Exciting Design instead of Exciting Manufacturing

A 3D-Printed Nozzle and Modified Dosing Method Deliver Reproducible Marbling in a Robust Process

Marbling is often a real eye-catcher in plastic components. However, the effect is difficult to create and there are some pitfalls when it comes to reproducibility. Novel nozzles for injection molding machines in combination with a special dosing technology allow marbled molded parts to be produced far more easily in a much more robust process.

Marbling leads to attractively designed molded plastic parts, but is not so easy to implement in production

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Marbled molded parts have been around since the early days of plastics when, for example, combs or buttons bearing a marbled pattern were produced. In some cases, the marbling happened unintentionally because homogenization in the plunger injection molding machine had still not been perfected. With the advent of screw injection molding machines, not only plasticizing capacity has increased, but above all significantly better melt homogenization has become possible, paving the way for colored molded parts without any color streaks on their surfaces. In addition, mixing elements are sometimes deliberately installed in injection units in order that mixtures of uncolored pellets and masterbatches may be converted into streak-free molded parts.

Now, marbling effects are created either mechanically with the aid of special marbling screws or by means of two-component injection molding machines. In the latter, two molding compounds of different color are injected into one cavity, usually by sequentially opening and closing valves which are located either inside the mold or between the machine nozzle and the mold. However, the production of reproducibly marbled parts in two-component injection molding machines is relatively costly, as two injection units are required and have to be operated.

Since parts with marbled surfaces often look very attractive and unique, they are still in demand, even though the manufacturing process is complex. A process by which they might be produced reliably and reproducibly without major technical outlay would therefore appear desirable. An ability to specifically influence the marbling patterns would also give designers additional freedom over the visual design. BASF SE, Ludwigshafen, Germany, has developed one such process that allows marbled molded parts to be produced with little outlay.

Marbled molded parts typically have patterned visible surfaces bearing such effects as color shading, color streaks,

lines and texture. The formation of the effect varies with the proportions of the different colors and the base color of the part. Although marbled molded parts manufactured in a production run are not absolutely identical, they look essentially very similar. Some of the patterns achieved with this technology are reminiscent of the appearance of natural materials, such as marble or wood. For high-contrast, clearly defined marbling patterns to be achieved, the admixed color batch must not be completely homogenized. At the same time, though, all the pellets must be completely melted and homogenized in order that the finished molded parts may possess the specified properties.

Initial trials conducted by BASF on molded parts revealed that the patterns differed according to whether they were produced with a needle-valve or an open nozzle. The number of flights of a screw tip was even discernible on the parts' surfaces. The patterns arise from the separating and merging of melt flows in the channels of the plasticizing unit. This insight prompted a decision to rethink the nozzle of the injection molding machine and to employ different melt channel geometries in the nozzle cap. For this purpose, a recess for accommodating interchangeable inserts was created in a standard nozzle cap. As a result, the channel geometry in the nozzle can be changed to create all manner of patterns **(Fig. 1)**. A symmetrical arrangement of straight channels, for example, results in symmetrical patterns.

Marbling proves to be particularly effective in the case of flat molded parts. But it is also possible to create three-dimensional articles that possess highly attractive marbled surfaces (**Fig. 2**). The marbling pattern is determined by the nozzle design and the mold's gating system and the subsequent spreading of the melt. Thus, it is also influenced by the location of the injection point and the filling behavior of the melt in the direction of flow during injection into the cavity. **Figure 1** shows the many possibilities for symmetrical parts that are gated centrally. Attractive patterns may also be achieved by using molds equipped with hot runners and tunnel gates **(Fig. 3)**. The resulting molded parts are not centrally gated and so the pattern of marbling streaks is completely different from those shown in **Figure 1**.

Fig. 1. All kinds of marbling effects can be achieved, depending on the channel geometry employed © BASF

Fig. 2. Not only flat molded parts but also attractive three-dimensional articles can be produced with a marbling effect. Correct dosing and the combination of "contrast" batches and coloring component during production are also important © BASF

Fig. 3. Molds fitted with hot runners and tunnel sprues can be used to produce very attractive patterns. As these molds are not injected from a central point, the marbling streaks vary in their pattern © BASF

Additive manufacturing processes offer a very high degree of design freedom over the production of nozzle inserts. In particular, they can be used to create channel geometries that cause the melt to swirl as it flows into the mold (**Fig. 4**). This affords a way of producing mirror-image patterns and rotationally symmetrical patterns. The swirling of the melt is clearly visible in the pattern shown in the **Title figure** and **Figure 1**. Such patterns were previously not feasible with conventional processes.

The nozzles can be produced by additive processes such as laser welding and layer fusion processes, such as fused deposition modeling (FDM) and fused filament fabrication (FFF). Catamold pellets from BASF, for example, can be used to manufacture the nozzle and nozzle inserts. Here, a filament made of Ultraform, a polyoxymethylene (POM) from BASF that contains metal powder, is printed by the FFF method, followed by debinding and sintering. The final step of the process entails adjustment work such as fitting the printed insert into the nozzle cap.

Just One Plasticizing Unit

The marbled parts can be produced on standard injection molding machines fitted with just one plasticizing unit. All that is necessary is to synchronize the dosing of the material with the injection molding cycle. The materials are fed as usual into the existing feed opening in the hopper area of the plasticizing barrel. Conventional, only slightly modified dosing devices fitted with two hoppers are used (supplied, e.g., by motan GmbH, Konstanz, Germany). The base material, which is usually mixed with a color batch, is supplied in the conventional way, while a further high-contrast color batch, e.g. black, is fed into the plasticizing unit separately with great precision.

As mentioned, the process can be carried out on commercial injection molding machines without the need for specialized equipment. Ideally, the sole requirement on the injection unit is that it meets certain specifications, e.g. a low ratio of shot volume to barrel size. The injection molding process itself is »

not different from usual, and the process parameters are normally the same. The various influencing factors on marbling are summarized in **Table 1**.

Correct Dosing of the Contrast Batches

Correct dosing and the combination of "contrast" batches and coloring component are also important in the production of marbled molded parts. The choice of color combination is key to a successful marbling outcome. If the contrast batch is overdosed, the coloring component very soon loses its brilliance.

Ultimately, mold design, part geometry and the nozzle used in the machine and in the hot runner determine the resulting pattern. In the course of conducting its development work, BASF tested molds fitted with conventional sprues as well as with hot runners. In both cases, attractive patterns were obtained. The finish of the mold cavity's surface has an additional influence on the patterns' appearance. Whereas highly polished surfaces accentuate the contrasts intensely, textured surfaces lead to an unobtrusive, matt appearance (**Fig. 5**), as is also the case when glass fiber-reinforced materials are processed.

Marbled molded parts are chiefly used for decorative purposes in the consumer goods sector. They serve as household objects, e. g. bowls, plates, cups, handles, and covers, as well as laptop lids and smartphone covers, as fashion accessories, e. g. buttons, as decorative elements in vehicle interiors, e. g. caps and covers, and as parts for toys. For many of these applications, the polymers should at least have a food contact (FC) classification, as is the case for Ultradur B4520 FC, a polybutylene terephthalate (PBT) supplied by BASF. In contrast, various polyamides (PA) such as the Ultramid Deep Gloss or Ultramid Vision family from BASF are suitable for automotive interiors.

With the aid of the process presented here, it is possible to reproducibly manufacture marbled molded parts in different patterns on standard injection molding machines fitted with novel nozzle inserts and special dosing technology. Aside from PBT and PA, the process lends itself to other thermoplastics that are currently undergoing testing. BASF offers its customers not only suitability tests on existing molds and machines, but also support with nozzle design and 3D printing of pilot series, with the selection of materials and colorants and process control, as well as assistance with implementation into mass production. Mold provings can be carried out on the converter's premises or at any time in BASF SE's pilot plant on the customer's own molds. ■

Fig. 4. Nozzle inserts made by 3D printing offer designers huge freedom of design. Flow-optimized channel geometries in the nozzles can be used to make the melt swirl on its way into the mold. This also supports the creation of rotationally symmetrical patterns © BASF

Fig. 5. The surface finish of the mold cavity influences the appearance of the samples. Highly polished surfaces strongly accentuate contrasts. Textured surfaces leads to a matt appearance © BASF

Influencing factors	Impact on marbling
Part geometry	↗
Sprue type, sprue position, gate	↑
Mold design (surface)	↗
Material (color, viscosity)	↗
Nozzle design	↑
Dosing	↗
Injection molding parameters	→
Dwell time	↗

Table 1. Influencing factors on the marbling
Source: BASF

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