Author: Klaus Vollrath, Aarwangen, Switzerland

Mercedes C-Class: the great stride to aluminum casting

Hybrid bodies with mass-produced aluminum structural castings

Mercedes Benz; C-Class T-Model (Photo: Daimler AG)

The body of the new C-Class is the first for Mercedes, which has completed the step from the former steel structure to a composite construction (**Figure 1**) for large-scale serial production. The combination of high-strength steels and aluminum makes it possible to design the car considerably lighter, while improving comfort, driving characteristics and passenger protection. Such a conversion of production technology is a truly Herculean task with numerous risks when undertaken on a large scale – four sites manufacturing up to 2,000 vehicles every day. The challenges for the specialists – charged with the task of making the appropriate technology so controllable that a smooth worldwide supply of the necessary parts could be guaranteed – were correspondingly large.

"As a result of the transition to an innovative aluminum hybrid design Daimler, in Stuttgart, Germany, has been able to save about 70 kg in the body-in-white of the new C-Class," says Axel Schmidt (**Figure 2**), Manager of Technology, Development and Project Management at DGS Druckguss Systeme in St. Gallen, Switzerland. This represents a weight saving of about 20-25 % of the total weight of the body-in-white, depending on the vehicle variant – an important contribution towards reducing fuel consumption and the emission of CO_2. The fuel consumption of the Bluetec C180 and C200 basis versions is only 3.8 l diesel/100 km with emissions of 99 g CO_2/100 km. In order to achieve this success, the engineers had to completely redesign the body-in-white while extensively exploiting aluminum castings, hot-formed steel components, and ultra-high-strength steels. Moreover, all the body parts visible externally are also made of aluminum. Ultimately, vehicle weight has been reduced by about 100 kg.

The advantages of extensive aluminum structural castings

"The new body contains a total of seven large-scale aluminum castings," adds Axel Schmidt. These seven components together only weigh 19.2 kg. Castings were used because these parts had to have a very complex geometry with numerous reinforcements and wall thickness transitions. The suspension strut consoles of the predecessor model consisted of five steel parts, while a total of 13 parts were required for the rear-axle cross-members. The advantage of using aluminum castings in these areas lies not only in the considerably lower specific weight compared to steel, but above all in the significantly greater degree of freedom for the designers, who can create even very complicated geometries with load-oriented wall thickness transitions and deep rib structures or projections – without having to worry about restrictions or additional joining processes. The advantages are considerable, not only regarding weight, the number of individual parts, and the necessary joining operations, but also in view of reduced quality-assurance costs.

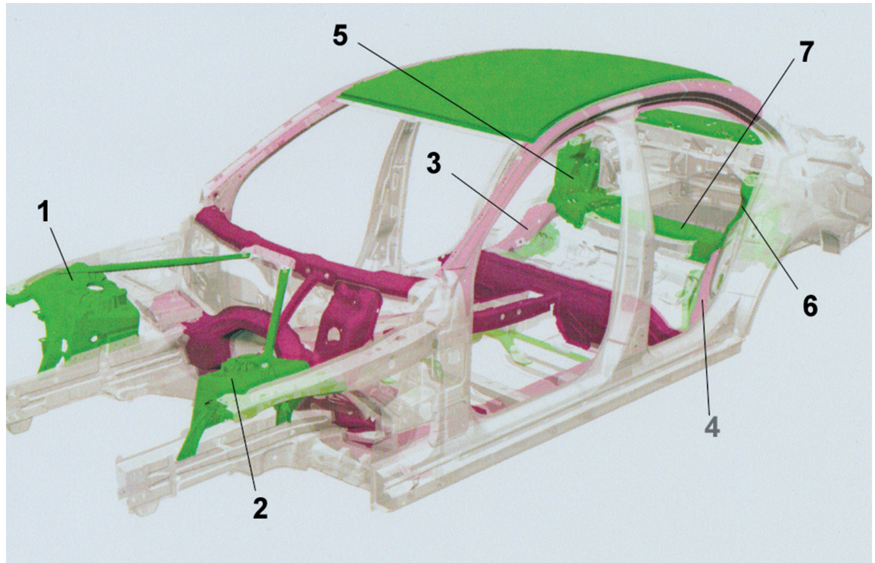


Figure 1: Aluminum structural castings in the body-in-white of the new C-Class: suspension strut consoles (1+2), rear side members (3+4), mountings for shock absorbers (5+6), and rear axle cross-member (7) (Graphics: Daimler AG)

The transition to worldwide mass production

"For us, the actual challenge in this project lay in jointly developing (together with Daimler and another partner) the process technology for large-series production on a worldwide scale," explains Axel Schmidt. Daimler had systematically prepared itself for this conversion for many years (**Figure 3**). The initial steps were the fully aluminum bodies for the sports car models SLS AMG and SL in small-scale production. These were followed in 2013 by the introduction of hybrid bodies made of aluminum and steel in the S-Class, with daily volumes of up to 550 units – already corresponding to mid-scale serial production. The introduction of the new C-Class in 2014 marked the final step towards large-scale production of up to 2,000 units a day. Which made it mandatory to ensure that identical standards – regarding the design, the process technology in the vehicle production plant, the package of connecting parts, quality definitions, and the so-called MB standard – were maintained worldwide at all four production sites (Germany, the USA, South Africa and China) and by all six suppliers. The casting suppliers had to observe worldwide uniform specifications for tools, alloys, castings and heat-treatment parameters, as well as for inspection and straightening equipment.

Top-quality technology development

"The invitation to join this development team was the result of hard work, which earned us a reputation as a technology pioneer in the area of producing large structural castings made of aluminum and magnesium," according to Axel Schmidt. The company had built up comprehensive mutual trust in development partnerships over many years. The team's task was to create all the prerequisites for the timely start of production of the new C-Class with four start-of-production deadlines on four continents – within just seven months. This involved developing and optimizing the cost structures, production chains, and qualification concepts. It was necessary to define joint standards for processes, tools, specifications and quality inspections in order to ensure comparable production processes and results. This meant going into details such as the extent of punching and machining processes, the positioning and clamping points for the mechanical processing, or the removal points for material samples. Further aspects involved the frames and the parameters for heat

Figure 2: "The absolute key to success ultimately remains the expertise to precisely master one's own processes – and the subsequent optimization of the costs situation," stresses Axel Schmidt (Photo: Johannes Müller)

treatment, the straightening concept (including a binding design for the alignment gauges), or a uniform packaging and dispatch concept.

Other aspects were also required to ensure a smooth worldwide supply of all the production sites with the necessary structural castings. For example, it was indispensable to work out strategies and procedures for the qualification of new suppliers and sites that had no experience of such structural castings. The design and implementation of serial production in China presented perhaps the greatest challenge in this project due to differences in the level of mastery of the technologies and in local mentality, the time shift and, last but not least, the language problem. "We at DGS are particularly proud of being the first European die-caster to have accepted and successfully mastered this enormous challenge," says a satisfied Axel Schmidt.

Casting the rear side members

"We produce four of the seven structural castings for the body: the two rear side members (**Figure 4**) and the two front suspension strut consoles," says Axel Schmidt. At its St. Gallen works, DGS came up with a particularly innovative casting concept for the side members with dimensions of 480 x 315 x 290 mm, a component weight of 1.4 kg, and wall thicknesses of 2.0 - 3.0 mm. For the first time, such large structural castings were produced in a four-cavity mold on a Carat 320 die casting machine from Bühler, which is the largest installed casting cell in Switzerland, with a closing force of 3,200 t. After casting, the parts are cooled in water and individualized by stamping. Then they are immediately placed on the specially designed component holding fixtures of the heat-treatment racks in preparation for a two-step heat treatment. This gives the castings the specified mechanical characteristics: tensile strength R_m ≥180 MPa, yield strength $R_{p0.2}$ ≥ 120 MPa and elongation at break A5 ≥ 10 %. An additional criterion is a bending angle of at least 60 % to fracture determined on a flat sample. This criterion proves the suitability of the material for joining by means of punch riveting.

Particularly high demands had to be met regarding the absence of defects in the castings. Casting takes place under high vacuum to ensure perfect microstructures. The melt is carefully refined before casting and flushed with inert gas in order to prevent gas and solid inclusions in the castings. Strict specifications apply for the selection and applications rules for mold release agents and plunger lubricants. Special requirements also apply for the microstructural and surface quality of the parts, particularly regarding the subsequent joining processes during body assembly.

Production of the parts for installation in Germany and South Africa – up to 370,000 units a year – takes place at the DGS parent plant in St. Gallen in Switzerland, while the Chinese DGS subsidiary in Nansha produces up to 130,000 units per year for China. The Mexican supplier Bocar – which entered into a close collaboration with DGS during the course of this project – is responsible for supplying the Daimler works in the USA.

Manual straightening

"One of the secrets of our success is the limitation of tension-related warping to a level that can be corrected by relatively simple adjustments," reveals Schmidt. In practice, warpage is virtually unavoidable with such large and thin-walled components. This is mainly due to internal stresses resulting from the casting and stamping processes and further exacerbated by heat treatment. The trick is to master the process so skilfully as to minimize these deformations – this sorts the good casters from the rest. As the part

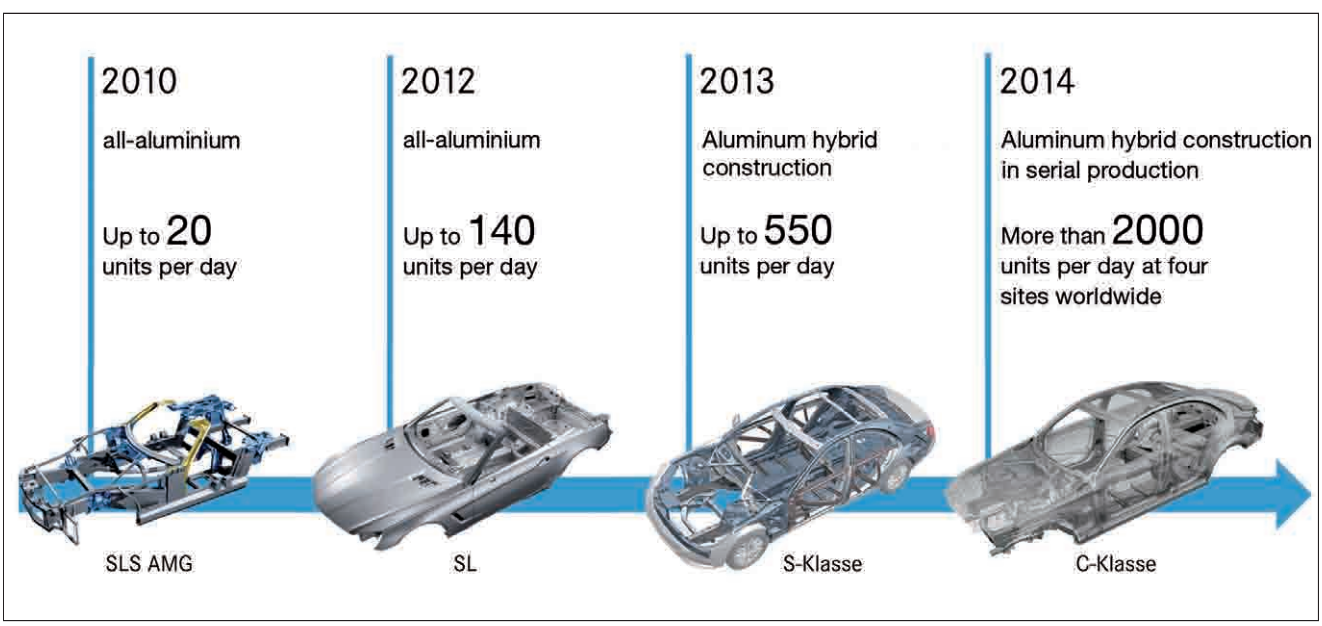
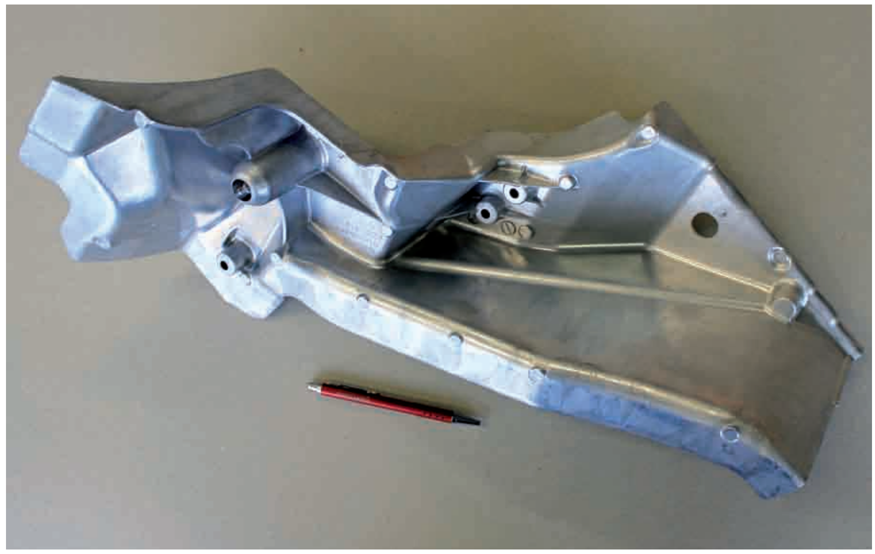


Figure 3: The step-up to mass production requires the clarification and mastering of the most varied of details. This is why it has been systematically prepared via several models over many years (Graphics: Dr. Pfitzer, Daimler AG)

Figure 4: The rear side members made of the alloy AlSi10MnMgSr have dimensions of 480 x 315 x 290 mm and only weigh about 1.4 kg each as a result of their low wall thicknesses of just 2 - 3 mm (Photo: Klaus Vollrath)



shape for ensuring tight gap dimensions – also in order to limit the joining gap for adhesive seams – may only deviate by a maximum of ± 0.5 mm from the CAD dimensions, every casting must be inspected and, if necessary, straightened.

DGS decided to make straightening a manual process in order to be able to profit from further process improvements, i.e. minimizing of deformations. An automated straightening process would require enormous investments and only be used for one specific component. Once installed, implementation of a subsequent optimization of straightening would no longer provide any major economic benefit.

In the manual straightening process the part is examined on an electronic measurement system before the diverging locations are manually straightened by experienced specialists. Experience and a feeling for the parts are the most important prerequisites for a rapid and reliable straightening process. The straightening process is only completed when the measurement system provides an 'in order' result for all the specified positions.

Fully automated further processing

"The further processing steps take place with the help of robotized automated systems," explains Schmidt. Grinding, which serves to prepare the parts for the subsequent joining processes in body construction, is particularly important. Grinding takes place in a fully encapsulated cell, in which several robots process the parts on different conveyor belts with a variety of grinding disks and brushes. The final station is a combined processing/assembly plant, in which the receiving threads for screwing onto the back axle are added and reinforced with a mounted stainless steel Helicoil. The thread is formed on a Milltap 700 CNC processing center from DMG with a special tool, and then the thread insert is fully automatically mounted in a specially developed assembly system. What distinguishes this station is its complete monitoring of the mounting process regarding the screw-in torque value, the position of the mounted Helicoils and, last but not least, removal of the Helicoil tang.

Mastering the production process as the key to cost optimization

"One of the decisive prerequisites for our success is the ability to reliably keep production processes under control within the tightest possible limits," explains Axel Schmidt. The narrower the achievable property range can be kept, the closer one can approach the limit values demanded by customers regarding part properties. Many quality-determining process steps, such as heat treatment, are cost-intensive. It is, in effect, giving away money if, as a result of major process fluctuations, one achieves 20 % elongation at break instead of the required 10 %. There are also frequently further disadvantages, such as higher reject rates due to blister formation and stronger deformations because of this type of heat treatment. Customers, however, only pay for exactly what they asked for and specified. The same applies for agreed tolerances and inspections. In order to be able to act successfully here one must, of course, have as precise a knowledge as possible about the process chain and its main parameters and interactions such as, for example, the effect of the individual elements in the alloy. These interactions also apply regarding the question of to what extent which stages in the entire process chain can be automated. Of course, each automation process has the positive effect that one can better control and document the parameters of the particular sub-process. On the other hand, however, automation involves additional costs. Complete automation of the production process, therefore, does not necessarily create an optimal solution. "The absolute key to success ultimately remains the expertise to precisely master one's own processes – and the subsequent optimization of the costs situation. Thanks to this capability, we are able to act successfully on fiercely competitive international markets despite high domestic wage levels," stresses Axel Schmidt.

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Picture galery showing the manufacturing process at DGS Druckguss in St. Gallen, Switzerland
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