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Guide for Additive Manufacturing — Design — Material Extrusion of Polymers[1]

This standard is issued under the fixed designation F3529; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Polymer material extrusion (MEX/P) describes an additive manufacturing (AM) process and offers an additional manufacturing option alongside established processes. Applications for MEX range from functional prototypes to simple fixtures and jigs to complex manufacturing aids and short manufacturing runs of parts with complex geometry. MEX has the potential to reduce manufacturing time and costs, increase part functionality, and has the capability of producing very large parts. Practitioners are aware of the strengths and weaknesses of conventional, long-established manufacturing processes, such as cutting, joining and shaping processes (for example, by machining, plastic welding or injection molding) and of giving them appropriate consideration at the design stage and when selecting the manufacturing process. In the case of MEX/P 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 MEX offers designers and manufacturers a high degree of freedom and this requires an understanding about the possibilities and limitations of the process.

Note that the term Fused Filament Fabrication (FFF) is sometimes used to specify the type of MEX process described in this document that refers to the extrusion of a thermoplastic filament in a layer. The term MEX will be used in this document, or MEX/P when it is desired to emphasize the deposition of polymer material, including thermoplastics, and other materials.

This document provides support to technology users, such as design and production engineers, when designing parts that need to be manufactured by means of MEX/P. It will help practitioners to explore the benefits of MEX/P processes and to recognize the process-related limitations when designing parts. It also builds on ISO/ASTM 52910 to extend the requirements, guidelines and recommendations for AM design to include the MEX/P process.

1. Scope

1.1 This document specifies the features of MEX/P and provides detailed design recommendations.

1.2 Some of the fundamental principles are also applicable to other AM processes, provided that due consideration is given to process-specific features.

1.3 This document also provides a state of the art review of design guidelines associated with the MEX/P by bringing together relevant knowledge about this process and by supplementing the scope of ISO/ASTM 52910.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3413 Guide for Additive Manufacturing — Design — Directed Energy Deposition

2.2 *ISO/ASTM Standards:*[2]

52900 Additive manufacturing — General principles — Terminology

52901 Additive manufacturing — General principles — Requirements for purchased AM parts

[1] This guide is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.04 on Design.

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[2] For referenced ISO/ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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52903-1 Additive manufacturing — Material extrusion-based additive manufacturing of plastic materials — Part 1: Feedstock materials
52903-2 Additive manufacturing — Material extrusion-based additive manufacturing of plastic materials — Part 2: Process equipment
52910 Additive manufacturing — Design — Requirements, guidelines and recommendations
52915 Specification for Additive Manufacturing File Format (AMF) Version 1.2
52921 Terminology for additive manufacturing — Coordinate systems and test methodologies
52950 Additive manufacturing — General principles — Overview of data processing.

2.3 *VDI Standard:*[3]

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

3. Terminology

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

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

— IEC Electropedia: available at http://www.electropedia.org/
— ISO Online browsing platform: available at http://www.iso.org/obp

3.1 *air gap*—a process variable that specifies the scalar distance between successive beads in a layer.

3.1.1 *Discussion*—If the bead spacing is exactly the bead width, then the air gap is 0. An air gap greater than 0 means that neighboring beads do not touch, while an air gap of less than 0 indicates that beads overlap.

3.2 *bead, n*—the deposited filament of material.

3.3 *downskin angle, δ, n*—angle between the plane of the build platform and the *downskin area* (3.4) where the value lies between 0° (parallel to the build platform) and 90° (perpendicular to the build platform).

3.3.1 *Discussion*—See Fig. 1.

3.4 *downskin area, D, n*—(sub-)area where the normal vector in relation to *z*-axis is negative.

3.4.1 *Discussion*—See Fig. 1.

3.5 *infill density, n*—a process variable that specifies the percentage of the interior regions of part cross sections that is filled with beads (3.2)

3.6 *nozzle, n*—tip of the material extrusion head through which the material is deposited on the build platform or previous beads.

3.7 *overhang, n*—part surface or feature with a downskin angle between 0° and 90°.

3.7.1 *Discussion*—See Fig. 2*a*.

3.7.2 *Discussion*—Synonym for *downskin area*.

3.8 *overhang length, a, n*—distance measurement for an overhang.

3.8.1 *Discussion*—See Fig. 2*a*.

3.9 *part consolidation, n*—a design strategy that involves combining multiple parts into one part, or fewer number of parts.

3.10 *support structure, n*—sacrificial material that is deposited to support part material in subsequent layers.

3.11 *unsupported bridge, n*—part surface or feature with a downskin angle of 0° that is supported on both sides.

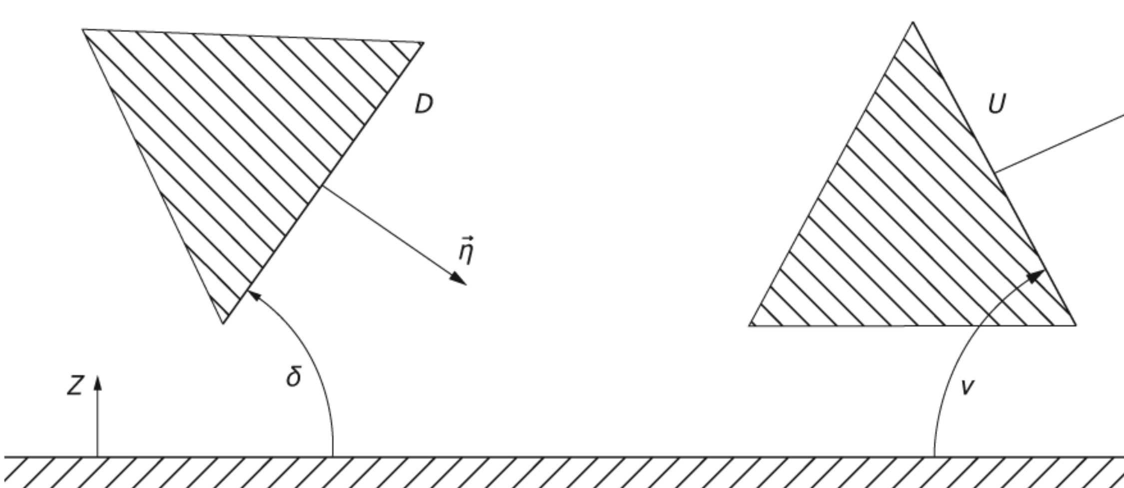
3.11.1 *Discussion*—See Fig. 2*b*.

3.12 *unsupported bridge width, w, n*—distance measurement for an unsupported bridge.

3.12.1 *Discussion*—See Fig. 2*b*.

3.13 *upskin angle, υ, n*—angle between the plane of the build platform and an *upskin area* (3.14) where the value lies

[3] VDI - The Association of German Engineers; available online.



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Source: VDI 3405: Part 3:2015.

FIG. 1 Upskin and Downskin Areas *U* and *D*, Upskin and Downskin Angles υ and δ, Normal Vector $\vec{n}$