY

Although the results seem to be very one sided, they have to be taken with caution because of some important caveats. The first is the target group of the expert interview, which was consisting of experts in the field of die casting, so a bias towards die casting technology is very likely in the sample

group. The second caveat is, that the two criteria product safety and reparability are very important to the customers and cannot easily be outweighed by other advantages. The last and probably most important caveat is, that all experts were viewing the comparison based on a Greenfield approach without any staff or infrastructure present. Based on that premise large-scale die casting might be the best solution at this point in time for electric vehicles. Legacy automakers rarely have the opportunity of setting up a plant on a green field and have to adapt their existing infrastructure for future projects. In this light a dismissal of conventional sheet metal shell design is absolutely premature. Concluding, it can be said, that large-scale die casting is a powerful new alternative to car body manufacturing and offers some interesting potential especially for Battery Electric Vehicles, but is not a best fit solution for all automakers or all future projects.

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