Losing Pounds and Cutting Costs with Injection Compression Molding

Production-Ready Process Development for Making Large Interior Parts

Swiss toolmaker Georg Kaufmann and Germany-based Daimler AG have developed a multifunctional, production-ready injection compression mold in a project aimed at making the rear door trim of an SUV by a technology that is more lightweight, more cost-effective and utilizable all around the world.

Despite larger outer dimensions and more features, the weight of the new Mercedes-Benz GLC has been reduced by 80 kg compared to the previous model. A small contribution to this has been made by the rear-door trim, the weight of which has been reduced by around 13 % through injection compression molding (© Daimler)

Producing large, thin-walled parts in the conventional manner by compact injection molding is a challenge per se – especially when a high-quality finish is required on the visible side and molded-on reinforcing ribs and mounting elements are needed on the rear. It is technically feasible, but it takes a lot of effort. For example, several injection points are required because of the long flow paths. To avoid weld lines or to locate them in optically less critical areas, it is not uncommon to employ cascade injection molding in hot-runner molds fitted with needle-valve nozzles which open sequentially during injection. Door trim is a typical part made by this method.

The rear-door trim of the Mercedes-Benz GLC is grained on the visible side and measures 1200 x 500 mm and – if produced by compact injection molding – has a wall thickness of 2.5 mm (**Fig. 1**). Molded onto the rear of this component are numerous mounting elements, in addition to honeycomb reinforcing ribs. These include, for example, 15 domes (retainers) for receiving the mounting clips, three cross-domes for accurate positioning placement of the component during installation, and two hang-in straps (so-called "third hand") as mounting aids (**Fig. 2**).

At the beginning of the project, various options for developing the rear-door trim were discussed on the basis of agreed targets. In addition to a substantial reduction in part weight and lower part cost, there was a desire to develop a technology that could be used across the automaker's various production locations without the need for excessive investment in tooling and production lines. It was also important in this context for the constituent material to be available worldwide. Following internal deliberations at Daimler, it was decided to collaborate with a tool maker, not least in order to gain experience for future developments and upcoming projects.

Three Process Alternatives in the Final Selection Round

When the choice of process technology was being discussed, foaming, especially chemical foaming, was suggested initially. However, achieving optically de- »

Fig. 1. The rear-door door trim of the Mercedes-Benz GLC is a part which is grained on the visible side (grain see image detail) and measures 1200 x 500 mm (© Georg Kaufmann Formenbau)

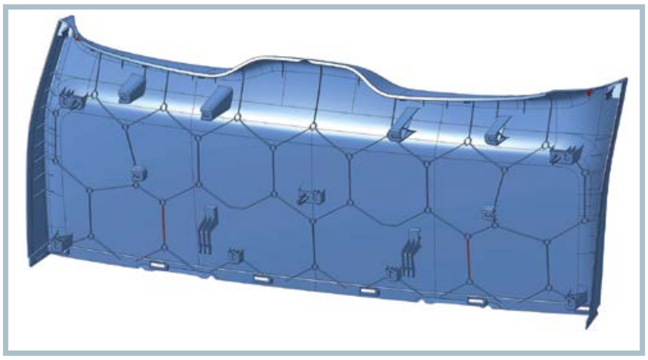

Fig. 2. Molded onto the rear of the component are numerous mounting elements, in addition to honeycomb reinforcing ribs (© Georg Kaufmann Formenbau)

manding finishes with such foamed components entails additional mold outlay, e.g. dynamic temperature control or the use of gas counterpressure. In particular, the sealing of the mold that is entailed with the last-mentioned variant is problematic both technically and in terms of associated costs. In addition, materials development (project start in 2011) was not as advanced back then as it is now. Physical foaming was out of the question due to the resultant unsatisfactory surface finish.

Instead, injection compression molding looked much more promising and so was studied as a possible further alternative, albeit in tandem with structural foam molding. The development partners decided to design and build the mold for protecting the technology in such a way that it was amenable to all three processes, namely compact injection molding, injection compression molding and structural foam molding. This enabled the compression molded parts and the foamed parts to be compared and evaluated with those of the compact variant. Moreover, mold proving trials were used to study the suitability of the material, which was refined further, for chemical foaming. Finally, the multifunctional mold opened up the possibility of making parts for certification testing and the various requisite test series (climate and material tests).

Just Three Injection Points for Injection Compression Molding

In the end, a production-ready positive steel mold featuring a hot runner system and nine needle valves was developed and built. Part and mold were developed concurrently, supported by repeated feasibility studies. This approach spawned further ideas on how to gain additional insights as the project unfolded. For example, a removable insert was incorporated into the mold to study how different thicknesses and heights of the reinforcing ribs affect the surface finish of the visible side, and to test different materials.

Other considerations were the points of intersection of the honeycomb structure – whether round connections or crossing points were better. Simulations were used to study the layout of the reinforcing ribs (arrangement, design and number) and their honeycomb structure. Different geometries for the retainer attachment were also studied. The mold is designed for wall thicknesses of 1.8 to 3 mm. A wall thickness of 2 mm was later determined for injection compression molding.

The nine injection points were the subject of further studies. Whereas compact injection molding would need at least five hot runner nozzles for the size of the present part, injection compression molding would require just three injection points. Admittedly, this insight was gained only as the project unfolded. The mold was designed for use with a standard polypropylene. Injection is cascade-controlled. While the mold was being completed, a test jig was made for installing the rear-door trim as realistically as possible.

The final decision to choose injection compression molding was based on the fact that it is widely established (**Fig. 3**). It is ideal for producing large parts with long flow paths and large flow path/wall thickness ratios. The process technology ensures that the molded parts are filled reliably, internal stresses are avoided and the surface is demolded cleanly. Injection compression molding is familiar from its use in the production of optical parts and polycarbonate roof glazing.

Five Short Proving Loops

Injection compression molding replaces part of the holding-pressure phase with a compression process. Shrinkage is then no longer compensated by pressing additional melt into the cavity, but rather by a displacement process that occurs on the mold side. The compression process thus acts over a large surface area. It allows for the production of parts with lower stresses because large amounts of plastic melt are no longer pushed in the direction of flow (**Fig. 4**).

The mold proving trials were carried out in collaboration with Engel Austria in St. Valentin, Austria, on an Engel Duo 1700-11050 injection molding machine with 17,000 kN clamping force and variable stroke/travel control. For the initial mold proving, compact injection molded parts were produced to act as reference. Subsequently, parts were made by injection compression molding and then later by chemical foaming. At the same time, the

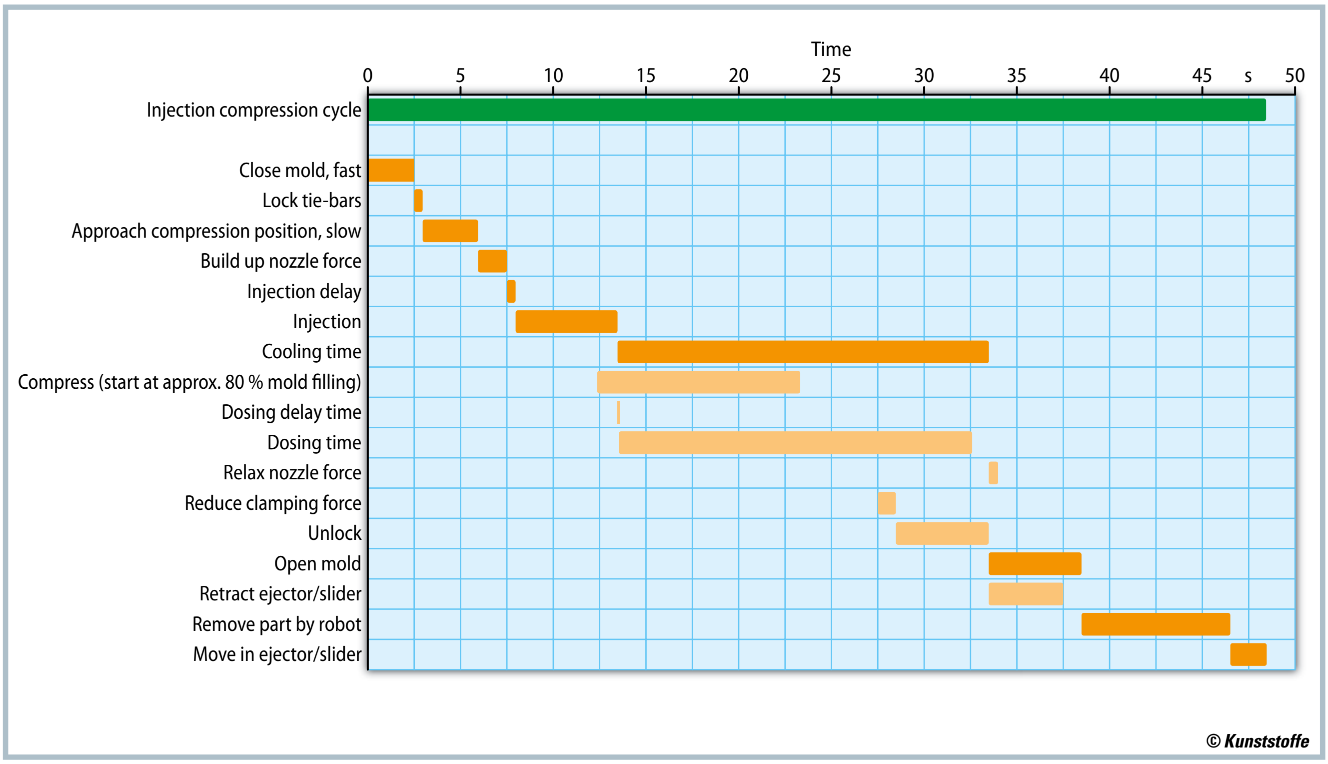

Fig. 3. Cycle-time diagram: Injection compression molding is ideal for producing large components with large flow path/wall thickness ratios. With this process technology, the molded parts can be filled reliably, internal stresses avoided and the surface demolded cleanly (source: Georg Kaufmann Formenbau)

parts for the development vehicles were also manufactured with the mold.

In total, only five proving loops were required, each lasting about one week. That the proving trials were performed so quickly was due to the close collaboration between the development partners, including the machine and raw material manufacturer, and to a highly detailed experimental design developed by Kaufmann. All this entailed playing through and discussing all possible scenarios in advance. The partners involved in each proving stage agreed beforehand on the exact procedure to follow. As a result, all provings were successful, i.e. all the optimizations led to the expected results. By the way, during the provings, the Tier 1 supplier was brought on board so that it could be familiarized with the technology.

Part Weight Reduced by 13 %

It transpired during the mold proving trials that a much lower clamping force (10,000 kN) is sufficient for injection compression molding. This translates to lower investment in plant and also lower machine costs. By late 2013, the mold and process concept had already been proved to the extent that the client issued the green light for production readiness (**Fig. 5**).

The rear-door trim is made by closing the mold to a gap of 3 mm. This is followed by injection to approx. 80 % filling capacity, whereupon the mold closes as part of the cycle. This sequence was determined experimentally and was systematically refined on the basis of the surface finish. When the mold is fully closed, the cooling phase commences. Demolding of the part starts while the mold is opening.

The level of weight reduction achieved was due in no small measure to the material involved. Produced by compact injection molding from standard PP with 17 % talcum, the part weighs around 1600 g and has shrinkage values of 1.1 % transversely and 0.8 % longitudinally. Injection compression molding alone reduced the weight of the part by 13.2 %. The project team expects a new reduced-density PP containing 10 % tal- »

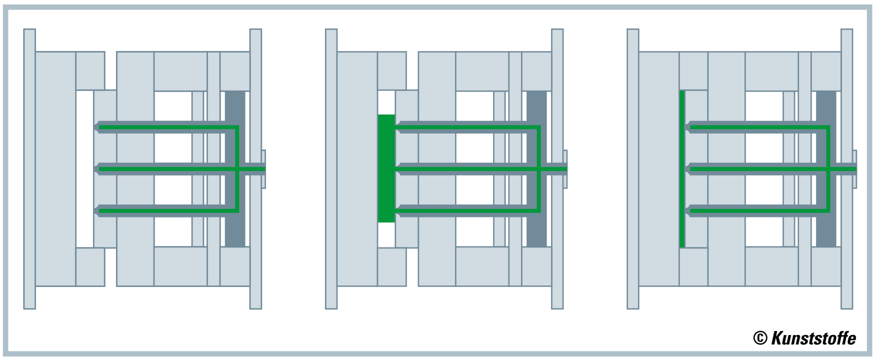

Fig. 4. In injection compression molding, the holding-pressure phase is partially replaced by compression across a large area. From left: the mold is closed to a gap of a few millimeters; this is followed by injection before the mold closes in the cycle and the compression step is carried out (source: Georg Kaufmann Formenbau)

cum to yield a further weight reduction of 6 % and thus a total of 19 % for the same shrinkage. This material is currently still undergoing approval tests. The mean cycle time is just under 48 s.

Thin-Wall Parts with Low Internal Stresses

Despite the greater complexity of the mold design and the greater outlay incurred on the controller for the injection molding machine, the parts made by injection compression molding cost around 11 % less. Given that this injection compression molding technology has been developed with a wide range of other parts across different series in mind, the potential for cost savings is huge.

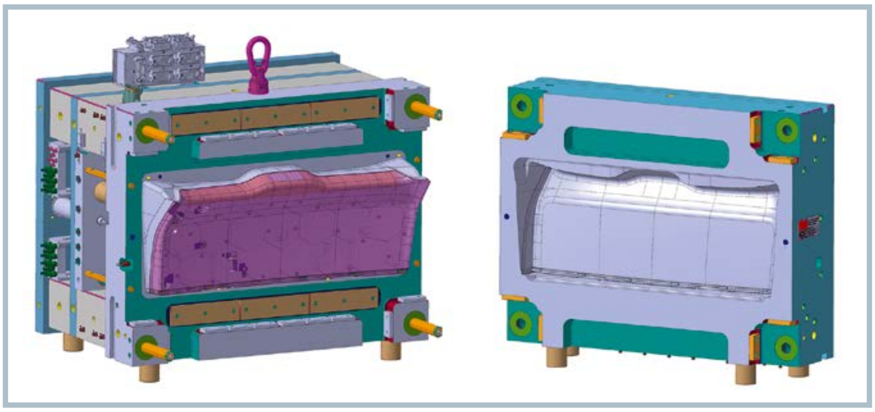

Fig. 5. Despite the greater complexity of the mold design and the greater outlay for the controller of the injection molding machine, parts made by injection compression molding cost around 11 % less (© Georg Kaufmann Formenbau)

In addition to the fact that injection compression molding makes do with a smaller machine of lower clamping force, the process offers countless advantages. Thus, surface reproduction is extremely good. The melt is fed at low pressure, which is why the parts have lower internal stresses and good impact strength.

The smaller wall thickness of the parts produced conserves material and so lowers the weight. To be sure, part rigidity is reduced because the wall is thinner, but this can be compensated by targeted part design (including simulation). In addition, the technology can be used worldwide because both the positive mold and the requisite controlled injection molding machine are state of the art.

Conclusion

Considerable savings on the weight and cost of a large interior part can be made by injection compression molding. The modular approach factors in the production of further rear-door trim by injection compression molding in the future. The concept will be transferred to other large trim parts as well.

A key goal for Daimler, aside from developing the part, mold and process, was to protect the technology with the aid of an independent partner. The project partners Kaufmann and Daimler have successfully completed other comparable projects by adopting this approach. The project managers are convinced that this approach is beneficial to all parties, including suppliers. Usually, the suppliers have to factor their development costs into the parts calculation, which is not always easy. In the present case, the supplier has the advantage of knowing that the component and mold are fully designed, the material has been approved, all the relevant data are available, and the production process has been cleared for series production. ■

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