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Aditivna proizvodnja - Smernica za tehnično načrtovanje taljenja praška na posteljici - 1. del: Laserska fuzija kovinskih prahastih plasti (ISO/ASTM DIS 52911-1:2017)

Additive manufacturing - Technical Design Guideline for Powder Bed Fusion - Part 1: Laser-based Powder Bed Fusion of metals (ISO/ASTM DIS 52911-1:2017)

Additive Fertigung - Technische Konstruktionsrichtlinie für Pulverbettfusion - Teil 1: Laserbasierte Pulverbettfusion von Metallen (ISO/ASTM DIS 52911-1:2017)

Fabrication additive - Lignes directrices techniques de conception pour la fusion sur lit de poudre - Partie 2: Fusion laser sur lit de poudre polymère (ISO/ASTM DIS 52911-1:2017)

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Additive manufacturing — Technical design guideline for powder bed fusion —

Part 1:
Laser-based powder bed fusion of metals

Titre manque —

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 261. ISO 52911-1 was prepared by Technical Committee ISO/TC 261, Additive Manufacturing in cooperation with ASTM F42 on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on Additive Manufacturing.

Under the general title *Additive manufacturing — Technical Design Guideline for Powder Bed Fusion* there are more standards under development, for example for Laser-based Powder Bed Fusion of Polymers.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 52911-1 is based on the VDI-Guideline (The Association of German Engineers) *VDI 3405 Part 3 Additive Manufacturing processes, rapid manufacturing — Design rules for part production using laser sintering and Laser-based Powder Bed Fusion of Metals*.

The purpose of this Guideline is to provide support for technology users when designing parts that need to be manufactured by means of Laser-based Powder Bed Fusion of Metals. Furthermore, this guideline aims to extend the ISO/ASTM DIS 52910 Standard Guide for Design for Additive Manufacturing with a focus on the powder bed fusion process.

Introduction

Laser-based Powder Bed Fusion of Metals (LB-PBF-M) describes an Additive Manufacturing (AM) process and offers an additional manufacturing option alongside established processes. LB-PBF-M has the potential to reduce manufacturing time and costs, and increase part functionality. Practitioners are aware of the strengths and weaknesses of conventional, long established manufacturing processes such as cutting, joining and shaping processes, e.g. by machining, welding or injection moulding, and giving them appropriate consideration at the design stage and when selecting the manufacturing process. In the case of LB-PBF-M and AM in general, design and manufacturing engineers only have a limited pool of experience. Without the limitations associated with conventional processes, the use of LB-PBF-M offers designers and manufacturers with a high degree of freedom and this requires an understanding about the possibilities and limitations of the process.

The PBF standards will be deployed as a series of guides for different PBF technologies. As known today, the series will include Laser-based Powder Bed Fusion of Metals (LB-PBF-M), Laser-based Powder Bed Fusion of Polymers (LB-PBF-P), and Electron Beam Powder Bed Fusion of Metals (EB-PBF-M). Each standard in this series will share Sections 1 through 5, where general information about the standards, the terminology, and the PBF process will be provided. All subsequent sections will focus specifically on one of the three technologies identified above.

Additive manufacturing — Technical Design Guideline for Powder Bed Fusion — Part 1: Laser-based Powder Bed Fusion of Metals

1 Scope

This standard aims to give design and production engineers a working basis which enables them to have informed consideration about the use of Laser-based Powder Bed Fusion of Metals. This standard describes the features of Laser-based Powder Bed Fusion of Metals and provides detailed design recommendations. Some of the fundamental principles can also be applied to other AM processes, provided that due considerations are given to the process-specific features. The purpose of this standard is to help practitioners explore the benefits of Laser-based Powder Bed Fusion of Metals and recognising the process-related limitations when designing parts.

The document also provides a state of the art review of design guidelines associated with the use of Powder Bed Fusion by bringing together relevant knowledge about this process and to extend the scope of ISO/ASTM DIS 52910.

2 Normative references

The following documents are referred to in the text in such a way that some or all of 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.

VDI 3405 Part 3:2015, *Additive Manufacturing processes, rapid manufacturing — Design rules for part production using laser sintering and laser beam melting*

ISO 17296-2:2015, *Additive manufacturing — General principles — Part 2: Overview of process categories and feedstock*

ISO 17296-3:2014, *Additive manufacturing — General principles — Part 3: Main characteristics and corresponding test methods*

ISO/ASTM DIS 52910, *Standard Guide for Design for Additive Manufacturing*

ISO/ASTM 52900:2015, *Additive manufacturing — General principles — Terminology*

ISO/ASTM DIS 52901:2015, *Additive manufacturing — General principles — Requirements for purchased AM parts*

ISO/ASTM 52915:2016, *Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2*

Also, please monitor if there are new standards available prepared by ISO/TC 261/ASTM F42 Joint working group 52 on standard test artefacts.

3 Terms and definitions

For the purposes of this standard, the terms and definitions as per ISO/ASTM 52900:2015 and the following terms and definitions apply:

3.1

curl effect - thermal and residual stress effects

this refers to aspects of heat-induced warping that is a dimensional distortion as the printed part cools and solidifies after being built

3.2

downskin area

D

(sub-)area whose normal vector $\vec{n}$ in relation to z-axis is negative (Figure 1)

3.3

downskin angle

δ

the angle between the plane of the build platform and the downskin area whose value lies between 0° (parallel to the build platform) and 90° (perpendicular to the build platform) (Figure 1)

3.4

upskin area

U

(sub-)area whose normal vector $\vec{n}$ in relation to z-axis is positive (Figure 1)

3.5

upskin angle

u

angle between the build platform plane and an upskin area whose value lies between 0° (parallel to the build platform) and 90° (perpendicular to the build platform) (Figure 1)

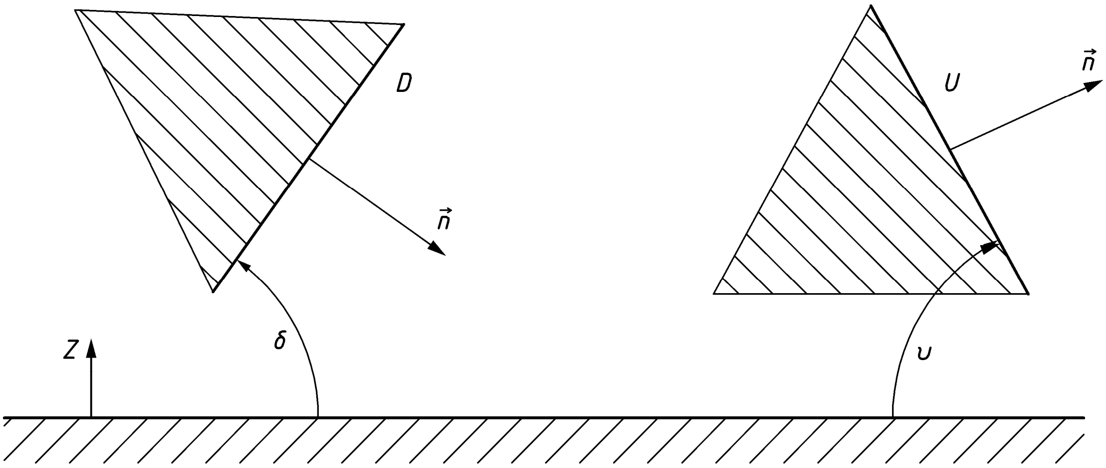

Figure 1 — Upskin (right) and downskin (left) areas *U* and *D*, upskin and downskin angles υ and δ, normal vector $\vec{n}$

[SOURCE: VDI 3405 Part 3:2015]

4 Symbols and abbreviations

4.1 Symbols

The following symbols are used throughout this standard, see Table 1:

Table 1 — Symbols

Symbol	Designation	Unit
a	overhang	mm
D	downskin area	mm^2
I	island	mm^2
$\vec{n}$	normal vector	—
Ra	mean roughness	µm
Rz	average surface roughness	µm
U	upskin area	mm^2
δ	downskin angle	°
υ	upskin angle	°

4.2 Abbreviations

The following abbreviations are used throughout this standard:

AM	Additive Manufacturing
AMF	Additive Manufacturing File Format
DICOM	Digital Imaging and Communications in Medicine
P	part
CAD	Computer Aided Design
CT	Computer Tomography
HIP	Hot Isostatic Pressing
MRI	Magnetic Resonance Imaging
LB-PBF	Laser-based Powder Bed Fusion
LB-PBF-M	Laser-based Powder Bed Fusion of Metals (also known as e.g. Laser Beam Melting, Selective Laser Melting)
LB-PBF-P	Laser-based Powder Bed Fusion of Polymers (also known as e.g. Laser Beam Melting, Selective Laser Melting)
PBF	Powder Bed Fusion
STL	STereoLithography format or Surface Tessellation Language

5 Powder Bed Fusion Processes – General Remarks

5.1 General

Consideration must be given to the specific characteristics of the manufacturing process used in order to optimise the design of a part. Examples of the features of Additive Manufacturing processes which need to be taken into consideration during the design and process planning stages are listed below. With regards to metal processing, it can be distinguished between for example Laser-based (today applied for metals and polymers) and Electron Beam-based (today applied for metals only) Powder Bed Fusion.

Polymers PBF uses in almost every case low power lasers to sinter polymer powders together. As with polymer powders PBF, metals PBF includes varying processing techniques. Unlike polymers, metals PBF often requires the addition of support structures (Section 6.4.3) due to material density and thermal characteristics. Metals PBF processes may use low-power lasers to bind powder particles by only melting the surface of the powder particles (sintering) or high-power (approximately 200 W to 1 000 W) energy beams to fully melt and fuse the powder particles together (melting). Sintering is distinguished from fusing by whether or not the metal achieves a partial melt (sinter) versus a full fusion. For the most part, laser-based PBF machines are capable of either, depending on exposure times and temperatures. Sintering often requires secondary processing (such as infiltration), while melting supports the creation of near fully dense parts.

Electron beam-based melting and laser-based melting have similar capabilities, although the beam energy from the electron beam is of a higher intensity and the process operates at higher temperatures than the laser counterpart, therefore typically also supporting faster build rates at lower resolutions. In general, electron beam processes subject parts to less thermal stresses (as powder material is preheated before processing) and have faster build rates, but the trade-off often comes with general greater minimum feature sizes and greater surface roughness than laser melting.

5.1.1 Size of the Parts

The size of the parts is not only limited by the working area/working volume of the PBF-machine. Also the occurrence of cracks and deformation due to residual stresses could limit the maximal part size. Another important practical factor that could limit the maximal part size is the cost of production having a direct relation to the size and volume of the part. In addition, cost of production can be minimized by choosing part location and build orientation in a way that allows nesting of as much parts as possible. Also, cost in powder needed to fill the bed to required volume (part depth x bed area) may be a consideration. Powder reuse rules impact this cost significantly. If no reuse is allowed then all powder is scrapped regardless of volume solidified.

5.2 Typical Advantages of the PBF process

PBF processes can be advantageous for manufacturing parts where the following points are relevant:

- Parts can be manufactured to near-net shape (i.e. close to the finished shape and size).
- Degrees of design freedom for parts are typically high. Limitations of conventional manufacturing processes do not usually exist, e.g. for
  - tool accessibility;
  - undercuts.