Continued Upswing for Injection-Moulded Components Made of Technical Ceramics

With new Ceramic Injection Moulding (CIM) compounds, components made of technical ceramics are gaining a broader footing. While they have already been in use for many years in the textile industry, thanks to current material and process developments, technical ceramic components are now becoming increasingly important in areas such as medical and dental systems, mechanical engineering, sensor technology and in domestic appliances. CIM components are substituting conventional starting materials on material and processing level, first because of the material-specific advantages, but not least because of the fact that unusual solutions can be realized thanks to the considerably higher degree of freedom in shaping injection-moulded components.

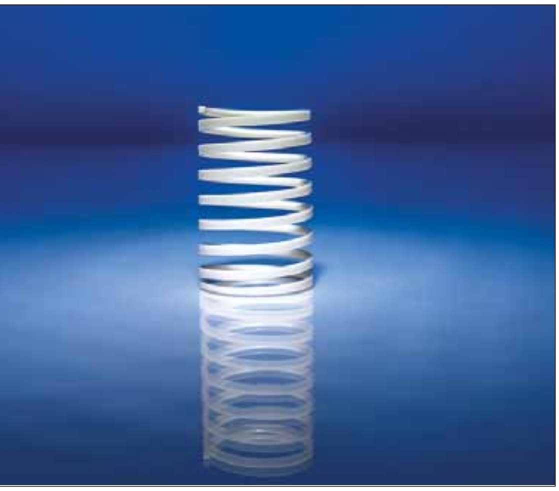

Fig. 1 Ceramic spring

A perfect example of the symbiosis of material and process is the ceramic grinding disk for fully automatic coffee machines that Kläger manufactures in series for a well-known customer. It demonstrates impressively the possibilities of cost-efficiently manufactured CIM components. An innovative product solution was evolved here from the symbiosis between material (ceramic) and process (suitable component geometry), for only the level of freedom achieved in the shaping process enabled the innovative geometric elements necessary to realize this component. From this evolved a ceramic component with a higher performance that was not only cheaper to produce, but also enabled easier installation.

Keywords
CIM, binder systems, plastic injection moulding

Development of injection moulding as reflected in the available materials

When industrial CIM processing with injection moulding machines began in the 1990s, there were basically only two injection feedstocks suitable for ceramic injection moulding. The first was catalytically debinded BASF-system Catamold while the second consisted of thermally debinded systems on wax basis. While the BASF system on POM- and therefore on thermoplastic basis did exhibit better flow properties, similar to plastic injection moulding, it had the disadvantage of catalytic debinding with nitric acid.

The wax-based systems, on the other hand, exhibited disadvantages in respect of their flow properties. In contrast to a "flowing" feedstock on thermoplastic-basis, the wax-based material tends to "flex", leading to the increased formation of weld lines and the risk of cracks. Especially with regard to use for thin-walled, filigree components, these materials were only suitable for use in certain circumstances. The green component strength was comparatively low, which made especially demoulding and therefore the mould concepts very complex. Other obstacles were encountered during the processing of relatively large volumes as the material cooled and solidified too quickly so it was no longer possible to compact the component homogeneously. The general guide value for the component wall thickness was therefore limited to 7 mm. Nevertheless, individual

Jens Graf
Kläger Spritzguss GmbH & Co. KG
72280 Dornstetten
Germany

E-mail: info@klaeger.de
www.klaeger.de

mixes of different materials could be compounded, which made the material properties individually adaptable. This is used by Kläger to this day with high competence for mixes with zirconia and alumina or compounds with contents of two base ceramics like, for example, zirconium-doped alumina (ZTA) or zirconia with added alumina (ATZ).

Latest developments widen material basis

In recent years, with materials and binder systems based on thermoplastic PP and PA, the basis for injection moulding of ceramics has been efficiently widened. The really big step was widening the binder systems to include PP and PA in addition to POM. All these plastics can now be thermally debinded, although in some cases preliminary debinding may be necessary. This last fact also shows how comprehensive know-how with regard to their processing and use is necessary. Not only knowledge of individual treatment of the compounds is important, the start of injection moulding, distribution and hardening of the materials in the mould is of elementary importance for the quality of a component series.

The two material systems, both the PP- and PA-based systems, exhibit good flow properties when used for relatively filigree, but also bulkier components. In addition, the green component strength has been optimized, the components are less sensitive, and it is therefore easier to remove them from the mould. This brings advantages especially for fully automatic injection moulding. Moreover, less material is deposited on the walls of the mould, which contributes to longer service cycles, and also enables a higher number of cavities in the mould – all aspects contributing to a more stable production with improved economic conditions.

Different binder systems require process-specific equipment

Depending on material and binder system, preliminary debinding based on acetone or isopropanol with appropriate plant hardware may be required. This conservative method of debinding in two stages incurs fewer problems, leads to fewer rejects and therefore to improved component quality. This offsets higher process costs.

Fig. 2 Heating pipe including runner (weight in green state: 375 g)

Mould and process expertise are needed

For the use of different binder systems, high material, mould and process expertise is extremely important. Every compound is different and has to be treated individually. The know-how, however, should not be reduced to the actual shaping process, injection moulding, but also influences the complete mould and process concept. Different mould and material temperatures, flow paths, cycle times, injection systems and times, the position of the components in the mould or their removal, the type and method of debinding, just like the different sintering curves and parameters, require understanding and management of the integrated process system.

Conclusion

Advances in the material development of ceramic injection moulding compounds over around the last five years give users greater potential both in technical and economic respects. Technical limits can be pushed even further with optimized processability. New geometries, both in respect of filigree demoulding and of volume and component size, are becoming possible. Consequently, fully new applications can be opened up. The development of compounds on the basis of different thermoplastic carrier systems. however, comes with technical challenges for the mould manufacturers and users. The bundling of know-how in the direction of material, mould, installed hardware and process is therefore more urgently needed than ever. This is where Kläger comes in with a big advantage. The company has always taken an integrated approach to the injection moulding process and is equipped inhouse to realize this process end to end. Material, mould and process technology are researched and holistically evaluated in advance with regard to the technical and economic aspects that result in the realization of a CIM injection moulding process for series production. Kläger is not only equipped to process all feedstock systems currently available on the market but has the concentrated know-how to implement this in a stable process in series production.

Kläger: leading in ceramic injection moulding, experienced in plastic injection moulding

Whether for grinding disks used in fully automatic coffee machines, nozzles for high-pressure cleaners, spray systems or filigree components for electrosurgery – the injection moulding of ceramic materials offers a much wider freedom in component geometry and consequently creates in many cases real cost advantages or enables the realization of previously non-achievable applications. Kläger's customers can depend on a full-service provider with decades of experience in this field – a "one-stop shop" for perfect and economically competitive

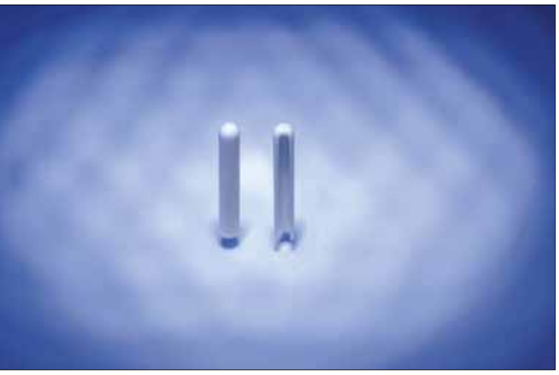

Fig. 3
Ceramic sleeve
(wall thickness: 0,2 mm; length: 18 mm)

ceramic injection moulding components in series. From development and simulation through design, the proprietary mouldmaking and the production up to adapted preliminary debinding, debinding and sintering. Whoever comes to Kläger with regard to powder processing, is given comprehensive support from the very beginning – to the finished component in series production!

Links between ceramics and plastic injection moulding are found in the process: Basically, plastic and ceramic materials can be processed in a similar way. The ceramic components have to be debinded after injection moulding and sintered to achieve their final shape and strength. Kläger has its origins in plastic injection moulding. Consequently, all customers can draw on sound knowledge and comprehensive engineering expertise from the two worlds for an ever individual process support.

In plastic injection moulding, Kläger currently processes over 300 different materials in over 2000 active articles. One focus are technical plastics, for which Kläger has a high material and process expertise, also for the substitution of metals with plastics. The injection weights range between 0,1 g – 450 g.

Fused Filament Fabrication (FFF) of Technical Ceramics

Fused Filament Fabrication (FFF), also known as FDM® is a thermoplastic Additive Manufacturing (AM) method in which an endless filament is used as a semi-finished product which is melted and deposited under a heated nozzle.

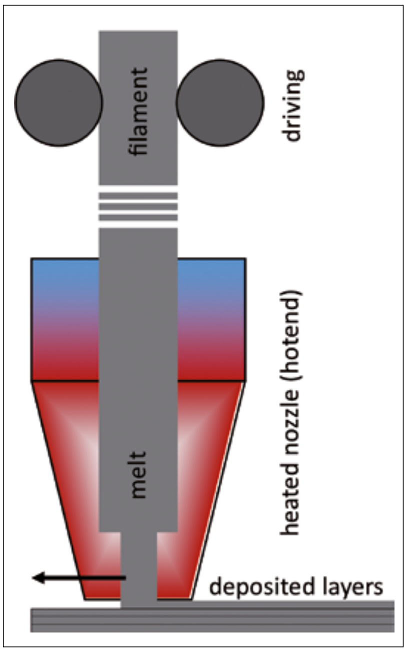

Fig. 1
Schematic view of the FFF process

Introduction

Components based on high-performance ceramics are applied in different areas of life as well as in science and technology. In all fields, a growing need for complex geometries with a wide range of individualization options and favourable manufacturing processes is identified. With the power of Additive Manufacturing (AM) completely new and highly complex geometries can be realized by selective adding of material to create undercuts or hollow structures. This possibility allows for shorter lead times and a rising efficiency as well. Strictly spoken: The way of thinking in today's fabrication guidelines has to be revised.

Fused-Filament-Fabrication (FFF), also known as FDM®, is a thermoplastic AM method in which an endless filament is used as a semi-finished product, which is melted and deposited under a heated nozzle. A scheme is shown in Fig. 1.

A component is imaged in accordance to computer-aided modeling, converted into the machine code (e.g. G-code), then transferred to the machine control and finally deposited layer by layer in a line-like manner. Through this method it is possible to produce large and complex components quickly and with high material efficiency.

Keywords
Additive Manufacturing (AM), Fused Filament Fabrication (FFF)

Johannes Abel, Uwe Scheithauer, Hagen Klemm, Tassilo Moritz, Alexander Michaelis
Fraunhofer Institute for Ceramic Technologies and Systems
Dresden, Germany

Tobias Schmidt
INMATEC Technologies GmbH
Rheinbach, Germany

Tobias.Schmidt@inmatec-gmbh.com
johannes.abel@ikts.fraunhofer.de