Powder Rheology of Steel Powders for Additive Manufacturing

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Introduction

- Powder rheology provides a novel tool for advanced evaluation of dry flow properties of metal powders.
- In this study, four similar stainless-steel MIM powders aimed for additive manufacturing were characterized with a powder rheometer (FT4, Freemantech Technology, UK).
- Bulk, dynamic flow and shear properties were determined by sampling 10 or 25 ml dried powder in each measurement.
- The powders were processed in a 3D-printing machine (Digital Metal AB) for correlation to the performance in terms of outflow at 42 microns layering and the tendency to move at subsequent layer application.

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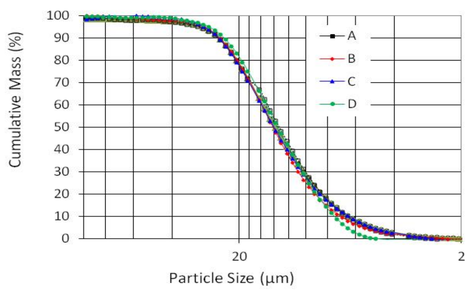
Steel powders

316 L stainless-steel powders of MIM quality aimed for additive manufacturing (AM) were studied and evaluated in a 3D-printing machine.



Powder	SSA (m^2/g)	Performance in AM
A	0.09	Good
B	0.10	Good
C	0.16	Less good
D	0.22	Bad

SSA=Specific surface area (multipoint BET)

Similar particle size distributions but clear differences in SSA

Shear

Shear cell measurement defined stress yield points (caused by internal friction) and indicated how easy the powders are prone to flow.

Shear cell

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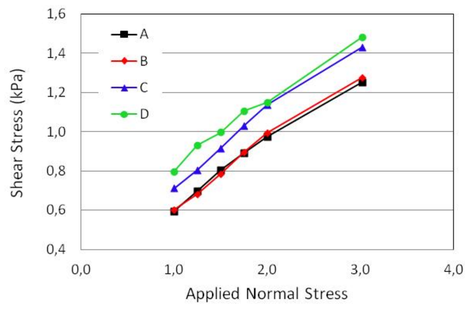


Mohr stress circle analysis

Powder	Cohesion (kPa)	UYS (kPa)	FF
A	0,22	0,63	6,62
B	0,19	0,56	7,57
C	0,27	0,83	5,29
D	0,46	1,31	3,53

UYS=Unconfined Yield Stress, FF=Flow function

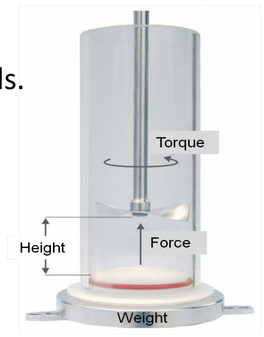
High shear stresses for moving the shear cell show high degree of friction between the metal particles and indicate less good flow performance.

Powder A and B showed clearly better flow ability with low UYS and high FF vs C and, even more, D.

Dynamic Flow

Flow energy was defined in conditioned and aerated state by a rotating blade, simultaneously moving downwards and upwards.

Blade set-up



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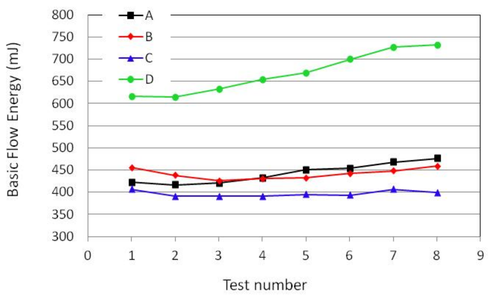
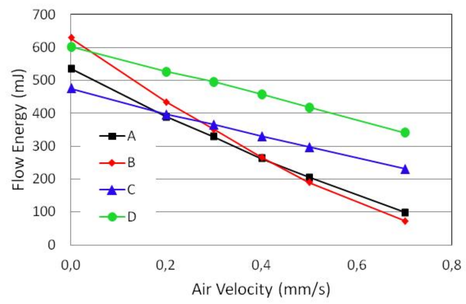
Flow in conditioned state



Repeated measurement with conditioning in between

Flow at aeration



Powder	BFE (mJ)	SE (mJ/g)	CBD (g/cc)
A	468	2,42	4,63
B	448	2,18	4,71
C	406	2,66	4,68
D	727	4,84	4,42

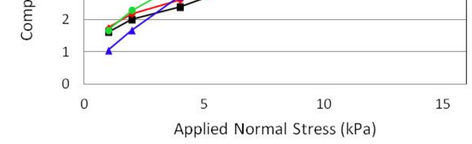
BFE=Basic Flow Energy, SE = Specific Energy (reflects cohesivity), CBD = Conditioned Bulk Density

High flow energy despite of low bulk density (CBD) for powder D indicated high degree of cohesivity whereas the other powders displayed low flow energy at comparably high bulk density.

High response (fast decrease of flow energy) to aeration indicated low degree of cohesivity, specifically for powder A and B.

Compressibility

Compression of the powder bed was conducted with a permeable piston.



High degree of compressibility for powder C and D expressed high degree of cohesivity, to be considered negative for the flow performance.

Conclusions

- Powder rheology has shown to be highly suitable for flow characterization of stainless steel powders for additive manufacturing.
- The essential flow properties of a steel powder for the powder layering process involved have been identified. Sufficiently high flow energy related to a high bulk density, low specific energy, high aeration response and low stress yield reflect low degree of cohesion and can be considered to support adequate performance in the application. Two of the tested powders (A and B) fulfilled these characteristics and performed properly in the 3D-printing machine. The bad performance of powder C and D could most probably be related to high specific surface area indicating different particle surface texture.
- Powder rheology is concluded to be a powerful tool for identification of the suitable flow properties related to specific processes and serves as a complement to conventional characterization methods for quality control of any kind of metal powder.

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