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# Characterization and usability of powders from renewable raw materials for 3D printing

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**Abstract**

Innovative materials and new manufacturing technologies can make a substantial contribution to conserving resources. Such a path can be taken by adapting additive manufacturing processes for the use of renewable raw materials. It is particularly important to consider residual materials, for which both cost of procurement are low and interest in using them as raw materials is substantial. Such powders have to be characterized in the first step. In the following steps, a printable mixture must be produced, suitable binders chosen and the powder must be 3D-printed by means of binder jetting. Subsequently, an assessment can be made based on component strength as well as surface- and geometric properties.

In the study, the first step in the described process chain - powder characterization - will be examined in more detail. Typical synthetic powders have a particle size of 40 to 100 µm and a close to spherical shape. Their properties allow for good thin powder layer creation using a rake system. The renewable substances considered here are mostly fibrous, have high length-to-width ratios and low flowabilities. The particle size and particle shape distributions, the moisture and the density have to be determined for characterization. Statements about special distribution functions, flowability or squeegee suitability, solid volume fraction or porosity and producible layer thickness are expected. The aim is to be able to assess usability for binder jetting for newly available raw materials.

With the help of the findings on powders made from renewable raw materials, it should be possible to make a statement about printability already from particle analysis or to verify a powder made from renewable raw materials specifically for 3D printing. In further investigations, specific properties of the 3D components will be analysed.

Additive Manufacturing, 3D printing, Parameter, Powder Characterisation

## 1. Introduction

Innovative materials and new manufacturing technologies can make a substantial contribution to conserving resources. Such a path can be taken by adapting additive manufacturing processes for the use of renewable raw materials. It is particularly important to consider residual materials, for which both cost of procurement are low and interest in using them as raw materials is substantial. Such powders have to be characterized in the first step. In the following steps, a printable mixture must be produced, suitable binders chosen and the powder must be 3D-printed by means of binder jetting. Subsequently, an assessment can be made based on component strength as well as surface- and geometric properties. In the study, the first step in the described process chain - powder characterization - will be examined in more detail.

## 2. Powder Characterisation – Theory

Spherical particles smaller than 100 µm are typically used for ceramic, plastic and metal powders [1]. In addition, the powders have a narrow particle size distribution (PSD) and thus a steep increase in the cumulative passage curve [2]. The cohesion of the powders is usually achieved by subsequent sintering. MIYANAJI [2] specifically investigates the influence of the particle size of steel powders on binder jetting and subsequent sintering. Smaller particles (8-20 µm) have a higher solids volume fraction and thus a higher density and hardness of the sintered parts. On the other hand, larger particles (54-105 µm) have a better flow dynamic of the binder droplets (droplets do not flow wide) and thus the printed parts have a higher accuracy in x- and y-direction than parts made of finer powder.

Powders with non-spherical particles have a poorer flowability and also a higher porosity due to a lower bulk density [3]. For the dependence of the flowability on the fineness of the powder, a poorer flow behaviour is expected at higher fineness. Of course, the PSD and particle shape distribution also play a role here. It is nevertheless assumed that similarly distributed and shaped powders also have a similar flowability [4]. In addition, SCHULZE [5] considers the bulk material behaviour of fibrous and plate-like particles from the point of view of bulk material behaviour. Using typical process equipment such as ring shear tester and pressure pot, he investigates the properties of flowability, modulus of elasticity, porosity and breaking strength. He concludes that the worse the length/with-ratio, the greater the particle friction coefficient, the solids volume fraction and the change in length of the particle length under load, the poorer the flow properties.

## 3. Experiments

In this paper it shall be determined which characteristic values describe the squeegee capability of powders from renewable raw materials well. The following parameters have been considered: moisture, particle shape distribution and PSD (with CAMSIZER XT), density (with helium pycnometer), bulk density [6], tap density [7], Hausner number [8] or Carr Index [9], pourability [10], slope angle [11] and flowability on a ring shear tester [12].

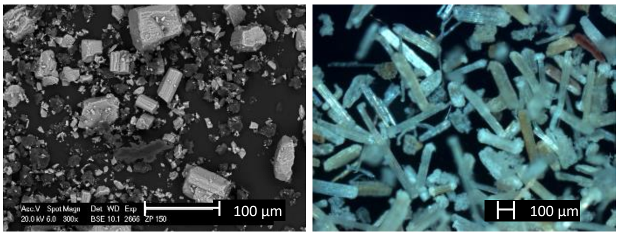


**Figure 1.** SEM image of ZP150 (left) and Miscanthus (right)

In Table 1 are some results summarised for the two powders ZP150 (standard powder for 3D printing) of Z CORPORATION® and Miscanthus grass (mixture of dust and milled powder). The crystal shape of ZP150 can be clearly seen in Figure 1 due to the very high proportion of gypsum. The Miscanthus is a natural product (renewable raw material) and fibrous. Therefore, the sphericity is small against the more cubic ZP150. The Miscanthus has a width (dimension on sieving) under 180µm - small enough to be processed in 3DP. Thus, the median particle size ($d_{50}$) is almost twice as high as that of the ZP150. However, both powders can be described well with a Rosin-Rammler-Sperling-Bennett (RRSB)-distribution, compare with Figure 2.

**Table 1.** Measured parameters for ZP150 and MiscanthusMiscanthus

| Parameter | | ZP150 | Miscanthus |
|---|---|---|---|
| Moisture [%] | | 0,61 | 8,26 |
| Density [g/cm³] | | 2,47 | 1,48 |
| Bulk density [g/cm³] | | 1,18 | 0,12 |
| Tap density [g/cm³] | | 1,48 | 0,16 |
| Hausner number [-] | | 1,25 | 1,28 |
| Carr Index [-] | | 20,1 | 22,1 |
| Slope angle [°] | | 42,3 | - |
| Pourability [g/s] | | 87,3 | - |
| Flowability (yield locus 0) [-] | | 5,40 | 6,00 |
| $d_{50}$ [µm] | | 44,0 | 72,0 |
| Sphericity $SPHT_m$ [-] | | 0,89 | 0,73 |
| RRSB-Distribution | $d_{63,2}$ [µm] | 53,0 | 84,0 |
| | n [-] | 2,02 | 1,40 |
| | $R^2$ [-] | 0,99 | 0,92 |

The two powders also show differences in their densities. Miscanthus measures a density of 3/5 of ZP150, and for bulk and tap density it is even more striking at 1/10. Therefore, significantly higher porosities can be expected even during printing. The flowability according to Hausner and Carr is sufficient or rather moderate for both powders. But further measurements have already shown that these two parameters do not reflect the squeegee ability very well. From the slope angle, the coefficient of static friction between the particles can be determined. For ZP150 the static friction coefficient is quite high at 0.91. For Miscanthus, however, a slope angle and a pourability cannot be measured due to a very poor flowability (particles get stuck). The pourability is a dynamic parameter – but while printing the material is not so air-conditioned. The flowability for both materials are in field of easy-flowing powders – Miscanthus even better. It can be assumed that the dynamic methods can better represent the squeegee capability.

An important factor influencing the flowability is the moisture content of a powder. For ZP150 this is very low. Miscanthus, on the other hand, has a much higher moisture content, since natural materials are usually hygroscopic. It should be noted that the flowability decreases with increasing moisture. A limit value for squeegee ability in relation to moisture is dependent on the material (normally moisture should remain under 10 %).

Both powders can be printed well in the 3DP process. The printed parts have an accuracy correlating to the particle size, hence also a limited precision. Still, the variation coefficient (ZP150 1.26 % / Miscanthus 0.84 %) is low with a percentage deviation of 3.07 for ZP150 and -2.81 for Miscanthus.

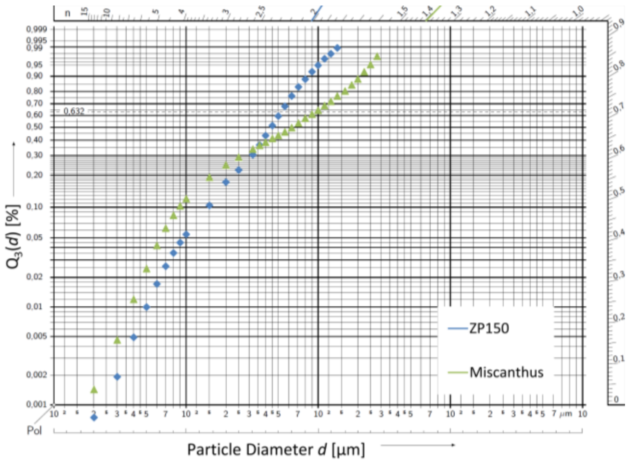


**Figure 2.** RRSB-distribution for ZP150 and Miscanthus

## 4. Conclusion

The examined powders ZP150 and Miscanthus show a very different particle size and shape as well as varied densities. On the other hand, Hausner number, Carr index and flowability are comparable. These dynamic parameters could be an indication for the squeegee ability of powders for Binder Jetting. However, the exact influences are not yet fully understood. A way to better evaluate the squeegee capability is to develop a test rig in which the mass per applied layer (squeegee density) can be measured.

All in all, it is assumed that the most important influencing variables are particle shape distribution, PSD and the internal friction angle. For these parameters the influence on the flowability should also be determined for other renewable raw materials and their mixtures with different binders.

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