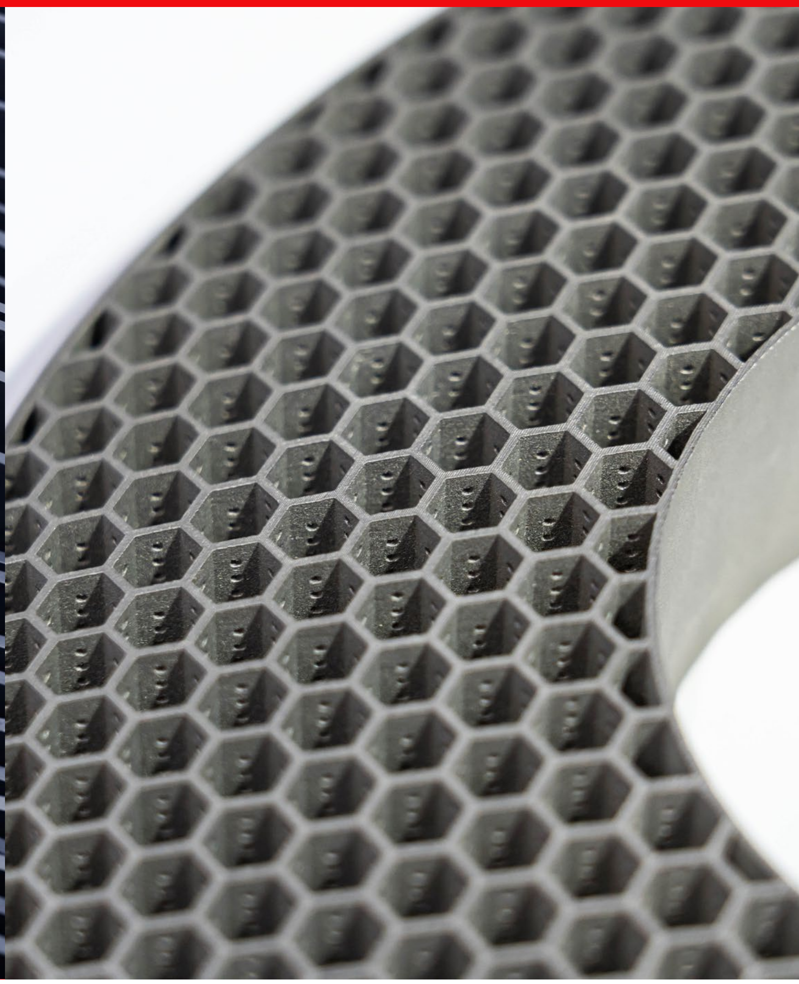
PAS 6011:2020

Additive manufacturing – Non-destructive testing for use in directed energy deposition – Guide



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Foreword

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The PAS process enables a Guide to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Relationship with other publications

PAS 6010, *Additive manufacturing – Wire for directed energy deposition (DED) processes in additive manufacturing – Specification*

PAS 6012, *Additive manufacturing – Wire arc – Guide*

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Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

As a guide, this PAS takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice.

Presentational conventions

The guidance in this PAS is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

Contractual and legal considerations

This Publicly Available Specification does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

Compliance with a Publicly Available Specification cannot confer immunity from legal obligations.

Introduction

Directed energy deposition (DED) is an additive manufacturing (AM) process, which focuses a thermal energy source to melt and fuse deposited materials. It is one of the seven main AM methods (ASTM/ISO 52900) and represents with powder bed fusion (PBF) one of the two main commercial processes for metal additive manufacture (MAM).

DED was one of the first AM processes, originating from the use of welding equipment in the 1960s to produce three-dimensional welding, and became part of AM in the 1990s. Despite its long history, DED is not as well-known as many other AM processes. It was extensively developed for military equipment and consequently received little publicity.

However, it is gaining greater commercial interest as it has a number of advantages over other processes. Particularly, DED can be:

- attached to a multi-axis manipulator, which adds material at almost any angle and does not require a build chamber;
- used to repair or upgrade existing parts, remodel or replace corroded areas; and
- applied to very large structures.

The term DED covers a range of commercial terminologies and implementations, all of which deposit and melt a feedstock material on a build substrate where it solidifies.

However, while DED methods are commercially attractive due to the lower costs in comparison with other AM processes, there is a lack of knowledge of the mechanical and lifetime performances of the parts produced by DED.

Traditional manufacturing processes are well defined and understood, but the increased complexity of AM processes leads to poor understanding. The relationship between process, geometry and microstructure of AM parts and the absence of predictive models make it difficult to validate the quality and integrity of the build. Accordingly, guaranteeing part mechanical performance is difficult. This gap in the assurance of the quality of AM parts is a key technological barrier that prevents the widespread adoption of AM technologies.

AM is especially attractive for industries, such as aerospace, with large, low volume, high-value parts in safety-critical applications. In these industries, the need for qualification and certification for requirements could not be greater. Therefore, in the absence of fully understood processes, the use of AM parts in such critical applications requires that parts are qualified by a detailed inspection.

While industry is pushing for in-situ methods, there is a lack of in-situ monitoring capability. Current in-situ methods are only suitable for part surface defects while real-time monitoring has not been adequately demonstrated for DED.

In the short to medium term, non-destructive testing (NDT) has been repeatedly identified as critical to the success of additive manufacture by providing a means of validating the quality of the build and to gather data to increase knowledge and understanding.

Therefore, this PAS focuses on the determination of the part quality through the use of NDT. It examines traditional, new and emerging techniques, identifying their suitability for use with DED. Geometric control and in-process sensing are not part of this document.

It makes recommendations for points in the process where specific NDT methods may be applied. The optimal points in the process for use of NDT include between deposition of layers and (intra-layer), after the build process (post-build), and if necessary in post-processing (finished/post process).

A subgroup of emerging NDT techniques which may have the greatest potential for future DED application is highlighted in Clause 11, with the aim that industry adopt and accelerate their development.

1 Scope

This PAS provides guidance on non-destructive testing (NDT) for use in directed energy deposition (DED) additive manufacturing (AM) processes and covers:

- typical causes and the nature of defects;
- review of other potentially relevant standards (welding);
- review of NDT methods' capability for DED AM;
- emerging NDT with potential for DED AM; and
- shortlist NDT methods with potential for validation trials.

This PAS is relevant to users who wish to identify suitable methods for the inspection of parts manufactured using a DED AM process.

This PAS is of interest to regulatory bodies, material suppliers, certification bodies, inspectors, and researchers.

This PAS does not cover NDT during DED AM builds and NDT trials, or other AM processes.

This PAS does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

2 Normative references

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

ASTM F3049, *Standard guide for characterizing properties of metal powders used for additive manufacturing processes*

ASTM F3187, *Standard guide for directed energy deposition of metals*

ASTM/ISO 52900, *Standard terminology for additive manufacturing – General principles – Terminology*

BS EN 1330-1, *Non-destructive testing – Terminology – Part 1: List of general terms*

BS EN 1330-2, *Non-destructive testing – Terminology – Part 2: Terms common to the non-destructive testing methods*

BS EN 1779, *Non-destructive testing – Leak testing – Criteria for method and technique selection*

BS EN 13018, *Non-destructive testing – Visual testing – General principles*

BS EN 13068-1, *Non-destructive testing – Radioscopic testing – Quantitative measurement of imaging properties*

BS EN 13068-3, *Non-destructive testing – Radioscopic testing – General principles of radioscopic testing of metallic materials by X- and gamma rays*

BS EN 13554, *Non-destructive testing – Acoustic emission testing – General principles*

BS EN ISO 3452-1, *Non-destructive testing – Penetrant testing – Part 1: General principles*

BS EN ISO 5579, *Non-destructive testing – Radiographic testing of metallic materials using film and X- or gamma rays – Basic rules*