

# Optimize powder injection molding by compounding the perfect feedstock

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### Abstract

Powder injection molding is a manufacturing process that helps save time and decrease overall costs compared to other production methods. A large number of mechanically complex products can be produced within shorter production times. The best base material for this process is fine ceramics (CIM) or metal powder (PIM) blended with a binder to form a freeflowing feedstock for the injection molding. To obtain a highquality end product it is important to achieve a homogeneous dispersion of the ceramic or metal powder within the polymer matrix. In the below application note we will describe how this is done with ceramic powder.

#### Introduction

We use the Thermo Scientific<sup>™</sup> Process<sup>™</sup>16 Twin-Screw Extruder (Figure 1), a lab-size compounder, to produce different CIM feedstocks and prove feasibility for injection molding. Binder systems based on waxes or polymers (e.g., LDPE, PP or POM) are selected for their ability to attain a maximum degree of filling with ceramic powders while still producing a viable feedstock for the molding process. After molding, the newly formed or so-called "green" parts undergo a heat treatment (sintering) to achieve their final size and strength. The end products may be things as diverse as catalyst beads or turbine blades. Usually, laboratory research and development will check for compatibility of the binder/powder system and the maximum degree of filling. Moreover, molding trials for feedstock formulations can easily be performed to optimize the composition of the various components. The Thermo Scientific<sup>™</sup> HAAKE<sup>™</sup> MiniJet Pro Piston Injection Molding System enables quick tests on the processability of the CIM feedstock. The samples obtained via this method can be sintered and used for mechanical testing.



Figure 1: Process 16 Twin-Screw Extruder.

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#### Materials and methods

A polyethylene wax-based binder was blended with zirconium oxide powder (Figure 2) to create a CIM feedstock. Compounding of the two raw materials was done using the Process 16 Twin-Screw Extruder with a 2.5 mm strand die and a conveyor belt for takeoff. Each of the components used its own dedicated powder feeder. Atmospheric venting was utilized to prevent potential disruptions caused by air bubbles. The product was cooled on a conveyor belt, and then easily cut to pellets and manually fed to the HAAKE MiniJet Pro.

Split feeding is essential, as brittle wax flakes and the fine ceramic powder would segregate when being fed as a pre-blend with just one feeder. This split feeding assembly is shown in Figure 3. It is advised to start feeding the wax first into the extruder and then subsequently add the ceramic powder. By doing so the wax acts as a lubricant that not only reduces wear to the barrel and screw, but also allows for maximized throughput. The process ran stably at the conditions showed in Table 1.

The obtained strand of the feedstock was broken into smaller pellets and manually fed to the MiniJet Pro (Figure 4) injection molding system to mold different specimen like discs or tensile bars. The injection molding process was carried out with parameters listed in Table 2.



Figure 2: CIM Feedstock raw materials. Zirconium oxide (top) and polyethylene wax (bottom).



Figure 3: Split feeding setup on the process 16 utilizing the ports of the fully ported barrel.



Figure 4: HAAKE MiniJet Pro Piston Injection Molding System with different molds for test specimen.

Table 1: Process parameters of compounding.

Description	Value
Cylinder temperature	160°C
Mold temperature	120°C
Injection pressure	800 bars
Duration time	10 s
Post pressure	400 bars
Duration time	5 s

Table 2: Process parameters of injection molding.

#### **Results and discussion**

Compounding worked well and all compounds produced showed excellent dispersion of the feedstock. The desired output of 6 kg/hr was reached with the given composition of powder and binder (85/15 % wt/wt) at approximately 25% of maximum torque. Neither the compounder nor feeding system was pushed to the limit in this situation.

Figure 5 shows different specimens that were produced during extrusion and injection molding. The extruded strands (5a) were brittle and easy to break down manually. It was also possible to extrude a sheet (5b) with an appropriate die attached to the Process 16. The injection-molded discs and tensile bars (5c) showed excellent surface quality, an indication of a very good dispersion.

#### **Conclusion and outlook**

The Process 16 Twin-Screw Extruder is the ideal instrument to produce CIM feedstock and develop optimal formulations for injection molding. The fully ported barrel allows efficient setup of different feeding strategies for the best process design. Even though it is a compact laboratory-scale extruder it is powerful enough to deliver throughputs for small-batch production. The good mechanical properties of the specimen produced with the HAAKE MiniJet Pro give a clear indication of the excellent dispersive mixing achieved with the above-mentioned twin-screw setup. The CIM feedstock can be directly used for time and cost-efficient mass production of ceramic parts.

For further characterization of the feedstock a modular torque rheometer like the Thermo Scientific<sup>™</sup> HAAKE<sup>™</sup> PolyLab<sup>™</sup> OS Modular Torque Rheometer can be employed. In this way mixer tests to determine the minimal binder amount or capillary measurements to obtain the feedstocks viscosity can be performed.



Figure 5: Extrusion and injection molding test specimen.

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