Whitepaper

The Future of **Structural Components** in HPDC.

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Taking die-cast structural components into the mass automotive market.

Abstract:
The continuing quest for lighter-weight components in the automotive industry has seen the emergence of a lucrative new market for die casting: structural components. The demand for these large, complex components, such as shock towers and longitudinal beams, was estimated to cover just under 6 million cars in 2018, many with multiple structural components. Current usage is predicted to grow to nearly 9 million cars by 2025.[3] But whilst these structural components offer a more rigid, lighter solution that car makers want, the cost for longer production runs has so far limited adoption to sports cars, luxury cars, SUVs and quality D segment saloons, where smaller runs make economic sense. But the economics of die casting are changing. Over the past few years, the costs of structural components have dropped by as much as 20 percent. This paper shows how a combination of advanced thermal management, the use of new alloys and careful product design could drive down production costs even further. Hereby die-cast structural components get more cost-effective for the mass car market. With new car production predicted to hit the 110 million vehicle mark in 2023[1], and with between two and six structural components per car, these technological advances could potentially transform the opportunity for die casters around the world. If the manufacturing chain – from die-casting machine manufacturers, to foundries and OEMs – work together, it will be possible.

Why are die-cast structural components so attractive to the automotive industry?

Die-casting foundries around the world are seeing fundamental changes in the automotive industry that are profoundly affecting the industry. Consumer demand and environmental regulation is driving significant changes in the kind of cars people want to drive and how they want to use them. Electric mobility is developing at a fast pace, with global sales more than doubling, from around 2 million in 2017 to 5.1 million in 2018.[2]

Every car manufacturer is focused on producing more sustainable vehicles – preferably at a lower cost. And a key element in reducing fuel consumption, extending battery range or reducing emissions, is in making cars that weigh less. This is the motivation that is fueling the growing demand for structural components.

The role of die-casting technology in vehicle weight reduction

Die casting large structural components is a proven route to reduce weight in vehicles. Die casting in aluminum alloys delivers exceptional strength and good formability, but with less weight than traditional steel structures.

This drive for lighter weight is independent of powertrain selection. As debates over the best sustainable motoring solutions rage, from ICE, PHEV, HEV, EV even hydrogen, and consumer attitudes and regional and local regulation skew demand across markets, investing in the production of structural components is a clear strategic solution for many die-casting foundries.

Pioneered in the German luxury car market, die-cast structural components are now being used in wider categories of vehicle, for a range of applications. (see Figure 1).

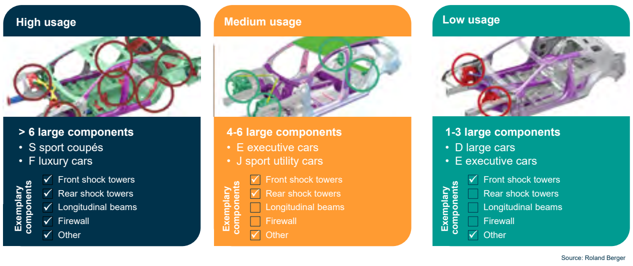


Figure 1: Current usage for structural components in the automotive market

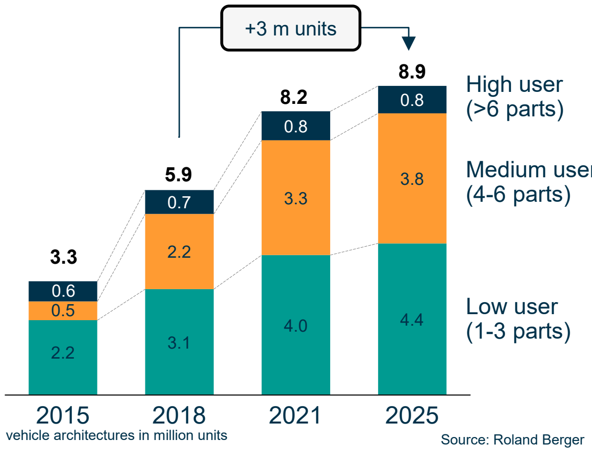


Figure 2: Predicted growth in current structural components, 2015 to 2025

Much of this growth is predicted to come from the E segment and D segment car market, and J segment sport utility vehicles.

An important application for die casting

S sport coupés and F segment luxury cars currently use the widest range of die-cast structural components, including front and rear shock towers and longitudinal beams designed for the dissipation of crash energy. The Jaguar I-PACE actually uses 15 structural components on each vehicle. E segment executive cars and J segment sports utilities use die-cast components in shock towers and rocker rein enforcements. Mercedes C-class is perhaps the highest volume user, with around 400,000 cars sold each year. D-segment large cars use die-cast parts for front shock towers and tunnel reinforcement.

This move to die casting structural components is gathering momentum around the world. Bühler analysis of this current available market, conducted by global consulting firm, Roland Berger (see Figure 2), shows growth in units is predicted to almost triple in the 10 years from 2015 to 2025, from 3.3 million units to 8.9 million.[3] The study takes into account the currently known production starts of the OEMs. New platforms could further increase the demand for structural components.

The potential for mass market adoption

The current reality is that while the investment costs for tools are low compared to other processes, the tools are subjected to considerably more wear which, in turn, increases the tool maintenance costs for longer production numbers. This currently makes overall unit costs too high to break into the C segment medium car market, or smaller mass market cars.

Bühler analysis shows that achieving cost savings that allow a breakthrough into the C segment market, together with greater adoption in existing car segments, could be a game-changer for the industry (see Figure 3), expanding the market from six million cars today, to over 25 million by 2030.

So the question is, what advances and techniques could be deployed now, with current technology, which would enable die-casting to break the cost barrier to mass market adoption?

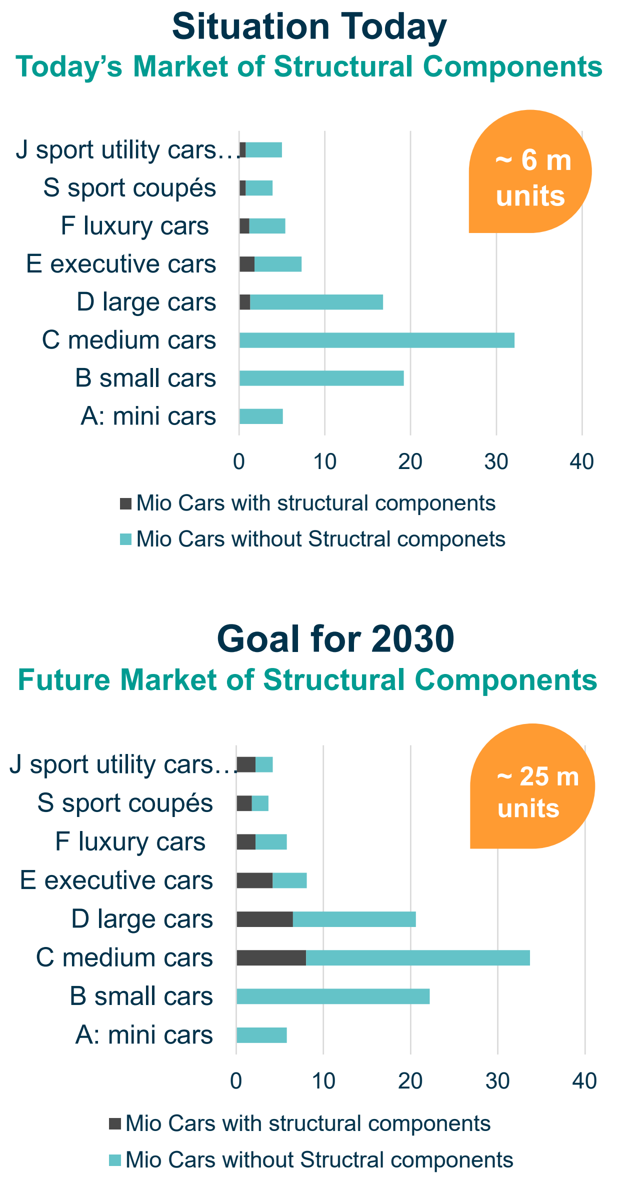


Figure 3: Potential structural component market growth with production cost savings

Three technological advances within our grasp

Using application knowledge gained across Europe, China and North America, Bühler has identified three areas where application-specific developments could deliver the production cost-savings the industry needs:

1. Thermal management
2. Alloy selection
3. Lightweight construction by product design

Using an advanced 4,400 ton machine, and assuming an application with two cavities with a three-plate tool, calculations show that using advanced techniques to reduce cycle times and improve die lifetimes will deliver significant cost reductions.

1. Improving productivity through thermal management

Thermal management is a key element in cycle times, die life and part quality. Improving thermal management in an existing process can therefore deliver improvement in all three of these areas.

A combination of improved thermal balance and the addition of targeted micro-spraying, together with optimum cell layout, can reduce cycle times for a typical structural shock tower by a third, from 90 seconds to just 60 seconds (see Figure 4).

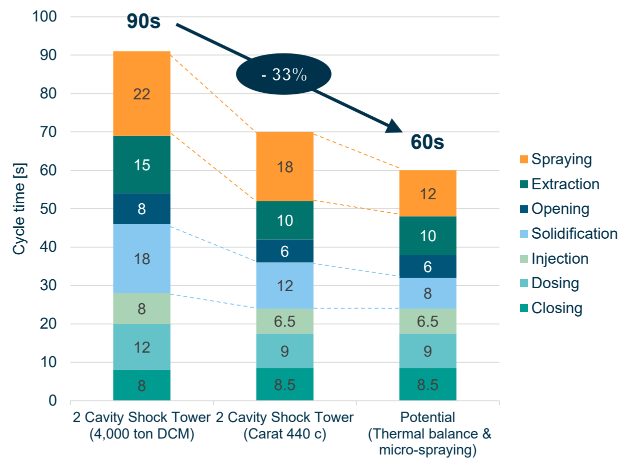


Figure 4: How better thermal management can reduce cycle times by up to a third

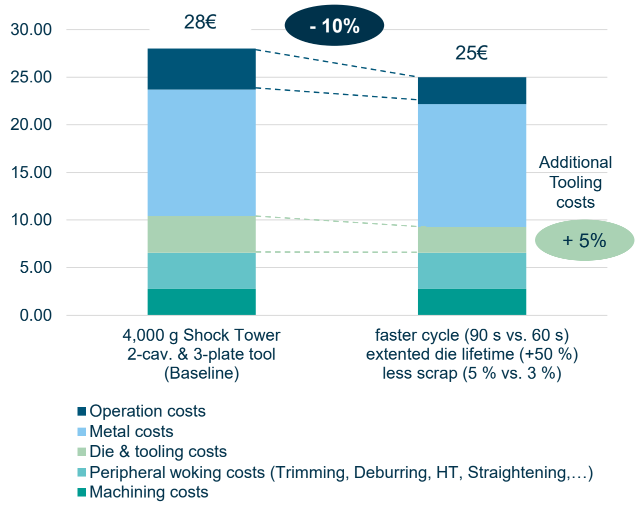
A well designed temperature concept allows the use of micro-spraying. This leads to a shorter solidification time and a significantly shorter cycle time. Productivity and quality are also improved.

Improved thermal management also puts less wear on the die, extending die lifetime. In this example, it is calculated die lifetime could increase from 80,000 to at least 120,000 cycles, an improvement of 50 % or more. This is a significant advantage for mass market production.

And this fine-tuning of the thermal process avoids hot spots and reduces shrinkage porosity - improving part-quality. This could reduce scrap rate from 5 % to 3 %, once again reducing overall production costs.

Cost savings for a typical shock tower

This combination of cycle time reduction, extended die life and scrap reduction, even with the need for some additional tooling, has the potential to reduce unit production costs by 10 % – an important first step in achieving an acceptable cost for mass market adoption. (see Figure 5)



Source: Bühler manufacturing cost saving study

Figure 5: Cost reduction using improved thermal management

2. Using new alloys to reduce process steps

Many of the structural components currently being produced with die casting play an important role in safety or crash damage mitigation. To meet the specific material requirements for crumpling on impact or absorbing crash energy in addition to functional requirements, there is a very high mechanical specification.

At the moment, these characteristics are achieved with special alloys that often require heat treatment and straightening. This is carried out after the part is cast, later in the process. In some cases straightening requires expensive manual work.

New alloys are constantly emerging that could deliver comparable or superior mechanical properties with reduced heat treatment requirement, or indeed, cut out the heat treatment process step altogether (see Figure 6).

	Standard Structural Alloys	New Alloy Systems	High Strength Alloy Systems
Alloy System	AlSi10MnMg	AlMg4Fe2	AlMg6Si2MnZr
HT	**T7**	**F**	T5
UTM Rm [MPa]	200-240	240-260	350-380
Yield strength Rp0,2% [MPa]	120-140	120-140	230-250
Elongation A [%]	**10-20**	**10-22**	8-12

Figure 6: Possibilities of different alloy systems for Structural components.

Alloys for structural components with high requirements in elongation and strength

Of course, any new alloy system will need to be approved and verified for the specific application, but the potential for improved quality and reduced costs is clear (see Figure 7). Indeed, in this example, there is the potential to reduce costs by a further 10 %, on top of the thermal management savings achieved in step 1.

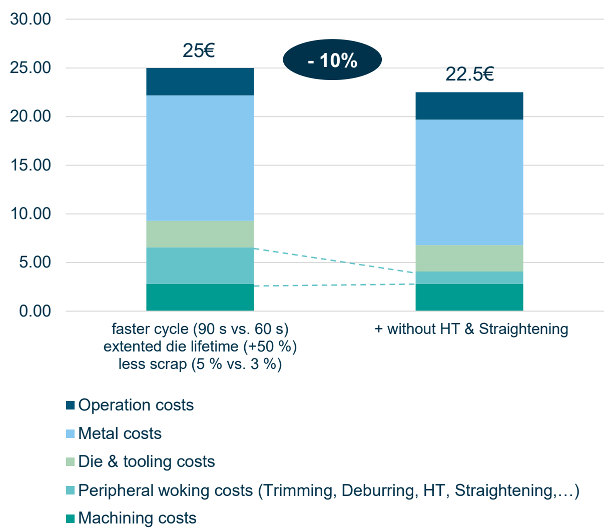


Figure 7: Potential cost savings from new alloys

3. Designing for weight saving

The drive towards die-cast structural components is motivated by saving weight.

Structural components cast in aluminum alloy today have an average wall-thickness of 2.5 mm, with material concentration around connection points and ejector marks. By contrast, with careful design of the part and the casting process, the same components can be produced with a wall width of just 1.8 mm. This can deliver up to 20 % savings in overall weight.

Of course, the level of achievable weight reduction is limited by structural integrity, which depends upon the loads and stresses on each part when in use, in a vehicle. Using the shock tower example, intelligent design could reduce the weight by 10 %, from 4,000 g to 3,600 g.

As well as helping to meet the argument for die-casting based on weight reduction, this would further reduce production costs by 4 % (see Figure 8), whilst creating a more sustainable product.

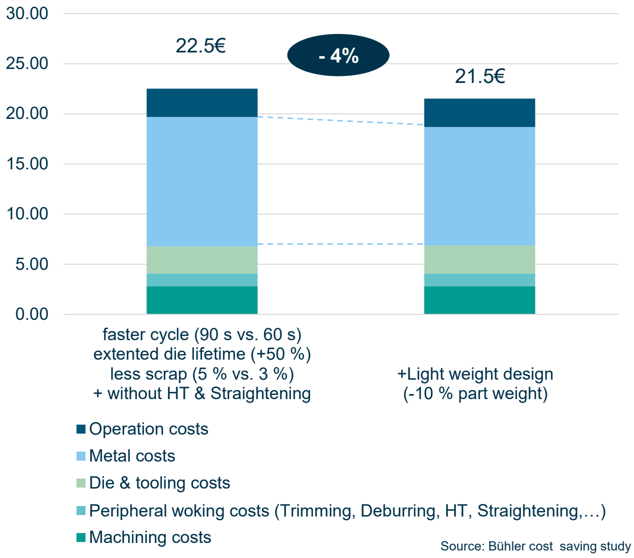


Figure 8: Cost saving potential by light weight design

An award-winning example of weight reduction

In 2018, the 1st prize at Euroguss for the optimized design of a casting, went to a part which incorporated a weight reduction of 19 % compared to the functionally identical part of the previous model.[4] This was achieved with a high-strength, highly flowable alloy in combination with a strength-optimized T6 heat treatment. The thin-walled design also saves a significant amount of material, thus contributing to a ustainable value chain.

An overall cost reduction of over 23 %

In this example, fine-tuning thermal management, introducing new alloys and redesigning the shock tower to optimize weight and production has reduced the unit cost of each part from 28 € to 21.50 €, an overall cost reduction of just over 23 %.

Crucially, that could be enough to make this an attractive proposition for C segment medium cars, opening up a lucrative volume market for die-casting foundries worldwide.

A powerful argument for application-specific cost-reduction programs

This paper describes a theoretical cost reduction program for a typical shock tower and makes a powerful argument for fine-tuning products and processes to reduce costs and improve quality.

At Bühler, investment in Industry 4.0 technology, AI, SmartCMS and world-class digital services like Predictive Analytics and Downtime Analysis are designed to enable customers to continually refine processes for ongoing improvement.

But every part has unique characteristics. Every application has specific parameters. And every foundry sets up and approaches cells differently. To make application-specific cost-reduction programs work, it's essential that car companies, OEMs, product designers, foundries and die-casting machine manufacturers all work closely together to achieve the break-throughs that will serve the automotive industry – and sustain the die-casting industry – for many years to come.

References

1. Wagner, Statistica, available at: https://www.statista.com/statistics/266813/growth-of-the-global-vehicle-production-since-2009/

2. IEA (2019), "Global EV Outlook 2019", IEA, Paris, www.iea.org/publications/reports/globalevoutlook2019/

3. Roland Berger (2019), Independent research for Bühler AG: Considers existing, known and projected architectures, congress presentations and interviews with industry experts.

4. DGS award-winning casting: https://www.dgs-druckguss.com/en/technology-and-innovation/awards

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