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3D Printing Powder in its optimum Form

Business Unit
GRINDING & DISPERSING

3D PRINTING POWDER IN ITS OPTIMUM FORM

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1. INTRODUCTION

For years, 3D printing has been experiencing growth comparable to that seen in chip development. There are already providers for online 3D printing with a network of numerous companies. CONTEXT reports stronger growth in 2020 despite the pandemic. IFI CLAIMS Patent Services is positive, with the ninth most patent applications of any technology, and LearnBonds forecasts economic growth of 155% in 2024 - equivalent to $40.8 billion. While in the past it was primarily prototypes and new developments that were produced using additive manufacturing, now it is used in small-scale production as well. As opposed to competing manufacturing methods, such as injection molding, there is no need for subsequent processing and, compared to machining, significantly less material is consumed.

2. THE FOUR IMPORTANT PILLARS OF 3D PRINTING

There are four important pillars to the successful production of a component with 3D printing: an idea, the CAD design (in combination with design software optimized for 3D printing), a suitable printer and the right material. Below we want to deal with the latter, the material.

For the plastics printing process, in addition to the filament process, solid material in powder form is used in most cases. Prerequisite for a component with a high, reproducible end quality is that the layer application be as uniform as possible. This in turn implies a bulk material that is as free-flowing as possible with a narrow particle size distribution.

The rheology in extruders is widely known and can serve as a comparison when considering a bulk material. High expansion and shear gradients are generated there. These stresses lead to melting of the plastic. A desired viscosity of the melted material can be set by specific mechanical and thermal measures in the extruder. Here, a high level of knowledge of the material is required in order to avoid oxidation processes. Another example of reliable use of rheology is plastic granules (3 to 5 mm), which serve as feed for injection molding machines or film blowing extruders.

3. THE RHEOLOGICAL BEHAVIOR OF BULK MATERIALS IN 3D PRINTING

For an improved layer structure in the material bed of the printer, the granules must be „trickled down" uniformly. This is achieved by a narrower particle size distribution. In comparison to melt rheology, the rheology of bulk solids differs primarily in its „memory". Bulk solids behave elastically under load up to the yield point. Below the load yield point, the behavior of bulk materials is reversibly elastic. Above the yield point, the desired flow of the material occurs. What is it about memory? A compacted bulk material has a higher yield point - the material has stored the previous load in itself. Such effects are used on railroad embankments or for foundations in building construction. Deposited bulk material in sacks or big bags shows similar behavior and thus interferes with good process reliability.

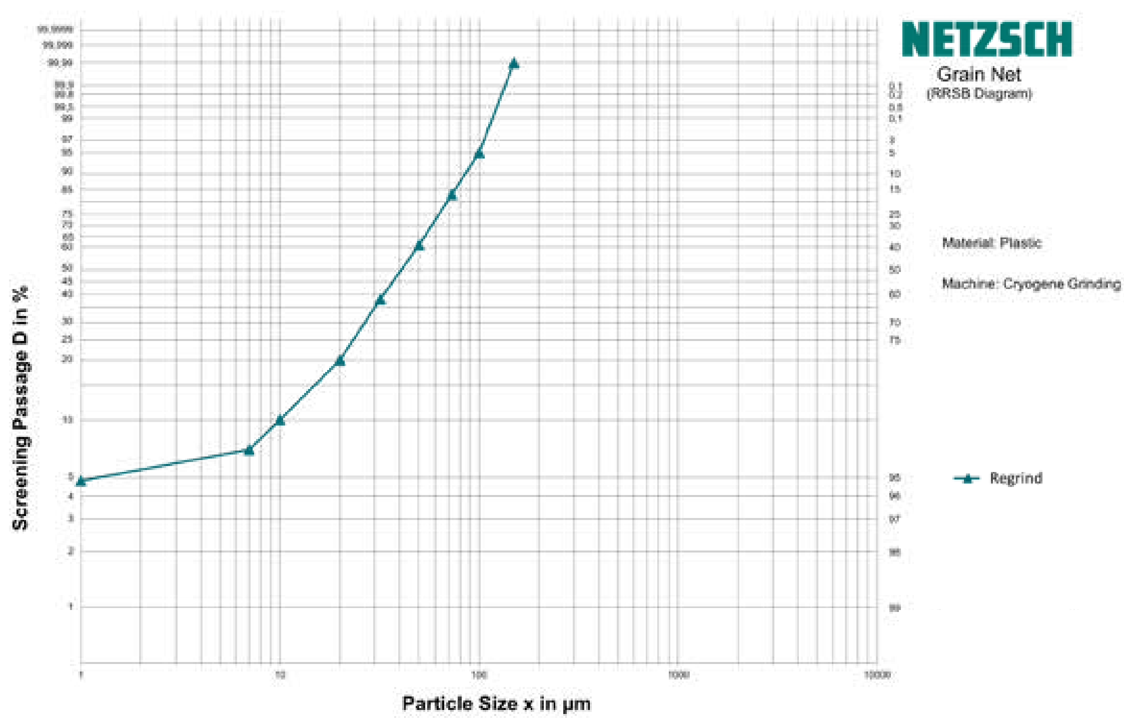
The rheology of bulk materials is influenced by internal and external friction. The external friction is the interaction of the bulk material with the machine wall or the inner surface of a big bag. In most cases, the external friction can be controlled by suitable material selection. Internal friction, on the other hand, is determined by the material properties of the powder. It is obvious that spherical grains cause less friction than cube-shaped particles. Ultimately, the decisive factor is the specific surface area of a powder and thus the number of contact points with the individual particles. What is meant by this?

Powders for 3D printing are often brought to the desired fineness through mechanical comminution using cryogenic mills. Normally, the mill produces a constant and wide particle size distribution due to the statistical effects of the impact stress (see Figure 1).

Through optimized process parameters, the particle size distribution can be somewhat restricted and thus „narrowed." However, smaller particles occur much more frequently in the quantity distribution curve than larger ones. This leads to significantly more frequent contact points with other particles and thus explains, in simplified terms, the rheological behavior of bulk solids. The „removal" of the smaller particles thus has a significantly greater influence on the number of contacts.

Figure 1

Particle distribution of a regrind



4. IMPROVEMENT OF THE FLOW BEHAVIOR OF POWDERS

Ground particles are present in cubic or irregular form. This deviation from the spherical shape increases the number of contacts and therefore the internal friction.

There are two ways to improve the flow behavior of powders:

- rounding the cubical particles
- further narrowing of the particle distribution

During rounding, mechanical stress breaks off edges or deforms particles to the point that they take on a spherical shape. However, we will not address this option any further here.

Powders < 150 µm and finer are used for 3D printing. For example, a particle size distribution in an impact mill is shown as the starting product in Figure 2. The RRSB diagram has become established for the representation of a particle size distribution. The passage (similar to the screening in sieve analysis) is plotted as a function of grain size. With this particle size distribution the fines can only be removed through classification. Classical screening machines reach technical limits when separating fine material < 300 µm. A disadvantage of screening machines is that electrostatic charges can build up on the screen deck during material movement.

During separation with deflector wheel classifiers, two adjustable forces act on the particles: the centrifugal force and the drag force of the classifying air. The air flow is usually generated by a fan and passes through the classifier housing from the outside to the inside. In most cases, the particles are dispersed by the air stream. In addition, the dispersing effect can be improved through design measures in the classifier. The entire air stream is drawn through the rotating classifier wheel. The centripetal force on the particles by the rotating classifier wheel prevents excessively coarse material from reaching the inside of the classifier wheel with the air stream. The fine material exits the classifier housing with the air stream and is separated from the air stream at a product filter.

Figure 2

Particle size distribution of a regrind for 3D printing

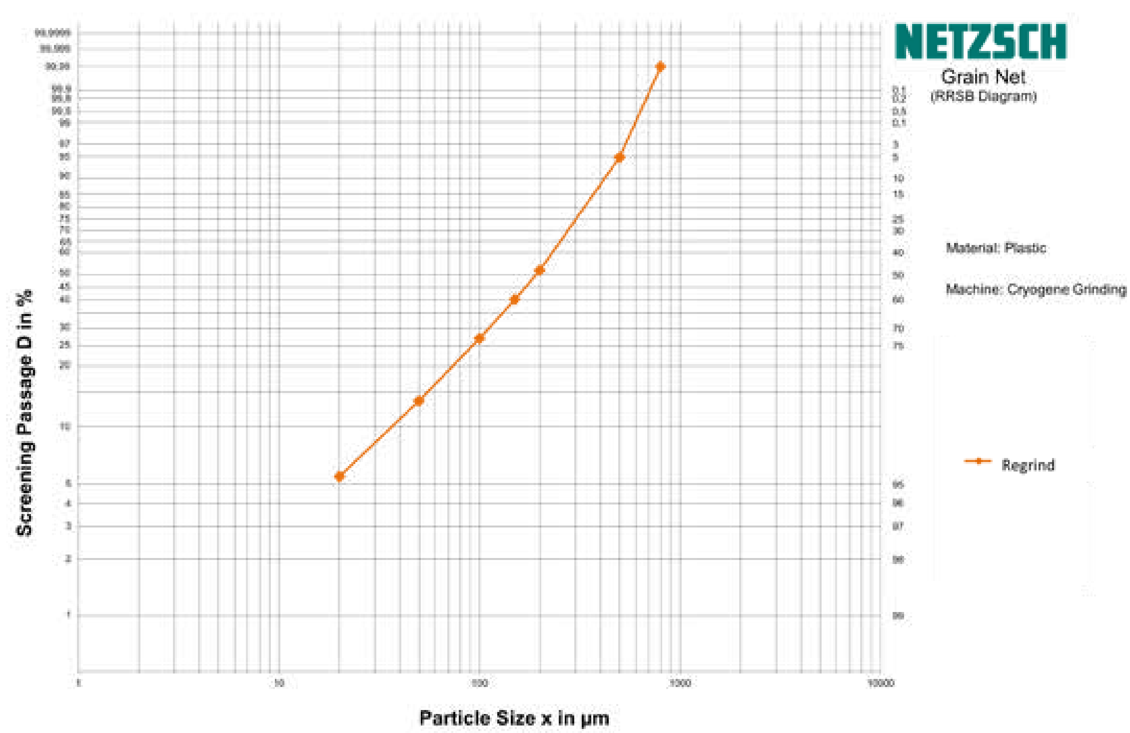
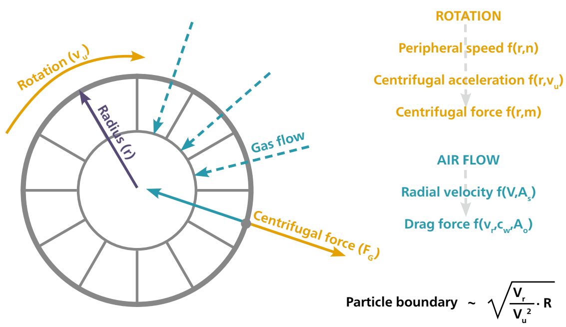


Figure 3

Simplified depiction of the physical laws of classification



In this process, the material separated from the fines is the end product – also referred to as coarse material.

The portion of fines remaining in the end product can be adjusted according to the requirements of the printing process or according to economic and physical aspects. Since the fines cannot be used for printing, they must be returned to the extruder.

The measured value for the coarse material yield is the course material output.

$$g = 1 - \frac{q_f(x)}{q_a(x)}$$

Here:

g: course material output

$q_f(x)$: particle size distribution sum of the fines

$q_a(x)$: particle size distribution sum of the feed material

This value describes how much of the feed material is coarse material.

The separation efficiency, or Tromp curve, is used to measure the classifying efficiency:

$$T_g(x) = \frac{g \cdot q_g(x)}{q_a(x)}$$

The Tromp curve describes the probability with which a particle of a certain size (x) will be relegated to the coarse fraction.

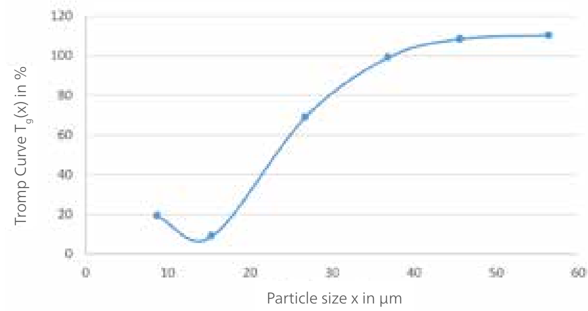
Here:

$T_g(x)$: separation efficiency

Figure 4 shows a Tromp curve for the separation of fines with a particle size of 50 µm.

Figure 4

Measured Tromp curve



5. SEPARATION OF PLASTICS

The quality of a classification is determined using the slope of the Tromp curve at 25% and 75%. A value of 1 is considered to be ideal separation.

$$\kappa = \frac{x_{25}}{x_{75}} = \frac{18{,}45\,\mu m}{28{,}79\,\mu m} = 0{,}64$$

Technically good classifications have a κ value of 0.6 to 0.9. The exemplary κ value at a separation of 50 µm can be rated as very good for plastics.

The specific classification energy is also of economic importance.

$$E_{spez} = \frac{E_{Sichter} + E_{Ventilator}}{m_g}$$

Here:
$E_{spez.}$: specific energy
$E_{Sichter}$: energy use for classification
$E_{Ventilator}$: energy use for the fan
m_g: mass flow of the course material

Here it is important to design the drives well. The decisive factor here is that the system and fan characteristic curves are run at the optimum point. Further potential lies in making full use of the frequency-controlled drives.

6. SUMMARY

In addition to the mechanical processing technology of classification, the system technology must of course be assessed with respect to the material properties. Most plastic powders are classified in dust explosion class St 1 or St 2, while others must not come into contact with humidity.

Processing that is safe for our employees is only possible on an ATEX-compliant, pressure shock resistant classifying system with approval for the respective dust classes.

NETZSCH Lohnmahltechnik is a specialist who is at your side with its know-how and diverse installed comminution and classifying technologies in order to realize various specifications in the short term.

The flow properties of plastic powders for 3D printing can be improved through separation of the fines by means of classification on the one hand, and through the use of different grinding technologies in the grain shape on the other.
NETZSCH Lohnmahltechnik has the process technology and technical prerequisites to optimize your product.

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