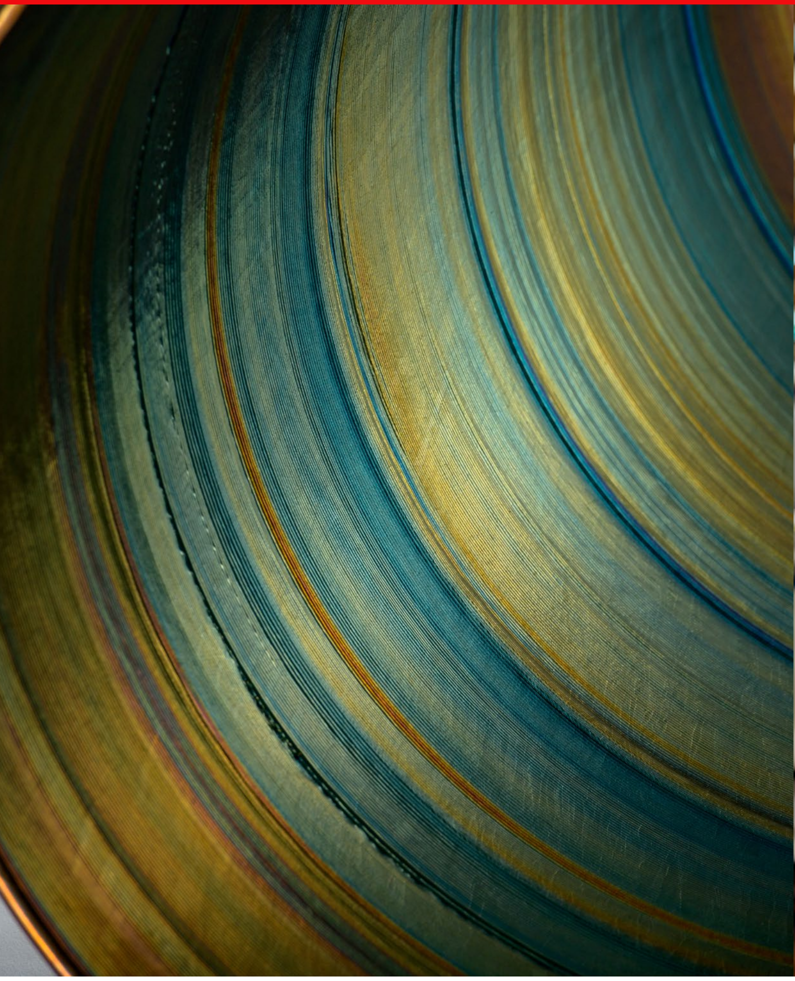
PAS 6012:2020

Additive manufacturing – Wire arc – Guide



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Foreword

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

PAS 6011, *Additive manufacturing – Non-destructive testing for use in directed energy deposition – Guide*

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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.

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The provisions of this PAS are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

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").

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

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

Introduction

In recent years, Additive Manufacturing (AM) has become an established manufacturing route alongside casting, forming, machining, joining and surfacing processes. Defined in BS ISO/ASTM 52900:2015 as "a process of joining materials to make objects from 3D model data, usually layer upon layer", AM is often cited as offering direct and decentralized production, with reduced dependency on expensive and dedicated tooling.

Whilst the field of AM has been subject to many technical advancements in the past three decades, the high cost (purchase, operation, maintenance and depreciation) of AM machines and materials present major challenges to AM progression [1]. There has been limited ability to replace conventionally made parts economically, particularly large parts. The application of AM has therefore been primarily focused on niche, high-value and technically-demanding parts of small-build volume, where the benefit of greater design freedom offsets the high cost.

Wire Arc Additive Manufacturing (WAAM) is a directed energy deposition (DED) additive manufacturing technology that is broadening the applicability of AM. Using an electric arc as a fusion source to melt wire feedstock, metallic end-use parts of medium-to-large build volume and low-to-moderate levels of complexity can be cost-efficiently produced. This capability can be attributed to the low cost of wire relative to metal powder used for powder-based AM for many materials, low capital expenditure, and a high deposition rate achievable within a flexible build envelope. Moreover, by lowering the barrier to entry, the non-tangible benefits of AM and DED may be accessible to more cost-sensitive manufacturers for the first time.

A compromise of the high deposition rate is that an as-built surface can be uneven and within a wide manufacturing tolerance. This means that WAAM is often reliant on post-process finishing to meet dimensional and geometric requirements. However, even with post-processing accounted for, substantial raw material and cost savings have been demonstrated in comparison to CNC machining and forging processes. Besides new part manufacture, as a DED process, WAAM can also be readily applied to feature addition and repair applications.

Recently, WAAM is becoming increasingly industrialized, with growth in both numbers of end users and equipment suppliers. The aerospace industry, as an early adopter of WAAM, has seen the process mature significantly for production of large titanium alloy aerospace components previously conventionally forged and machined. For example, WAAM parts produced by Norsk Titanium achieved US Federal Aviation Authority certification for production of WAAM parts for the Boeing 787 Dreamliner in 2015 [2]. Other applications of WAAM have been demonstrated in space, nuclear, automotive and marine industries, as well as in design, architecture and art.

NOTE *The Military Aviation Authority, UK MASAAG Paper 124 Issue 1 and DNVGL-CG-0197 provide guidance for qualification and certification of WAAM for military and marine applications, respectively. General certification guidance for AM, including recommendations applicable for WAAM is provided in guidance documents by ABS 299 and Lloyds Register. Information on materials, material tolerances, and quality control procedures and processes for the aerospace sector for Wire Fed Plasma Arc DED is provided by SAE AMS-7004, and for Titanium alloy preforms, SAE AMS-7005.*

Despite the growing interest and application, there is limited information to aid prospective users in effective implementation of WAAM. This PAS is intended to fulfil this need through providing practical guidance to enable organizations to embrace the technical and economic opportunities associated with WAAM.

1 Scope

This PAS provides an overview of the wire fed arc directed energy deposition, more commonly known as wire arc additive manufacturing (WAAM), process characteristics, benefits and limitations relative to other DED and conventional processing routes. This is intended to aid potential users in evaluating the suitability of adopting WAAM for a given application. It also covers:

- the general architecture and sub-systems that constitute a WAAM machine and their effect on WAAM capability;
- key process parameters and their influence on the WAAM process;
- considerations for effective WAAM path-planning, monitoring and control, and post-processing; and
- terminology relevant to WAAM.

This PAS does not cover other additive manufacturing processes, process qualification or quality assurance, nor does it provide guidance for a specific user application or material.

This PAS is aimed at WAAM machine developers and process parameter developers.

This PAS may also be of interest to potential end users of WAAM technology.

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.