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Directed Energy Deposition – Laser Beam (DED-LB) Manual

CU 08

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Directed Energy Deposition – Laser Beam (DED-LB) Manual

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Coverage:

1. Introduction to the Process DED-LB

2. DED-LB Manufacturing Strategy
(Fixturing, Positioning and Nesting, Layer Thickness, Dosing Factor (Powder Capture Efficiency, Powder Optimization), Interaction of Layers, Distortion avoidance, Deposition rate/Production Rate (Deposition Rate, Production Rate), Hybrid Build Strategies, Parameters adjustments along the layer)

3. Equipment and accessories
(Optical System, Powder/wire Feeding System, Gas System, Powder Feeding System (Powder feeding and Conveyance Systems), Deposition Direction (Types of Nozzles), Sieves and Filters (Sieves, Filters)

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Coverage:

4. DED-LB Build substrate
(Common defects, Influence of Inclined Substrate in DED)

5. Post processing

6. Consumables (Feedstock)

7. Advantages and Limitations

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CU 08 DED-LB Process

OBJECTIVES:

UNDERSTAND THE PRINCIPLES OF DED-LB PROCESSES

UNDERSTAND DED-LB PROCESS FEEDSTOCK

UNDERSTAND DED-LB PROCESS LIMITATIONS

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On successful completion of this module a student should have knowledge of:

1. DED-LB systems
2. Laser characteristics
3. Build platform
4. Powder/wire
5. Gases
6. DED-LB equipment, accessories, including build platform, feedstock and other consumables
7. DED-LB process parameters and variables, including post-processing operation

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Introduction to the Process DED-LB

Additive manufacturing (AM) was born as a rapid prototyping technology with the process of joining materials in successive layer by layer to make objects. It allows designers to produce accurate physical prototypes directly from 3-Dimensional Computer-Aided Design (3D-CAD) model in few hours.

DED-LB is a technology that works by melting material that is fed to a local site on the build layer, usually occurring within an inert gas atmosphere. While this can be used for nonmetal materials, it is predominately used with metals and metal alloys.

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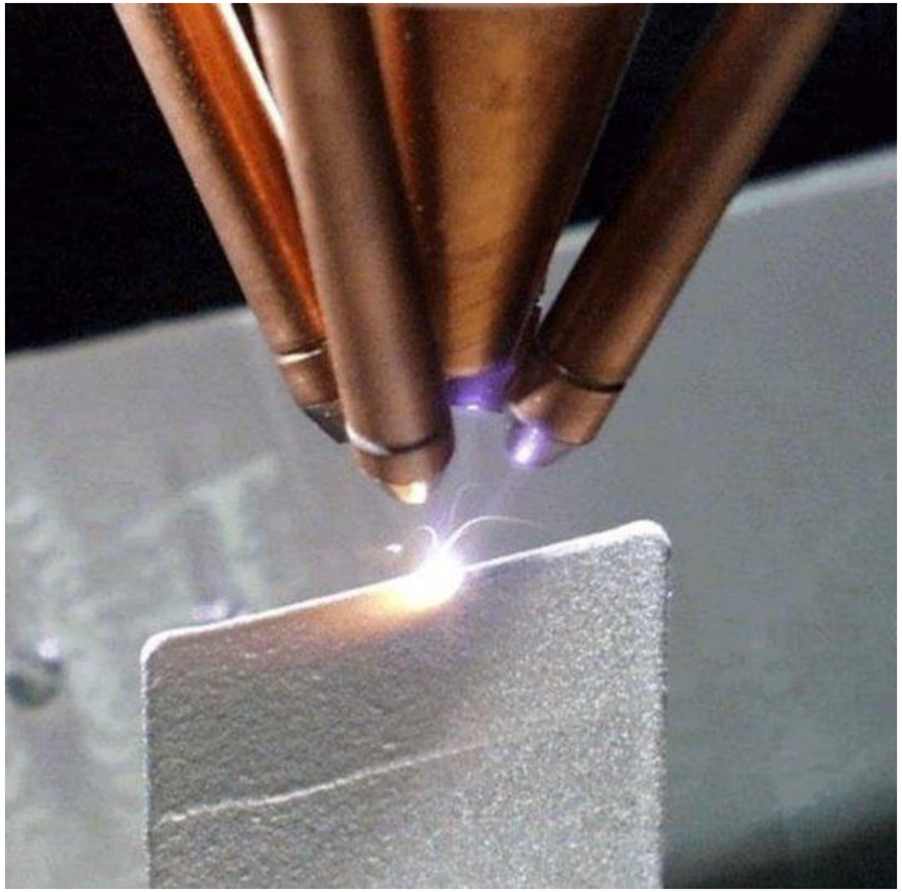

In laser DED, the material in the form of powder or wire is fed into the melt pool. The powder is usually blown coaxially from either a conical nozzle or a multi-nozzle powder delivery system into the processing zone.

In laser DED based on wire feeding, the wire metal is usually fed from one side (mostly from leading edge of melt pool). With the advancement of this technology, new laser heads are capable of feeding wire from center that is being exposed to the coaxially split laser beams.

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Fixturing

- **Control Workstation**
- **Laser Source**
- **Powder feeding system**
- **Multi-axis CNC system**

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Configurations that can appear in the machines:

Fixed Tables: Fixed tables exploit the very large working envelope to process large parts and provide great accessibility from all sides. The accuracy of the part could be improved by better securing the substrate in the same position.

Split Cabin: The Split Cabin configuration allows the working volume to be separated in a removable wall and a sliding roof into two halves, where the parts are alternatively processed or loaded/unloaded in total safety. In this way, machine productivity is increased and, when needed for larger parts, the wall can be removed to restore the entire working envelope.

Turn Table: The installation of the turn table has the function of keeping the pool of fusion created in a horizontal plane.

Automatic Shuttles: “The Shuttle Tables allow quick and automatic movement of parts and accessories outside the work area from the sides or from the front of the machine”. This perfect solution allows large, heavy parts to be handled outside the work area. It is also vital in the case of complex configurations.

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Layer Thickness

Every part manufactured using a process of AM is built layer to layer. **Layer thickness** is one of the most important aspects to consider as it varies depending on the parameters that the operator inputs into the machine.

The laser generates a small molten pool typically **0.25-1 mm** in diameter and **0.1-0.5 mm** in depth on the substrate, into which feedstock material (wire or powder, or a combination of both) is injected.

The amount of track overlap is typically **25% of the track width**. Results in re-melting of previously deposited material, and typical layer thickness employed are **0.25-0.5 mm**.

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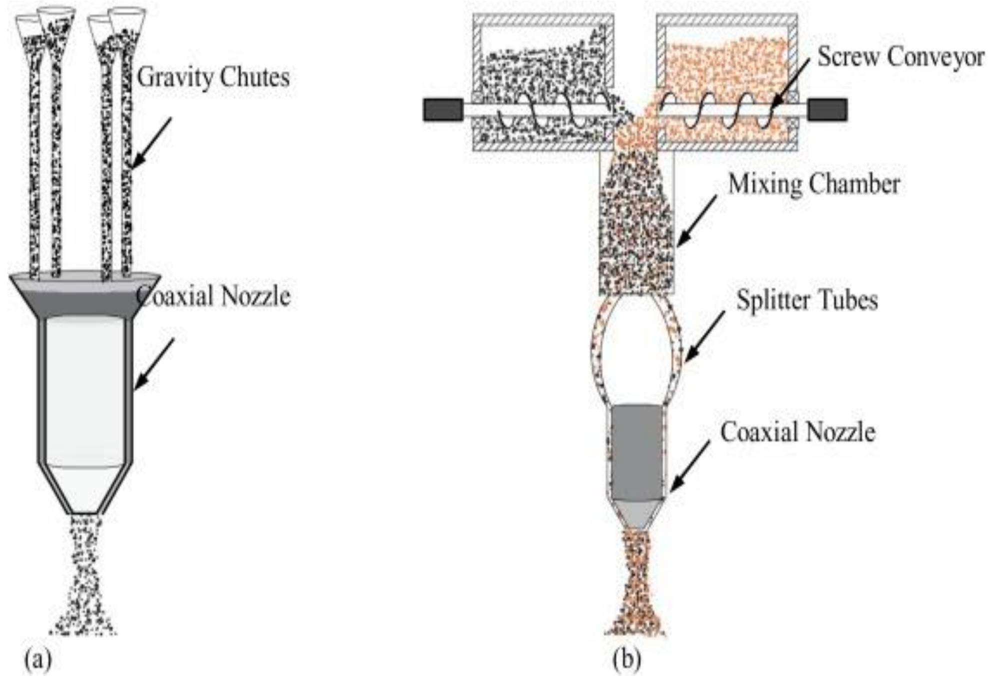
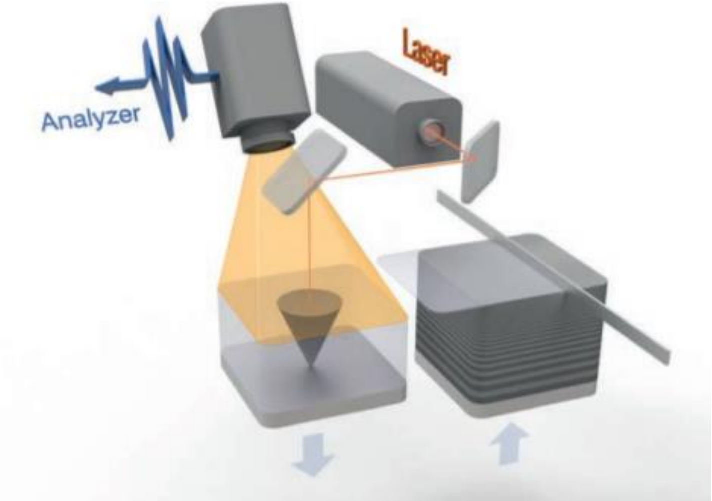
Dosing Factor

Amount of powder needed to properly cover the
Exposure area of each layer without over or under dispensing powder.
The quantity of powder can increase or decrease.

- **Gravity powder conveyance system**
- **Screw for powder metering**

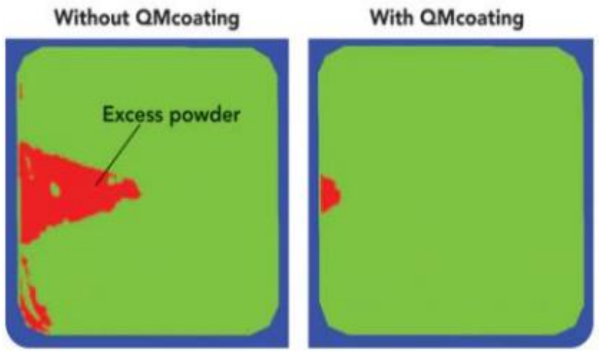


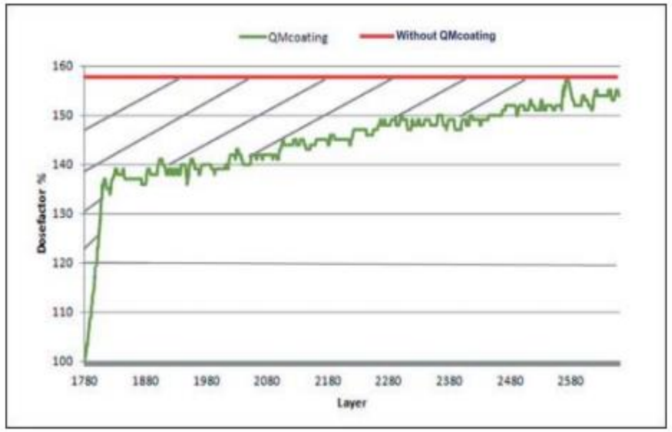
Dosing Factor – Powder Optimization



QM Coating advantages:

- The real-time monitoring of the dosing factor;
- The reduction of setup times;
- The powder savings;
- The guarantee of an optimal coating throughout the entire build process.





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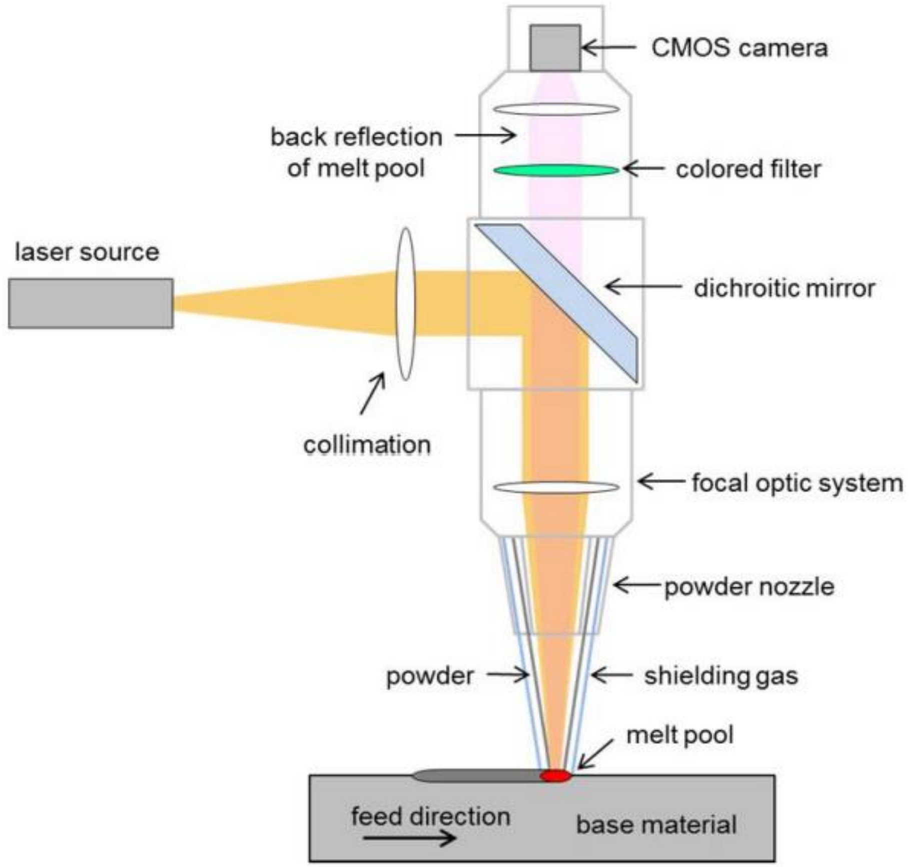
Optical System



- **Laser source** – is responsible for providing the laser beam for the process. There are different types of laser sources currently available (typically between 500 W and 6000 W), each with diverse functional characteristics.
- **Chiller** – normally attached to the laser system, responsible not only for cooling it, but also for cooling other machine components. Deionized water is commonly used as a coolant, and it must be adjusted to circulation system materials, since it can be highly aggressive with some material (ex. Copper).
- **Collimator** – attached to the lased head, responsible for receiving the diverging light from the optical path, and producing a parallel beam, increasing its output quality.

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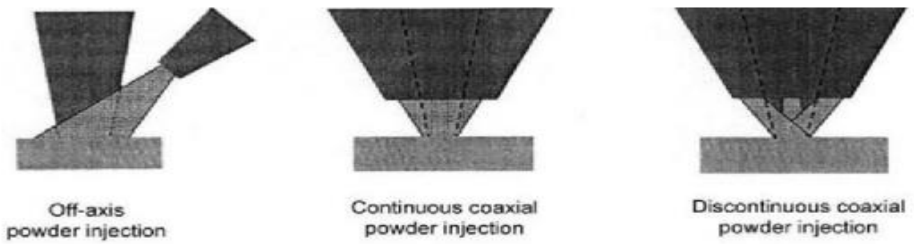
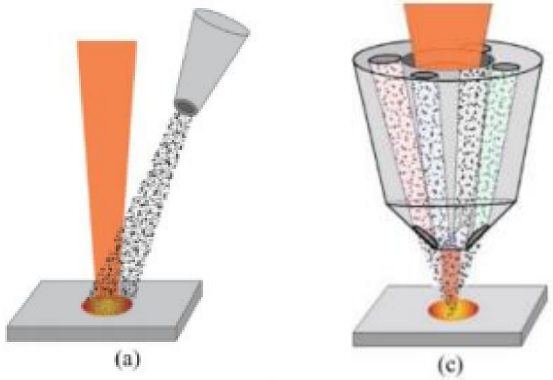
Powder/Wire Feeding System



Powder injection can be done using 3 methods:

- Off-axis powder injection (there is only a single powder stream fed laterally into the laser beam);
- Coaxial continuous powder injection (the powder stream cone is produced and encloses the laser beam);
- Discontinuous coaxial powder injection (the laser beam is fed coaxially by three or more streams of powder).



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Powder/Wire Feeding System

Powder feeding arrangement	Advantages	Disadvantages	Suitable for
Lateral or off-axis 	• Part accessibility • Width of deposited track: 0.5–25 mm • Laser power up to 20 kW maximum	• Directional deposition • Less powder efficiency • Alignment between powder and laser beam • No integrated protective gas feeding	• Directional deposition • Specific requirements in terms of part accessibility
Continuous coaxial 	• Unidirectional deposition • Width of deposited track: 0.3–5 mm • Applied laser power: up to 3 kW maximum • Powder efficiency: maximum 90% (diameter of powder-gas jet in the focus: minimum 400 μm) • Integrated protective gas feeding	• Restricted part accessibility • Gravity influence, no deposition for tilting angles >20 degrees because of inhomogeneous powder density distribution	• 3D deposition up to tilting angles of approximately 20 degrees • Largest effect from integrated protective gas feeding
Discontinuous coaxial 	• Unidirectional deposition • Width of deposited track: 2–7 mm • Applied laser power up to 5 kW maximum • Unrestricted 3D functionality • Integrated protective gas feeding	• Restricted part accessibility • Low powder efficiency (diameter of powder-gas jet in the focus: minimum 2.5 mm)	• 3D deposition up to tilting angles of 180 degrees (overhead processing is feasible)

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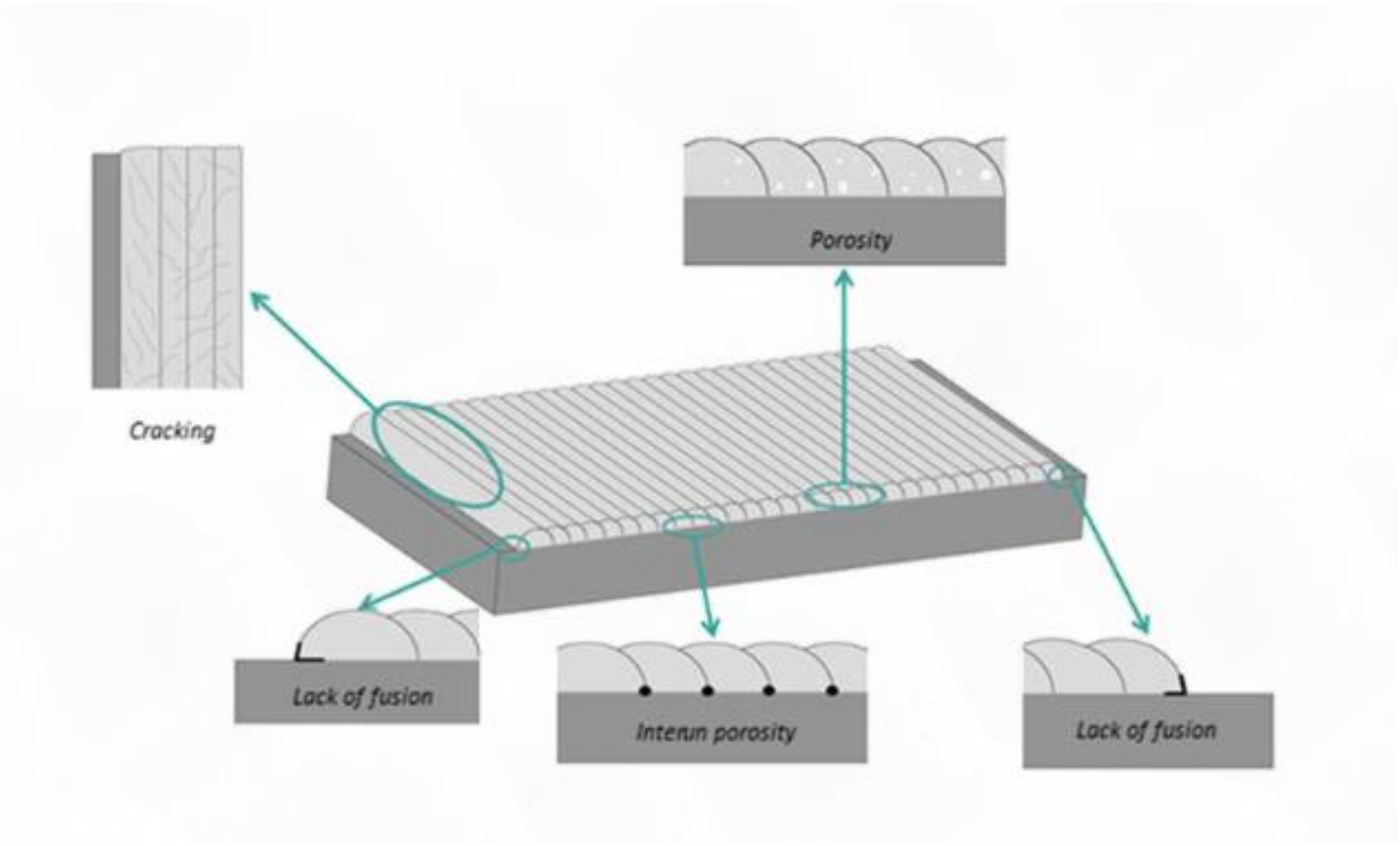
Defects

During deposition a range of defects may occur:

- Porosity
- Lack of Fusion (LoF)
- Cracking
- Residual stress

Some may be mitigated during pre or post-process:

- Parameter/process optimisation
- Post processing



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Defects – Porosity

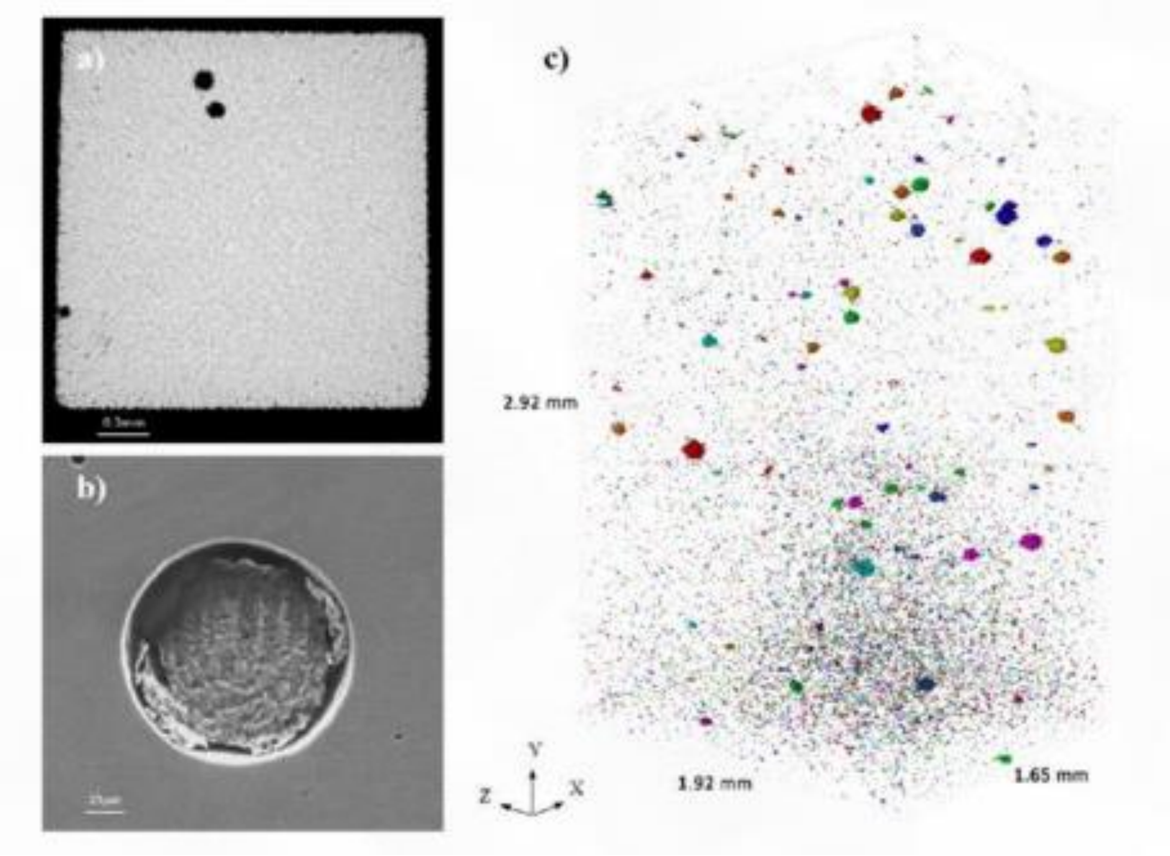
Typically, spherical
Can occur throughout the component

Why does it occur?

- Incorporation of gas contained powder particles
- Over-melting
- Incorporation of process gases
- Poor track stitching

How can we avoid?

- Good quality powder
- Optimisation of parameters
- Melting
- Shielding and delivery gases



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Defects – Lack of Fusion

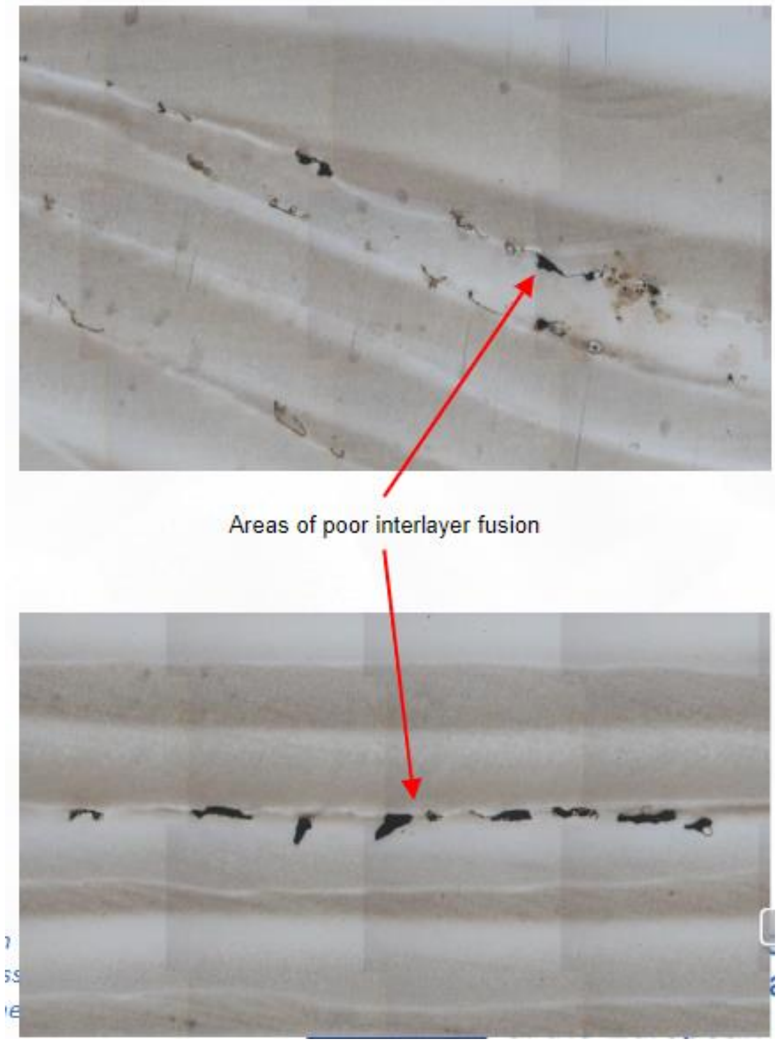
Typically, irregular and non spherical
Occurs between layers or coating substrate interface

Why does it occur?

- Due to insufficient melting of substrate or previous layers
- Oxides can also inhibit fusion (Aluminiumoxides especially)

How can we avoid?

- Increase re-melting depth
- Optimisation of parameters

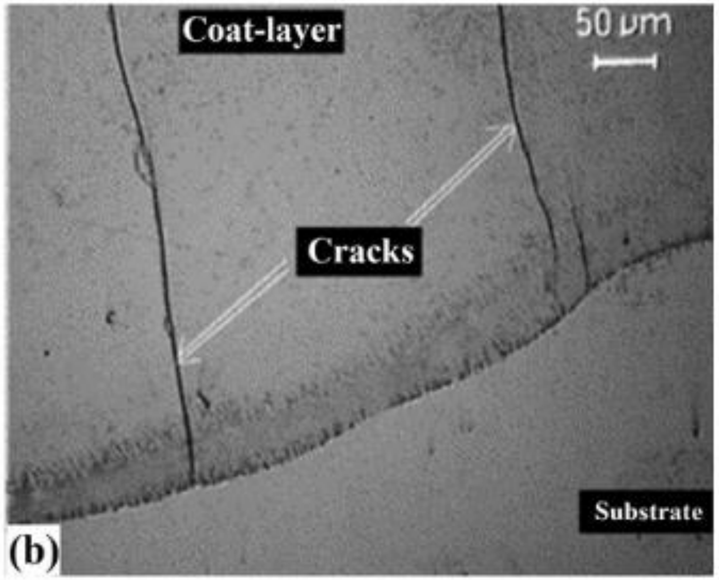


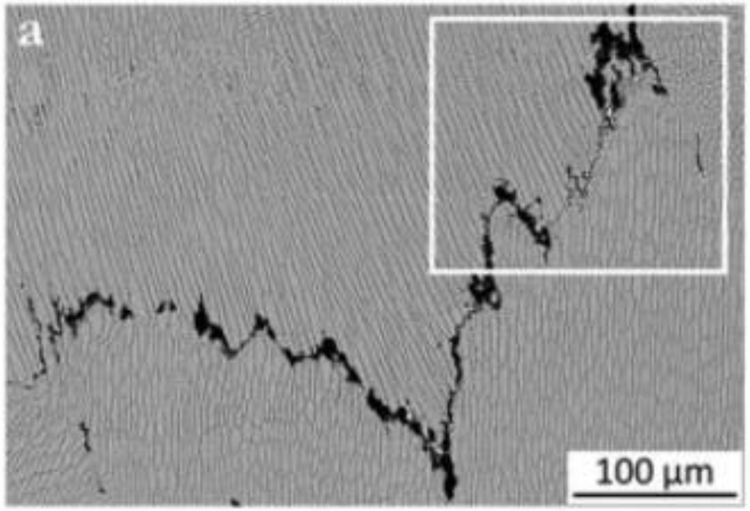
Defects – Cracking

Macro and microscale cracking

Why does it occur?
- Hot tearing
- Liquation cracking
- Differential thermal contractions

How can we avoid?
- Parameter optimisation-aimed at reducing cooling rates
- Pre-heating -aimed at reducing residual stresses
- Buffer layers for thermal property gradation
- Material selection





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Advantages

- High productivity;
- Capability of manufacturing parts with complex geometries
- Capability of creating a surface layer to improve the surface’s properties
- Wide range of alloys that can be used
- Low impact on substrate’s properties

Disadvantages

- High cost of the necessary equipment;
- Powder material is expensive;
- Design freedom more limited than Powder Bed Fusion;
- The need to have post-processing steps to obtain good surface rectilinearity

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Checklist – On successful completion of this module a student should be able to:

- Describe the DED–LB systems, including the components and their functions
- Distinguish different types of feedstock
- Associate the interaction of the process heat source with the feedstock
- Recognise the DED–LB parameters and the influence of their adjustment on the as-built part (e.g., deformation)
- Recognise the characteristics of the DED–LB build platform, feedstock and other consumables
- Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED–LB
- Recognise the basic principles of 3D CAD systems and machine control software

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- Explain how the DED-LB process works
- Explain the influence of modifying process parameters on the as-built part
- Discuss the influence of build platform, feedstock and other consumables characteristics on part manufacturing
- Identify areas that will need thermal compensation
- Identify the cause of defects and propose methods for their mitigation
- Discuss the adequacy of selected equipment and accessories on the part manufacturing
- Distinguish the different regimes and processes of failure and describe the factors controlling them and the boundaries and limits between them

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- Select specific materials for different applications to meet part requirements
- Identify specific metallurgical aspects of DED-LB parts
- Identify the variables used to define the DED-LB manufacturing strategy

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