At first, a stress analysis was conducted for the wear-resistant die to determine the occurring stresses taking process-relevant parameters such as rheological properties of the extrusion mass into consideration. Afterwards, the ceramic material was chosen taking the mechanical and chemical stress as well as manufacturing-relevant aspects into account. In order to be able to use the different machining methods like grinding, erosion and ultrasonic treatment, both conducting and non-conducting ceramic materials were used. By means of finite element modeling the die was designed for the specific application. The ceramic components were manufactured by cold isostatic pressing, green machining, sintering and final machining.

»ToolEx« is one of further five demonstration systems which are developed within the framework of the Fraunhofer Demonstration Center »AdvanCer« (system solutions with advanced ceramics).
In April 2008, the Expert Group on Ceramic Injection Molding was founded. The expert group is a technical working group consisting of industrial companies and research institutes which have the objective to further develop the innovative process chain of ceramic injection molding (www.keramik-spritzguss.eu).

In addition, reliable partners of the Fraunhofer Demonstration Center »AdvancCer« (Fraunhofer institutes IWM, ISC and IZFP) are able to support customers in simulation tasks, thermooptical measurements or non-destructive testing.

Survey

Ceramic injection molding

Ceramic injection molding (CIM) plays an ever increasing role in those applications where components with complex geometry have to be produced in large quantities. The specific advantage of this method is that components with undercuts, cross and longitudinal holes can also be produced near-net-shape without using machining. For that reason, CIM coming from plastics industry has successfully been established since the end of the eighties similar to metal powder injection molding in powder metallurgy.

Method

Aside from the standard oxide materials alumina and zirconia, and others, mixed oxides and non-oxide ceramics such as silicon nitride, silicon carbide or aluminum nitride may also be processed using ceramic injection molding. When applying CIM it is absolutely necessary that the starting material has good plastic properties. Synthetic ceramic powders are used for advanced ceramics, and therefore they have no natural moldable constituents. They are mixed with organic binder systems giving them thermoplastic properties. These masses, also called feedstocks, are prepared in specific kneaders, twin-screw extruders or shear roll compactors. The feedstock’s rheological properties are characterized by the forces acting on the kneaders and high-pressure capillary viscosimeters. The feedstock’s thermal properties like specific heat capacity, thermal expansion, thermal conductivity as well as thermal diffusivity required for the simulation of the filling behavior may be determined in a thermooanalytical laboratory. The feedstock is added to the injection molding machine as granulates which are molten in the plasticizing unit. Then, the mass is injected into the cavity of the mold with high pressure giving the component its shape. There, the feedstock solidifies, and is then ejected from the cavity. In order to obtain a ceramic component the thermoplastic binder must be removed by extraction in solvents, catalytical or thermal de-binding. To optimize the debinding process of injection molded components, appropriate heating regimes based on thermooanalytical investigations are developed. Afterwards, the component is sintered where it obtains its final properties.

Trends

Aside from the challenge to produce injection-molded components with ever decreasing tolerances, higher purities and without process-related defects, trends are seen towards miniaturization of components as well as towards large components with increasing wall thicknesses. Multi-component injection molding is considered a promising trend in CIM. Using this method also coming from plastics industry, it will be possible in future to produce multifunctional components consisting of ceramic materials with different properties without additional costly and time-consuming joining steps.

Current developments

Within the framework of the »CarCIM« project funded by the EU, Fraunhofer IKTS and thirteen partners from seven European countries develop two-component ceramic components for automotive and railway applications including gear wheels for fuel pumps, glow plugs, valve seats and brake shoes for high-speed trains. For these components the material combinations of Al2O3/ZTA, Si3N4/MoSi2 and Si3N4/SiAlON were realized by multi-component injection molding. The injection molded composites made of stainless steel and ZrO2 were developed within the framework of the »CoShape« project and a joint research project of the Fraunhofer IFAM and IKTS. The same material combination was used for in-mold labeling which was investigated in the »GreenTaPIM« project funded by the German Federal Ministry of Education and Research (BMBF). Here, demonstrators for mechanical engineering and minimally invasive surgery were developed.
Fraunhofer
60 years of dedication to the future.

Founded in Munich in 1949, the Fraunhofer-Gesellschaft is the largest organization for applied research in Europe. With its unique model of performance-based financing, it has become a role model for contract research and is in demand for innovation in the whole world. Presently, about 15,000 employees work in 57 institutes. The total turnover of the society is 1.4 billion euros. That Fraunhofer presents itself in such an excellent condition on its 60th birthday must be credited to its employees. «They are our most important asset. They combine knowledge and ability, scientific excellence and market orientation», describes Prof. Hans-Jörg Bullinger, the president of the Fraunhofer-Gesellschaft, the important characteristics of the Fraunhofer researchers. «Our executive stuff must perfectly master the balance between research and industrial practise and even entrepreneurial thinking such as that of our namesake and role model, Joseph von Fraunhofer», Bullinger explains.

News

Annual conference of the Fraunhofer-Gesellschaft in Munich
»Fraunhofer is in motion: 60 years motor for innovation.« Under this slogan about 850 guests from politics, industry and science met in the Zenith-Kulturhalle in Munich on June 23 to celebrate 60 years Fraunhofer-Gesellschaft and to honor the winners of the Fraunhofer science awards. A very special guest at the annual conference was Chancellor Angela Merkel who pointed out the importance of the research organization. «Orientation towards the future is the most important key feature of the Fraunhofer-Gesellschaft. Its success is to turn innovative ideas into new products in cooperation with industry and with creativity and innovation to contribute to Germany’s leading position as a place for science and industry.« The award-winning projects, which were presented in an exciting show are positive examples to demonstrate how science is useful to men. Prizes were awarded to innovations for traditional branches of industry like jewellery production as well as technologies for the protection against counterfeit goods, and the diesel particulate filter made of ceramics to protect men and environment. The award-winning filter is based on a porous silicon carbide material developed at the Fraunhofer IKTS, which can be sintered at about 400 K lower temperatures in comparison to common materials on the one hand and with regard to filtration efficiency, pressure loss and thermo-mechanical stability it shows top quality among filter materials on the other hand. The innovative technology was developed in multidisciplinary team work and in cooperation with Clean Diesel Ceramics GmbH, a subsidiary company of the HUSS group. After a pilot phase at the IKTS the results of the research work were transferred rapidly into production. Until now about 30 new jobs have been created in the plant of the company in Großenhain (Saxony). A new filter segment design, especially developed for applications outside automotive (i.e. construction machines, street sweepers, excavators), enables to produce a range of filter geometries and filter sizes in a flexible way. At the same time the elaborate finishing with diamond tools can be avoided, reducing material waste by about 20 % saving energy resources as well. Due to a special shape of the channels the increase of backpressure during soot loading is lower. This leads to a longer regeneration cycle and saves fuel. Furthermore a higher strength and therefore a higher robustness of the filter segments can be achieved.

»Long Night of Sciences«
On June 19th all universities and research facilities of Dresden invited for the »Long Night of Sciences«. This event, which took place place for the 7th time, found general approval of the visitors. The stream of visitors did not stop until midnight. About 3,000 visitors, among them there were a lot of children and young people, came to get enthused about science.

Current training courses and conferences at Fraunhofer IKTS

- September 7 and 8, 2009: Industrial seminar »Spray drying«
- October 7 and 8, 2009: Advanced training course »Thermoplastic shaping of advanced ceramics – Technology and training«
- October 29 and 30, 2009: Advanced training course »Debinding of ceramic components«

For further information please see www.ikts.fraunhofer.de

Current »AdvancCer« training courses

- Advanced Ceramic Materials for Technicians and Engineers «
- Part 3: Construction, quality assurance and application: November 12 and 13, 2009 in Freiburg
- Part 1: Introduction into ceramics: manufacturing technologies, properties, applications: March 10 and 11, 2010 in Dresden

For further information please see www.advancer.fraunhofer.de
Ceramic components – intelligently and cost-efficiently shaped

Success Stories

The demand for porcelain insulators as result of the electrification initiated the foundation of the first Rauschert factory in 1898. Soon, the textile industry also recognized the advantages of abrasion-resistant hard porcelain for their thread guides.

The wet pressing process developed for series production allowed the production of many differently shaped components. From 1960 onwards alumina gained acceptance in the processing of chemical fibers due to its increased wear-resistance. A milestone in the processing of chemical fibers was the adoption of the Degussit standard compounds. By final machining the sintered components are shaped and the surface is adjusted to the specific requirements.

The Arburg PIM team: Uwe Haupt, Marko Maetzig and Hartmut Walcher (from left)
Source: ARBURG GmbH + Co KG

Advanced ceramic components made by micro-injection molding.
Source: Rauschert Heinersdorf-Pressig GmbH

maching steps could be saved. Moreover, the method allowed more designs. Today, 20 injection molding machines are operated round the clock in the different factories of Rauschert. As a pioneer of ceramic injection molding, Rauschert developed its own feedstock and produces its own molds and tools. Aside from alumina, zirconia, titanium oxide, and steatite are processed. The developed know-how is used for components in mechanical engineering, medical technology, sensor and propulsion technology.

Rauschert is specialized in micro-injection molding and ceramic/plastic material compounds. By final machining the sintered components are shaped and the surface is adjusted to the specific requirements.

Process and automation technology for ceramic injection molding

Arburg is one of the world’s leading manufacturers of injection molding machines with clamping forces between 125 and 5,000 kN. The product range is completed by robotic systems and other peripherals. Thanks to their modular design, the all-round machines can be equipped for specific applications and can thus be used for all injection molding processes, including powder injection molding (PIM) of metal and ceramic materials. The ALLROUNDER machines used are based on the current series machines. However, the plasticizing cylinders, for example, are adapted to the particularly abrasive properties of the materials.

Arburg played a pioneering role in the development of this technology in its own PIM laboratory and, with its extensive expertise, consistently continues to develop new powder-injection molding applications. As early as 1962, Arburg delivered its first injection molding machine (then still a piston version) for the processing of ceramic materials to Feldmühle. However, the PIM process only made its final breakthrough once commercial binder and feedstock producers became successfully established on the market. Accordingly, the first systematic testing of powder materials and their processing was carried out at Arburg at the end of the eighties. In the PIM field, the company covers the entire range of powder injection molding processes: From the appropriate machine technology through to customer consulting – from the choice of feedstock to mold design and the injection molding process, through to debinding and sintering. The excellently equipped PIM laboratory is available for extensive tests under practical conditions. Information and pointers on automation and the selection of machinery as well as special PIM training courses complete the offering.

In order to test and demonstrate the entire process of powder processing – from mixing and preparation to injection molding, debinding and sintering of the components – Arburg has a well equipped PIM laboratory.
Source: ARBURG GmbH + Co KG