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Additive manufacturing — Round robin testing — General guidelines

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Foreword

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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).

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This document was prepared by ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM Committee F42, *Additive Manufacturing Technologies*, 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, and in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438, *Additive manufacturing,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document outlines the steps with regard to aspects of design to conduct and run a round robin study (RRS) to assess the degree of variability in an additive manufacturing material or process.

The RRS can be used to study variations arising from the AM production process including feedstock, machine operation, process control, and post processing. The RRS plan can identify various aspects of the AM process to be considered to execute the study so that it is possible to maximize the consistency of the results based on the objective of the study.

Additive manufacturing is still a developing technology and round robin studies play an important role to help generate the information needed to populate materials engineering databases, determine design allowables, and improve processing and post-processing consistency in order to drive maturation.

The result of the RRS is a qualitative or quantitative assessment of the material used or the process variability, rather than the assessment of accuracy and precision of a specific test method from an inter-laboratory study. Additionally, RRS can involve other entities besides laboratories.

Round robin studies differ from normal research studies by having different participants, each trying to undertake a nominally identical process. The aim is to determine the effect of the desired variables on the process outcome. The output can be used for different applications such as the demonstration of process robustness or for derivation of material property data. A well-conducted RSS does not guarantee small variability, but ensures that any observed variability is indicative of the material or process, not poor study design.

Additive manufacturing — Round robin testing — General guidelines

1 Scope

This document is focused on the management of the round robin study (RRS) and can provide guidance for the scope development, planning, and execution of the RRS study. It can provide guidance to identify the feedstock, machine operations, process controls, and post-processing operations prior to running the study. RR organizers can identify controlled and free parameters in the study. This document can also provide guidance on the selection and use of test methods that can be applicable. The RRS investigates the variations found in AM parts. The outcome of the study can be used to improve the maturation of AM technologies.

A RRS, as described in this document, is different from an inter-laboratory comparison because an inter-laboratory study establishes the variability in a measurement method when undertaken by multiple users on a well-controlled artefact.

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.

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 terminological 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
process control document
document recording process variables, procedure followed, and building notes

4 RRS task force and RRS manager

The RR task force is the executive team responsible for establishing the goals and scope of the round robin study. The procedure presented in this guide can consist of sequences to help the RRS task force in preparing the RRS. Once the RRS has been developed, an RRS manager can be assigned to assist participants with operational questions.

The RRS task force can be the sole arbiter of technical issues.

5 Develop a round robin study

5.1 Suggested steps to develop a round robin study

Suggested steps in an RRS are given in Table 1.

Table 1 — Sequence of a round robin study

Sequence	Procedure	Clause/subclause in this document
1	Determine goal and select the RRS task force	5.2
2	Determine scope of RRS	5.3
3	Develop a manufacturing plan	5.4
4	Process control document	5.5
5	Develop a measurement and testing plan	6
6	Solicit participants	7
7	Provide RRS plan	8
8	Pilot run (if needed)	9
9	Full scale run	10
10	Data handling	11
11	Prepare study report	12
12	Record keeping	13

5.2 Identify the goal of the study and select the round robin task force

Identifying the objective of the study is an important first step. Once the goal of the study is determined, an RRS task force can then be formed consisting of interested parties with relevant experience in AM. The RRS task force can name an RRS manager who is able to assist RRS participants during the pilot and full-scale runs. The RRS task force can then develop the RRS plan that includes:

a) scope and purpose;

b) manufacturing;

c) measurement and testing plans,

d) soliciting participants;

e) guiding the study;

f) collecting data;

g) interpreting data;

h) preparing a final report.

5.3 Prepare scope of round robin study

The RRS task force can determine process selections such as feedstock material, process parameters, and methods that are required to be controlled. It is possible that AM RRS can be a useful tool for determining the repeatability and reproducibility of an AM process, assessing production readiness, and populating material databases and material data sheets for design purposes. The output of the RRS can be a reporting of statistical variations in AM part properties.

5.4 Develop a manufacturing plan

A manufacturing plan sets forth the AM process, feedstock, process parameters and sequence of activities needed to produce a specific part. The following outline can provide a minimum guide of information that can be included in the plan, however, it is possible that the RRS can have more details than what is listed.

a) Part description (part geometry, including build platform and lattice structure).

The part description can provide full details of the part or parts, including tolerances of each part, support layout, lattice structures, and tolerances for any specified surface textures or embossed labelling. Depending on the study, the source file (CAD, scan, or other source type), part file or files, and build file may be supplied along with specified tolerances. Instructions on the placement and orientation of digital components within the AM systems build volume can be included.

b) Machine requirements (including make/model, software, maintenance, calibration, etc.).

The manufacturing plan can clearly define the AM machine requirements such as, but not limited to

— make/model,

— type of AM process being studied,

— platform,

— atmosphere,

— machine software version,

— last date of maintenance, and

— machine calibration.

c) Facility requirements (environment, stability, process gas, etc.).

The requirements of the facility where the machine is located. This can include environment (temperature and humidity), stability (e.g electrical, mechanical, magnetic), provision (process gas, cooling water, air etc).

d) Feedstock requirements (handling, storage, specification, etc.).

Since feedstock can produce significant variation of results, it is possible to accurately quantify and control the source, specifications, and traceability of the feedstock. Requirements can also include feedstock conditioning prior to component fabrication.

The RRS task force can define the following feedstock qualities:

— feedstock supply:

  1) RRS team acquires feedstock and distributes it to participants;

  2) RRS task force can define feedstock specification and quantities to procure by participants;

— feedstock batch properties: can be the same for all participants:

  1) chemical composition;

  2) physical properties;

  3) batch properties:

    i) virgin;

    ii) used: with limits on prior re-use;

iii) blend: defined by the RRS team;

— feedstock conditioning (if needed).

The RRS task force can provide participants with detailed instructions for the storage, safe handling and use of the feedstock. It is possible that this includes environmental exposure and any recycling/reprocessing steps that might be necessary during the production of the parts in the study. Detailed records of the material including all processing and environmental exposure it has undergone can be recorded in the process control document so that full traceability of the material is possible.

e) Hardware setup requirements (user training, operator proficiency, machine setup).

Instructions can be provided to participants for machine setup, and can include:

— user training, operator proficiency;

— environmental conditions (internal to the machine);

— machine performance validation (calibration and qualification);

— machine setup;

— machine cleaning;

— material handling;

— equipment maintenance and revalidation processes;

— after maintenance or servicing the machine can be validated.

f) Software setup requirements (programs, user training, operator proficiency, build file setup).

Specification of software to be used including version. Operators can be highly proficient with the build processing and machine software so it is possible for them to create job files from the part files provided by the RRS task force. They can also possess a fundamental understanding of the processes needed to use machine software to execute the build with the proper processing parameters.

g) In-process requirements (monitoring, data collection, environment).

AM machines have an increasing amount of in-process monitoring, data collection, environmental monitoring, and feedback control. As much of this data can be recorded as possible, even if it cannot be controlled, so that it can be correlated with the final part properties. Depending on the study design it is possible that the machine will use internal feedback control to maintain certain processing conditions. A record of the in-process monitoring can be retained.

h) Process completion (data reporting, sample numbering).

There is a possibility of the RRS manager providing guidance as to what to do if planned or unplanned build interruptions occur during the study. This can occur due to process errors, machine interruptions, or environmental changes. If the error is serious, the build can be terminated at the discretion of the RRS manager. If the build is interrupted and then restarted, the participant can record causation of the stoppage, build height, and procedures undertaken to restart the build. The RRS manager can be informed of any deviations or if there is a problem with completion of the manufacturing plan.

i) Post processing requirements (heat treatment, machining, sample numbering).

Most AM processes require some form of post-processing before the part can be used. Post-processing can include removal from the machine itself, the build platform, support removal, finish machining or thermal post processing. The RRS task force can specify the post-processing steps or they can collect test parts from each RRS participant prior to post-processing while still attached to the build platform. The RRS task force can have a single organization undertake all the post processing operations, or have multiple organizations perform them. The post-processing procedures along with facility performing