Answers to Demands – Fitting Binder Systems for Growing CIM Requirements

INMATEC Technologies GmbH is a well known producer of ceramic feedstocks for Ceramic Injection Moulding (CIM). Founded in 1998 the product portfolio has grown to a veritable diversity of standard feedstocks and also to a wide range of custom tailored feedstocks according to customer demands. A newly developed binder system called INMAFLOW is now introduced into the market.

Fundamentals: ceramic powder and polymers

Ceramic Injection Moulding (CIM) is an advanced shaping technique for complex high-tech ceramic parts produced in large quantities.

Ceramic feedstocks, the feed material for CIM, are composed out of the ceramic powder and the binder components, the polymers. The homogenisation of powder and binder components needs to be perfect for achieving highest and even green density in the injected part. This is the precondition for a dense end-contour part finally after the debinding and sintering processes.

The processing of a ceramic feedstock requires polymer components which are able to withstand the severe forces which are needed to break up agglomerates ceramic powders tend to form. Only a few organic polymers can be used for this purpose – keeping in mind that they have to have the property of being willingly injection moulded with a high load of ceramic powder. The so called green injected part should have a high green stability due to the binder properties. Moreover the binder needs to hold the injected part in shape during the debinding process where after – to quote F. Schiller: "the moor has done his duty, the moor can go" – the polymers should escape the part in a decent time without causing any damage.

Moderate temperatures should be possible during the injection moulding process as well as during debinding which should be an environmentally friendly and quick process.

The well known INMAFEED feedstocks from INMATEC are based on a wax binder system.

Besides these existing feedstocks INMATEC has developed an additional binder system called INMAFLOW based on synthetic polymers such as polyamides. Therewith the request of certain industries for multiple sources for basic raw materials is fulfilled, but – even more important – the main focus on "robust design" can be satisfied, wider processing settings and at the same time very challenging part designs are possible.

Keywords
ceramic injection moulding, feedstocks, polymers, waxes

Ceramic feedstocks

Since more than 15 years INMATEC produces ceramic feedstocks on the basis of the commercially available Embemould binder system. These feedstocks are called INMAFEED feedstocks. The Embemould binder system is based on polyolefin waxes and has a two-stage debinding – almost 50 % of the binder is soluble in water, the remaining amount is removed by the second thermal step.

The duration of the debinding process is depending on the wall thickness of the part produced, part geometry and last not least on the grain size of the powder. It may last from 36 h up to several days. Combined with the sintering process the total process time from injection to the sintered part may last as long as two weeks.

The INMAFEED feedstocks are injection moulded with mass temperatures around 160 °C and mould temperatures around 55–65 °C. Some skills and experience are required to determine the optimal parameter settings for a continuous production. The INMAFEED feedstocks on the basis of commercially available alumina and zirconia powders are well introduced into the market.

CIM as a shaping technique for ceramic parts with complex geometries has entered all branches of industry. As a consequence the demands for highly specialised parts in terms of special fields of operation are growing, special ceramic powders have to be designed for special purposes. Moreover on one hand large parts shall be realised as well as on the other very small parts resp. parts with extremely low wall thicknesses.

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INMATEC started a binder development to be able to answer to these needs. A binder has been developed which has basic ingredients of synthetic nature. The main component polyamide guarantees for a high green stability of the green part coming out of the injection moulding machine. The binder system has been called INMAFLOW.

The processing temperatures of INMAFLOW based feedstocks are quite moderate with 90–100 °C and mould temperatures are sufficient with approx 20 °C. These low temperatures settings allow short cycle times, even with parts with high volume.

The debinding process is also a two-stage process – the first step requires a solvent debinding, the solvent is acetone. In less than 12 h the solvent debinding is finished and the thermal debinding step follows which needs 18–22 h. As a consequence finished sintered parts may be achieved with a total cycle time of less than five days.

A safe and secure solvent debinding is possible with solvent debinding units working with a closed tank system and a solvent recovery. The re-distillation of the solvent in the closed system offers an environmentally friendly, a work-safe and quick possibility of debinding CIM parts.

INMAFLOW feedstocks characterization

For the demonstration and characterization of the INMAFLOW properties two feedstocks processed – one on the basis of a fine alumina powder, CT1200 SG (Al_2O_3, 99,8 %, Almatis), one on the basis of a zirconia powder (TZ-3YS-E, Tosoh).

Flow abilities

INMATEC is member of the German experts group CIM (Expertenkreis Keramikspritzguss).

This organisation owns a test mould which members are able to use for their purposes. With this mould it is possible to mimic all different kinds of circumstances possibly showing during CIM. Whether different modes of temperature regulation, various gating geometries, cavity surfaces or core design, all this is represented in this mould. The part design which has been used to characterise the flow abilities of the INMAFLOW-feedstocks is a rectangular

Tab. 1
Feedstock properties

Feedstock	Powder Basis	d_{50}	Sintered Density
INMAFLOW K1010	99,8 % Al_2O_3	1,2 µm	3,99 g/cm³
INMAFLOW K1012	ZrO_2, 94,5 %,Y_2O_3 – PSZ	0,6 µm	6,05 g/cm³

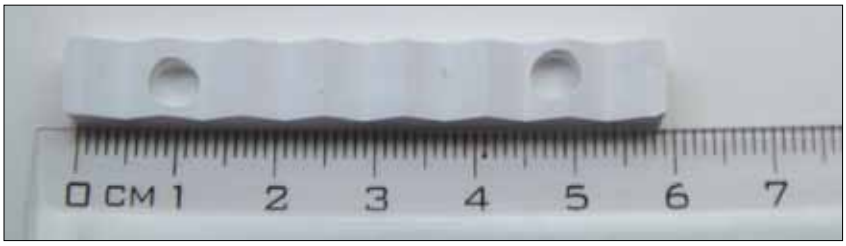

Fig. 1
Test bar for evaluation of filling behaviour

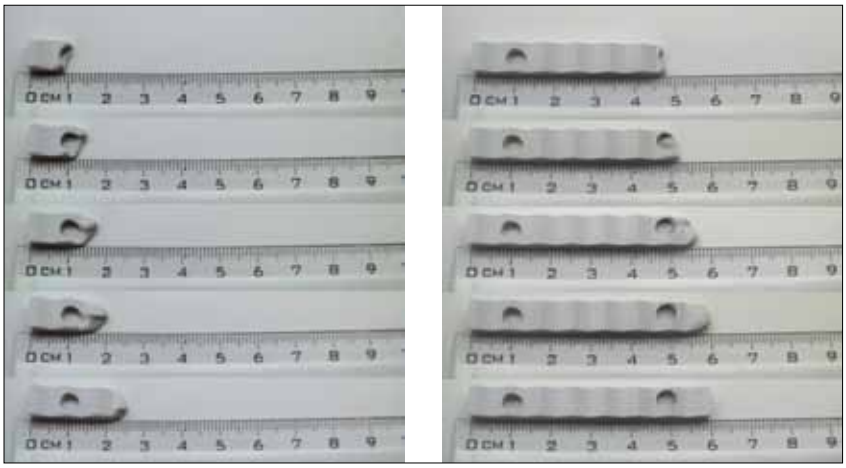

Fig. 2
Filling study INMAFLOW K1010

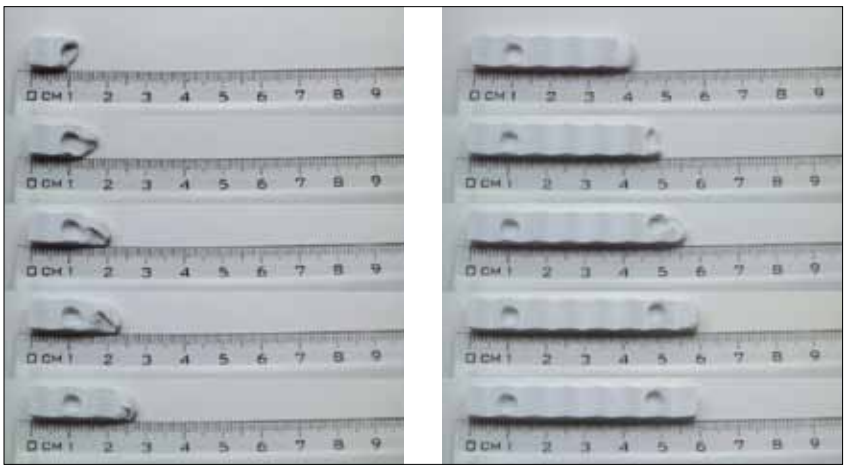

Fig. 3
Filling study INMAFLOW K1012

Tab. 2
Filling behavior of feedstocks

	INMAFLOW K1010, Powder Basis 99,8 % Al_2O_3 (CT1200 SG)	INMAFLOW K1012, Powder Basis ZrO_2, 94,5 %, Y_2O_3 – PSZ (TZ-3YS-E)
Temperature mould	25 °C	25 °C
Temperature feedstock	95 °C	100 °C
Switch over pressure	423 bar	385 bar

bar with a serrated surface and two staggered cores which have to be surrounded by the flowing feedstock. Thus this special cavity design represents typical geometric challenges CIM engineers face.

The flow behaviour shall be visualised by filling the cavity in 0,1 cm³ steps. By this proceeding it is possible to show the flow behaviour and the mode of flow front joining behind the obstacle formed by the core pin. As can be seen on the pictures the INMAFLOW feedstocks flow easily and the flow fronts join supplely. This is valid for both types of feedstock, INMAFLOW K1010 based on an alumina powder as well as INMAFEED K1012 based on the zirconia powder. Although the INMAFLOW K1012 is based on a very fine zirconia powder (TZ3YS-E), the pressure needed for injection is moderate.

Green parts feature a high green stability and a nice and smooth surface. Best results have been achieved when the cavity surface is polished. If needed or wished green parts can be machined easily.

Debinding

The debinding procedure is a two-stage process starting with a solvent debinding.

The chamber of a commercially available debinding unit is loaded with the green parts, the lid is closed and the debinding programme starts. The chamber is filled with acetone, the debinding solvent. 12–24 h later the parts can be removed from the debinding unit – the used acetone is distilled for re-use within the debinding unit.

After the solvent debinding step more than 50 % of the binder are solved out. The remaining binder in the parts is now removed during the second step of the debinding procedure which is a thermal process.

The thermal debinding cycle is a linear ramp from room temperature up to 325 °C. After 18–22 h of thermal debinding more than 90 % of the binder (in total) are removed from the part.

The sintering process may follow now.

INMAFLOW feedstocks summary

The newly developed binder system INMAFLOW stands out for:

Binder components:
- synthetic origin
- secured multiple sources.

Injection moulding:
- moderate processing temperatures
- broad window for processing parameters
- short injection cycles
- high flow abilities
- easy flow front joining.

Post-processes:
- high green stability
- green machinable
- quick debinding process
- short total process time.

INMAFLOW present state – future outlook

At this point INMATEC has successfully evaluated all its standard feedstocks on INMAFEED binder basis also with the INMAFLOW binder system.

The last important property which has to be mentioned is the final shrinkage of the INMAFLOW feedstocks. The present INMAFLOW feedstocks are adjusted to the INMAFEED shrinkage. A modification of the adjustment of the shrinkage to already existing moulds is possible and has been proven already.

Testing the INMAFLOW feedstock is simple – INMATEC is able to provide the feedstock sample as well as the debinding service for first injected parts.