



AEROSPACE MATERIAL SPECIFICATION

AMS7027™

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Electron Beam Directed Energy Deposition-Wire
Additive Manufacturing Process (EB-DED-Wire)

RATIONALE

This is an initial release specification for the EB-DED-Wire process.

AMS7027 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

1.1 Purpose

This specification establishes process controls for the repeatable production of aerospace parts by EB-DED-Wire. It is intended to be used for metal aerospace parts produced by additive manufacturing (AM), but usage is not limited to such applications.

1.2 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order form a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E2281 Standard Practice for Process Capability and Performance Measurement

ASTM E2587 Standard Practice for Use of Control Charts in Statistical Process Control

ASTM F3187 Standard Guide for Directed Energy Deposition of Metals

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Full document details: SAE AMS7027

For more information on this standard, visit
<https://www.sae.org/standards/content/AMS7027/>

Documents

Standard Sharing Hub

2.2 AWS Publications

Available from American Welding Society, 8669 NW 36 Street, #130, Miami, FL 33166-6672, Tel: 1-800-443-9353 or 305-443-9353, www.aws.org.

AWS A3.0 Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying

2.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO/ASTM 52900 Additive Manufacturing - General Principles - Terminology

2.4 Terminology

2.4.1 Definitions

The following definitions apply in addition to those defined in ISO/ASTM 52900 and ARP1917 Rev A:

ACCEPTABLE TO CEO: Does not require prior written approval from CEO prior to implementation into production. Any changes require notification to the CEO prior to part shipment. This allows producer to make a decision and the CEO the right to disapprove the decision.

AUTHORIZED BY CEO: Requires prior written approval from the CEO.

BUILD ENVELOPE: Largest external dimensions of the x-, y-, and z-axes within the build space where parts will be fabricated.

DEPOSITION FILE: The electronic file that is supplied to the EB-DED-Wire machine for manufacturing one or more parts. This includes but is not limited to part geometry, location, orientation, and process parameters.

EB-DED-WIRE MACHINE OEM: Company that manufactures the electron beam directed energy deposition machine.

ELECTRON BEAM DIRECTED ENERGY DEPOSITION (DED)-WIRE: Additive manufacturing process in which a focused beam of electrons is used to locally melt and deposit wire to form three dimensional shapes.

FEEDSTOCK MANUFACTURER: Company that manufactures the metallic wire to be used in the EB-DED-Wire machine.

FEEDSTOCK: Metallic wire which is melted during the EB-DED process to become a deposited bead and constitute the deposit.

INTENTIONAL INTERRUPTION: To plan to break the continuity of the deposition process (i.e., a KPV of the PCD).

KEY PROCESS VARIABLES (KPVs): Aspects of the manufacturing process that may impact the capability to meet the specified requirements. These requirements include physical, chemical, metallurgical, mechanical, or dimensional properties.

PREFORM: The product which results from the deposition of wire feedstock onto a substrate prior to finished part processing (machining, etc.).

PROCESS CONTROL DOCUMENT (PCD): A collection of procedures and requirements that are used to document and to control variation of a product.

PRODUCER: The entity using the EB-DED-Wire process to produce a perform.

PURCHASER: Organization that issues the PO to the producer.

SUBSTANTIATION: The process of assessing the ability to meet the requirements of a specific application and to satisfy all relevant requirements is variously called qualification, certification, substantiation, validation, and compliance within different documents used within different engineering organizations and involving different certification authorities.

SUBSTRATE: It represents the base metal utilized to initiate the deposition of EB-DED-Wire material. This material may remain a portion of the preform as the finished part or may be removed/reused.

UNINTENTIONAL INTERRUPTION: To break the continuity of the deposition process without planning (i.e., not a key process variable of the PCD).

WELD BEAD: As defined in AWS A3.0.

2.4.2 Acronyms

AM	Additive Manufacturing
CAD	Computer-Aided Design
CEO	Cognizant Engineering Organization
EB-DED-Wire	Electron Beam Direct Energy Deposition-wire
KPV	Key Process Variable
OEM	Original Equipment Manufacturer
PCD	Process Control Document(s)

3. TECHNICAL REQUIREMENTS

3.1 Process Control Document (PCD)

The PCD shall be established by the producer, substantiated (see 2.4) with respect to the specified requirements, and authorized by the Cognizant Engineering Organization (CEO). Once authorized, all aspects of the PCD are considered to be a fixed process and any changes to the PCD shall require substantiation prior to the change being implemented into production. Changes to the PCD that can affect a KPV must be authorized by the CEO. All other changes to the PCD must be acceptable to the CEO. The PCD shall address the following aspects of the EB-DED-Wire process:

3.1.1 Key Process Variables

- 3.1.1.1 The producer shall establish values, tolerances, and measurement frequency for all KPVs of the EB-DED-Wire process including, but not be limited to, the variables defined in Appendix A. These values and tolerances shall be substantiated with respect to the specified requirements and be authorized by the CEO. Any change to a KPV shall be authorized by the CEO.
- 3.1.1.2 Process variables may be omitted from the PCD when substantiated by the producer and authorized by the CEO.
- 3.1.1.3 The values of any KPVs considered proprietary by the producer may be assigned a code designation and recorded by the producer in an internal document. Each variation in such variable value shall be assigned a modified code designation.

3.1.2 Process Interruptions

- 3.1.2.1 Unintentional interruptions (see 2.4.1) shall be rejected.
- 3.1.2.2 Intentional interruptions shall be substantiated (see 2.4.1) by the producer, incorporated in the KPVs of the PCD, and authorized by the CEO. Intentional interruption(s) shall be defined in the PCD as a key variable (see Appendix A).

3.1.3 Digital File and Software Configuration Control

The producer's configuration management process shall establish configuration control to ensure the correct software and files are used in the production of components using EB-DED-Wire. This system shall include internal procedures to control electronic files, conversion settings, and machine parameters. All files shall be traceable through revision control and have access control.

3.1.4 Calibration and Verification Plan

3.1.4.1 Procedures for calibration and verification shall be established and substantiated by the producer to measure and adjust, at a minimum, all variables required by the EB-DED-Wire machine OEM, as well as those identified as required in Appendix B to meet the specified requirements. The plan shall include procedures, values, tolerances, and frequency of verification of each variable specific to the application.

3.1.4.2 All procedures performed shall be recorded via manual or electronic means and maintained for a period compliant with requirements of the ordering documents.

3.1.4.3 When authorized by the CEO, calibration and verification variables may be omitted when substantiated to have no impact on the ability for the part produced to meet the specified requirements.

3.1.5 Maintenance Plan

3.1.5.1 Procedures for maintenance shall be established and substantiated that include a checklist of activities, instructions to perform each activity, and the frequency by which that activity shall be completed.

3.1.5.2 At a minimum, maintenance plans shall include all activities and instructions that are required by the EB-DED-Wire machine OEM.

3.1.5.3 Additional maintenance items unique to the installation, facility, or specific application shall also be documented and included in the maintenance plan.

3.1.5.4 The maintenance plan shall include all ancillary equipment required to meet the specified requirements.

3.1.5.5 All maintenance performed shall be recorded via physical or digital means and maintained for a period compliant with requirements of the ordering documents.

3.1.5.6 Maintenance plans shall include all wear and life limited items that have been determined critical to consistent and reliable production

3.1.6 Substrate and Feedstock Material Handling and Storage Plan

Procedures for handling and storage of substrate and feedstock material(s) shall be established, substantiated, and authorized by the CEO to meet the requirements defined by the finished part material. At a minimum, the substrate and feedstock material handling plan shall include the following:

- The procedure to substantiate that the substrate and feedstock used in the EB-DED-Wire machine complies with the specified requirements including the inspection procedures.
- Storage conditions for the substrate and feedstock.
- Substrate and feedstock lot traceability and tracking to maintain traceability compliant with the requirements of the CEO.
- Conveyance and transport from any storage location to the EB-DED-Wire machine.
- Methods for substrate preparation and cleaning (see 3.1.6.1).

Additional recommended elements of a material handling and storage plan can be found in Appendix E.

3.1.6.1 Substrate Cleaning and Preparation

Prior to the process, surfaces of workpieces shall be free from heavy lubricants, halogen compounds, and other foreign matter, that may cause product to become noncompliant. Product coated with light oils need not be cleaned prior to pre-EB-DED thermal treatment and EB-DED process, provided that the oil either vaporizes or burns off during preheating. Halogenated solvents and methanol shall not be used to degrease workpieces unless the workpieces are subsequently cleaned using an alkaline solution or an acid pickle. Such cleaning shall be performed prior to pre-EB-DED thermal treatment and EB-DED process. Surfaces of fixtures, racks, etc., shall be clean and free of dirt, water, oil, grease, paint, ink, crayon markings, die pick-up, fingerprints, and other foreign material. After cleaning and prior to pre-EB-DED thermal treatment and EB-DED process in inert gas or vacuum furnaces, personnel handling material shall wear clean gloves that ensure no handling residue is left of the material.

3.1.7 Moisture and Contamination Control Plan

Procedures shall be implemented to minimize the risk of moisture, foreign material, or both that would change the performance of the items produced in the EB-DED-Wire process. The producer shall identify potential sources of contamination throughout all aspects of the EB-DED-Wire process, including feedstock storage and handling, EB-DED-Wire machine, EB-DED-Wire consumables, and ancillary equipment, and establish procedures to minimize the sources of such contamination. The plan shall include procedures, values, tolerances, and frequency of verification of each variable specific to the application.

3.2 EB-DED-Wire Machine Approval

For each individual EB-DED-Wire machine, the producer shall demonstrate that the items fabricated in the EB-DED-Wire machine conform with all requirements of the applicable material specification. The CEO shall define the requirements (number of specimens, analysis method and acceptance criteria) and the producer shall meet those requirements. This substantiation shall be authorized by the CEO prior to implementation into production. Each machine shall meet the following requirements at a minimum:

- Calibration and verification plan are executed and is in compliance with the requirements of 3.1.4.
- Preventative maintenance is performed, documented, and is compliant with the requirements of 3.1.5.
- Material testing is performed using specimens extracted from preform(s) built within the extents of the build envelope defined in the PCD including the extremes of the x, y, and z positions and orientations in the x-y plane and z direction.

3.3 EB-DED-Wire Process Approval

The process approval moves beyond machine approval and incorporates all KPVs of the PCD including final part geometry in the finalized deposition layout. The CEO shall define the requirements (i.e., how many preforms, how many machines, how many feedstock lots, required testing etc.) and the producer shall demonstrate the capability to meet those requirements. This substantiation shall be authorized by the CEO prior to implementation of the process for production.

3.4 Statistical Process Control (SPC)

Statistical process control shall be used to quantify and reduce variation, improve, and monitor the EB-DED process. This includes use of process capability and performance measurement per ASTM E2281 and use of control charts in SPC programs per ASTM E2587. The producer shall have reaction plan authorized by the CEO in place to respond to actions, improve the overall process, and identify special causes of variation. The KPVs identified in the SPC Required column of Appendix A shall be controlled and maintained.

4. QUALITY ASSURANCE PROVISIONS

4.1 Calibration and Verification

The producer shall maintain documentation of all activities performed per the calibration and verification plan defined in 3.1.4.

4.2 Maintenance

The producer shall maintain documentation of all activities performed per the maintenance plan defined in 3.1.5, as well as any unplanned maintenance.

4.3 Substrate and Feedstock Handling and Storage

4.4 The producer shall maintain evidence that the substrate and feedstock comply with the substrate and feedstock handling and storage plan defined in 3.1.6.

The producer shall have a procedure to ensure and document that the EB-DED-Wire process is executed in accordance with the PCD. At a minimum, this procedure shall include:

- Selecting the correct deposition file.
- Selecting the correct machine settings and parameters.
- Pre-deposition machine check procedure per the KPVs defined in the PCD.
- Substrate material and preparation requirements.
- Substrate installation and fixturing requirements.
- Feedstock loading requirements.

4.5 EB-DED-Wire Process Requalification

After initial machine and process approval, the producer shall demonstrate capability per 3.3, and as defined by the CEO, following the occurrence of any of the following events:

- A change to any of the KPVs defined in the PCD.
- Preform or witness coupon rejection caused by the EB-DED-Wire process. Specimen failure cause shall be concurred by the CEO.
- Changing the machine location or environment.
- Change in feedstock supplier.
- Machine repair involving critical system components or subsystems including, but not limited to, the electron beam generation and control hardware, high voltage unit, vacuum system, the wire feeding system, or the positioning system.

In order to reobtain qualification status, the producer shall demonstrate that the items fabricated in the EB-DED-Wire machine conform with all requirements defined by the CEO and the applicable material specification. The CEO shall define the testing requirements (number of specimens, analysis method, and acceptance criteria) and the producer shall meet those requirements. This substantiation shall be authorized by the CEO prior to implementation into production.