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Additive manufacturing of ceramics — Design — Design guidelines

Fabrication additive de céramiques — Conception — Lignes directrices relatives à la conception

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Foreword

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Additive manufacturing of ceramics — Design — Design guidelines

1 Scope

This document specifies part properties, design freedom, strengths and applications of additively manufactured (AM) ceramic materials. It is aimed at product planners and designers and provides the necessary basic knowledge about ceramics and the possibilities specific to AM ceramics, including strengths and limitations of the most utilized ceramic AM process categories. In-depth previous knowledge in these areas is not assumed.

2 Normative references

The following document is referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 and the following apply:

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
binder system
mixture of different organic or inorganic materials that after curing/drying/solidification bind the particulate material together forming the *green body* (3.8) before shaping

3.2
brown body
green body (3.8) that has undergone pyrolysis/*debinding* (3.5)

Note 1 to entry: The brown body has very low mechanical strength, as the individual particles adhere to each other solely due to surface forces as well as frictional and positive locking.

3.3
ceramic
any material that is classified as an inorganic, non-metallic crystalline solid

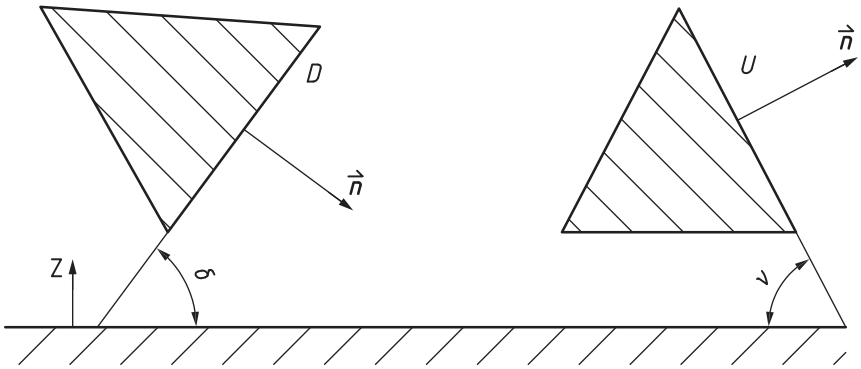
3.4
cleaning
removal of adhering excess of feedstock from the *green body* (3.8)

3.5
debinding
process of removing all binder from the *green body* (3.8)

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3.6
downskin angle
δ
angle between the build platform plane and a downskin area, *D*, whose value lies between 0° (parallel to the build platform) and 90° (perpendicular to the build platform)

Note 1 to entry: See Figure 1.



Key

D	downskin area
U	upskin area
$\vec{n}$	normal vector

Figure 1 — Upskin angle, υ, and downskin angle, δ, according to ISO/ASTM 52911 series

3.7
granulate
solid, flowable feedstock for powder bed-based AM processes

Note 1 to entry: Granulate is a specially produced compound of many individual powder particles that has significantly improved flow properties compared to a standard powder.

3.8
green body
part in intermediate state of processing, where the intended geometrical shape is given, but the bonding of the intended part material is yet to be established (which occurs during *sintering* (3.14))

Note 1 to entry: For multi-step ceramic processes, the green body typically will consist of a powder held together by the binder system.

Note 2 to entry: The mechanical properties of a green body made from powder materials are essentially determined by the binder system.

3.9
green machining
machining of the *green body* (3.8) to attain the desired geometry or surface quality

Note 1 to entry: Green processing can include the removal of supports and the integration of special geometric features.

3.10
hard machining
machining of the *sintered part* (3.13) to achieve the desired geometry, dimension or surface quality to the final dimension

Note 1 to entry: Due to the high hardness of the sintered part, hard machining is very time-consuming and places very high demands on the machining processes and tools.

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3.11
infiltration
process where a fluid material (liquid, vapor or slurry) is introduced into the connected pores of a porous ceramic preform

3.12
shrinkage
volume reduction of a part without mass change during *sintering* (3.14)

Note 1 to entry: Volume reduction due to material removal (machining) is not referred to as shrinkage.

3.13
sintered part
part after *sintering* (3.14) with the final (*ceramic* (3.3)) properties

3.14
sintering
thermal process for compacting and bonding the (*ceramic* (3.3)) particles, taking place at temperatures below the melting temperature

Note 1 to entry: Generally, sintering is accompanied by shrinkage.

Note 2 to entry: The temperature during sintering is above the debinding temperature but below the melting temperature of the ceramic material.

3.15
suspension
liquid feedstock with suspended particulate (i.e. *ceramic* (3.3) powder)

EXAMPLE Slip, ink, paste, slurry, etc.

Note 1 to entry: The suspension can be solidified by removing components of the binder system or initiating cross-linking reactions.

3.16
undercut
design feature, such as a horizontal protrusion, cavity or internal channel, that juts out from the main body and cannot be produced without supports

3.17
upskin angle
υ
angle between the build platform plane and an upskin area, *U*, whose value lies between 0° (parallel to the build platform) and 90° (perpendicular to the build platform)

Note 1 to entry: See Figure 1.

3.18
white machining
machining of the white body to realize the desired geometry or surface quality

Note 1 to entry: The subsequent shrinkage during sintering should be considered and compensated for by an appropriate oversize.

Note 2 to entry: White machining processing can include the removal of supports and the integration of special geometric features.

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