
Welcome to the

# THE NEXT LEVEL

of Additive Manufacturing.

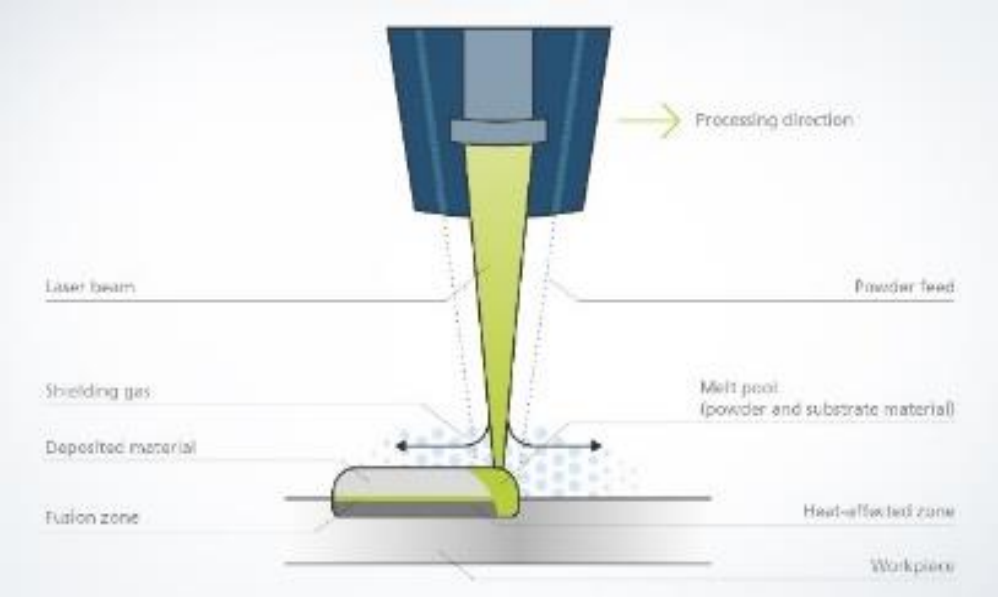
rapid + tct

# The additive manufacturing multitool Laser Metal Deposition – applications from automotive to aerospace

# LMD Overview and Basics



- The Laser beam creates a melt pool on a component surface.
- Powder is feed into the melt pool and liquifies.
- While the nozzle is moved the material cools down due to heat transfer into the component.
- A weld bead with a metallurgical bond to the substrate is created.



# LMD Main Parameter



- The 3 most important process parameter for a high-quality weld are:
  1. **Laser Power**
  2. **Process Speed (velocity)**
  3. **Powder Feed Rate**
- Other parameters are:
  - Shield & Carrier Gas Flow
  - Gas Configuration
  - Beam Size
  - Powder
  - other

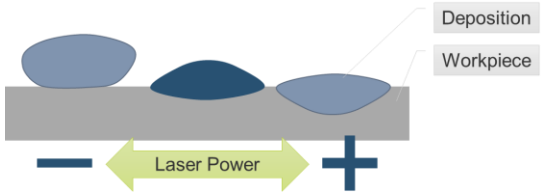

There is always a complex correlation between all parameters

# Parameter Influences



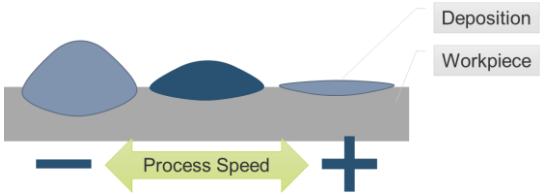
## Laser Power

- Main influence: **melt pool size**, **bead width**, **mixing, heat input**
- too low > bonding & fusion issues. Risk of delamination!
- too high > high mixing of materials, high heat input



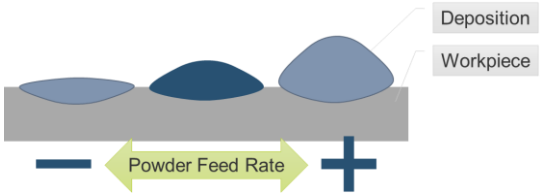

## Process Speed

- Main influence: **deposition height & mixing**
- too low > larger deposition height and increased mixing
- too high > lower deposition height and reduced mixing




## Powder Feed Rate

- Main influence: **deposition height & mixing**
- too low > high mixing and low deposition height
- too high > low mixing and larger deposition height.



# Materials for LMD

| Fe / Steels | Ni | Co | Cu /Bronze | Al | Ti | Other |
|---|---|---|---|---|---|---|
| ▪ 316L | ▪ Inconel 625 | ▪ Stellite 21 | ▪ CuAl | ▪ AlSi10 | ▪ Ti-6Al-4V | ▪ WC in Ni |
| ▪ 1.2344 | ▪ Inconel 718 | ▪ Stellite 6 | ▪ CuSn | ▪ AlSi20/30 | ▪ Ti 6246 | ▪ WC in Fe |
| ▪ 1.2365 | ▪ Hastelloy X | ▪ Stellite 12 | ▪ CuNiSi | ▪ AlSi40 | ▪ Ti17 | ▪ TiC in Ni |
| ▪ 1.4435 | ▪ Waspalloy | ▪ Stellite 1 | ▪ CuW | ▪ AlSi10Mg | ▪ TiAl | ▪ TiC in Fe |
| ▪ CPM 3V | ▪ *Rene 41* | ▪… | ▪ CuCrZr | ▪… | ▪… | ▪… |
| ▪ CPM420V | ▪ *Rene N5* | | ▪ GrCop | | | |
| ▪ … | ▪ *Rene 88DT* | | | | | |
| | ▪ … | | | | | |

| Typical Powder Particle Size |
|---|
| **LMD** |
| 15 – 45µm |
| 20 – 53 µm |
| 20 – 63µm |
| ***44 – 106 µm*** * |
| ***45 – 90 µm*** * |
| 53 – 120 µm |
| 53 – 150 µm |

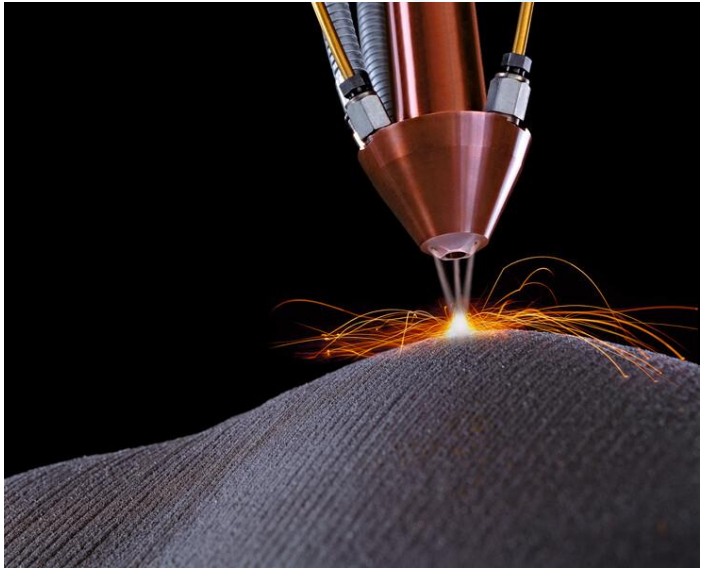
** Recommended size*

- Mechanical properties can be tailored by use of adapted – e.g. in-situ alloyed – metals
- For some alloys pre- and/or posttreatment is needed to achieve max. material properties
- Most common powder grain sizes can be used

# Advantages of LMD

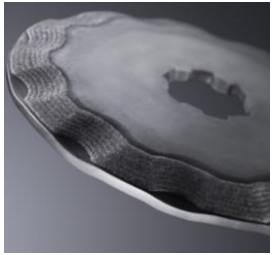


- Good controllable process
- Scalable process
- Precise material deposition
- Low thermal impact on the workpiece
- Low dilution between base and deposition material
- Big variety of available materials and material combinations
- Equipment integration and implementation flexibility

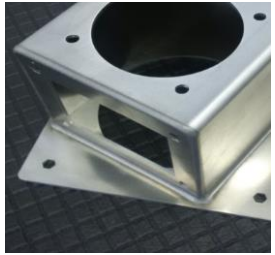


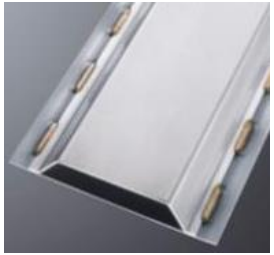
# Main Application Fields

## 1 Cladding



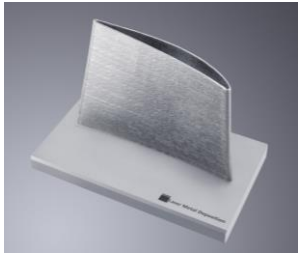
## 2 Joining / Welding





## 3 Repair

## 4 Additive Manufacturing



# Main Application Fields and Examples

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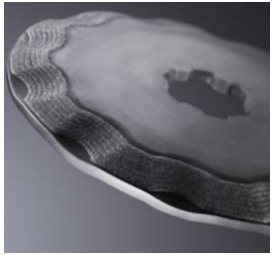

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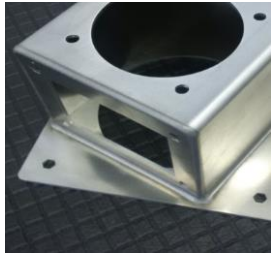

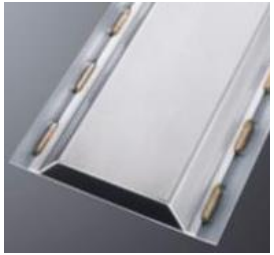

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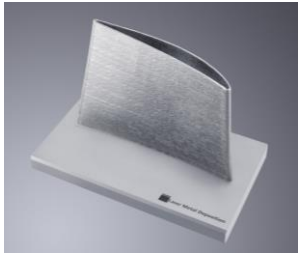
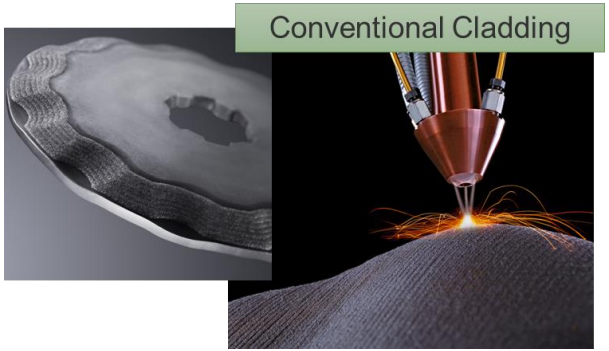


# LMD Application Field - Cladding



- Used for surface functionalization, improvement of corrosion and wear resistance.
- Layer thickness is variable and can easily be adjusted (single layer vs. multi layer depositions).
- Blending of material is possible, and widely used to increase e.g. wear resistance with tungsten carbide.

- Highspeed Laser Metal Deposition / Highspeed Cladding is a process variant to quickly apply layers on parts (alternative to hard chroming or thermal spraying).



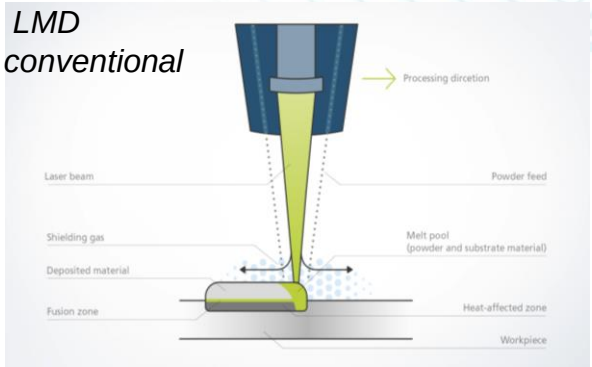

# High Speed Laser Metal Deposition (HS-LMD)

## General Characteristics:

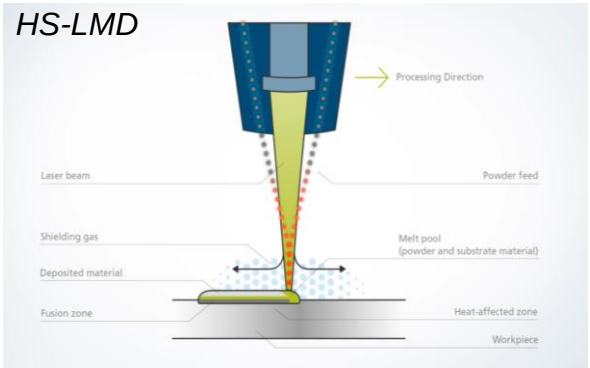
- Most of the laser energy is used for heating up the powder particles instead of the workpiece's surface.
- Powder particles are heated close to its melting point, before touching the workpiece's surface.
- This shortens the needed interaction time of powder, laser beam and melt pool and allows highest process speeds.
- Resulting in small heat affected zone and low dilution.

| Process Values & Results | LMD | HS-LMD | Factor |
|---|---|---|---|
| Process speed | 0,5 - 4 m/min | > 100 m/min | 50 |
| Surface rate | 1 – 100 cm²/min | > 1000 cm²/min | 10 - 1000 |
| Heat affected zone | 500 - 1000 µm | < 10-50 µm | 20 - 100 |
| Possible layer thickness | ≥ 500 µm | 50 - 500 µm | 1 - 10 |
| Surface roughness $R_z$ | 100 - 200 µm | 10 - 20 µm | 10 |

*LMD conventional*




*HS-LMD*

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# Main Application Fields and Examples

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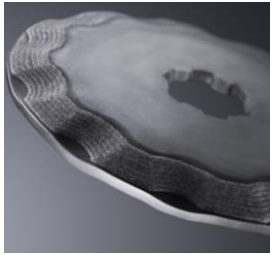

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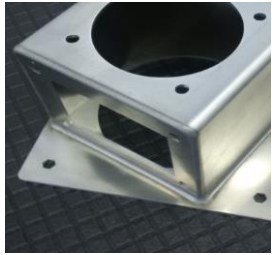

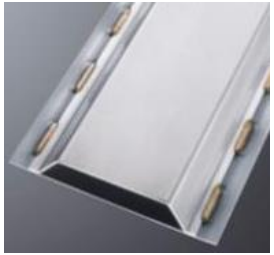

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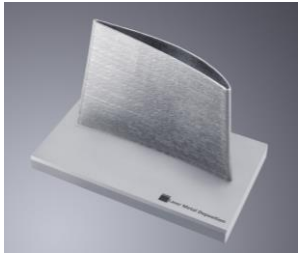
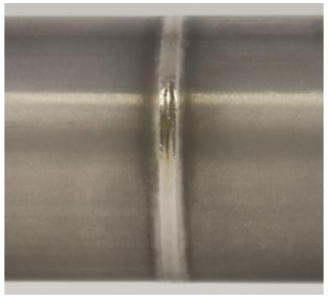
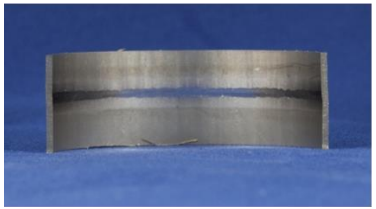
## 4 Additive Manufacturing



# LMD Application Field Joining

- Joining operations with use of powder as filler material.
- Great for:
  - Gap Bridging
  - Dissimilar metal welding
  - 3D Joints
- A joint preparation is crucial for successful welding when full penetration is required.
- Hermetically sealed welds can be accomplished.

Example Titanium Welding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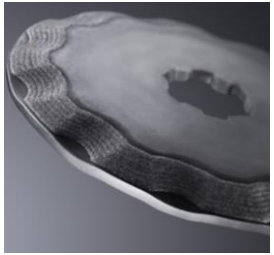

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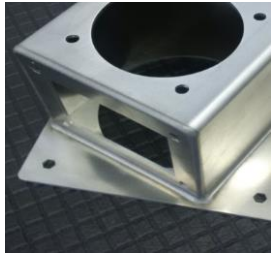

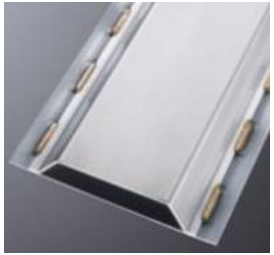

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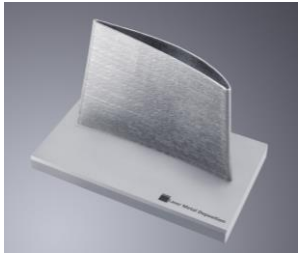


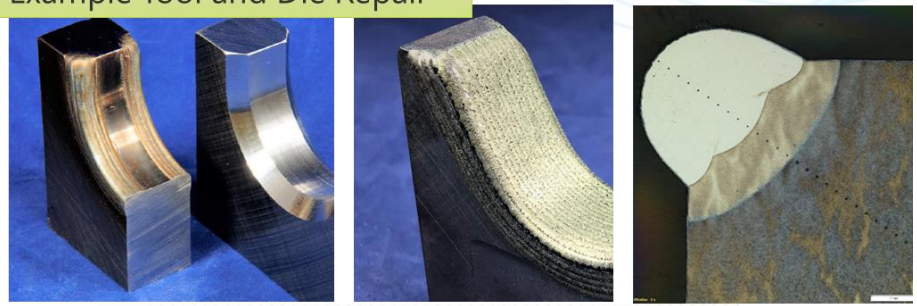
# LMD Application Field - Repair

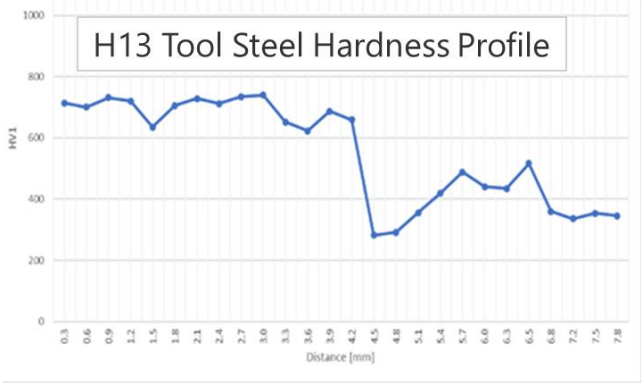
- Refurbishing of worn or defective parts.
- Combining freeform character with the wide material range allows for many possible applications.

Application examples:

- Tool and Die repair
- Blade repair
- Damaged Part Repair with machine integrated 3D Scanner

Example Tool and Die Repair



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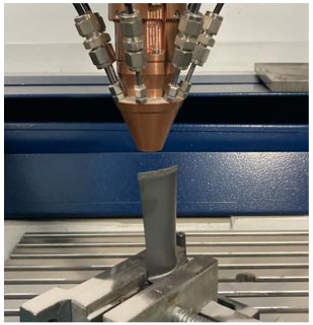
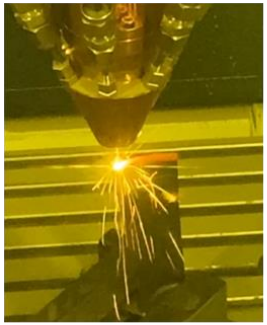
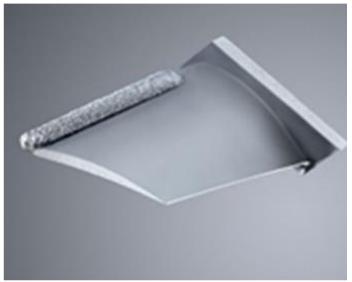
# LMD Application Field - Repair



## Example Blade Tip Repair



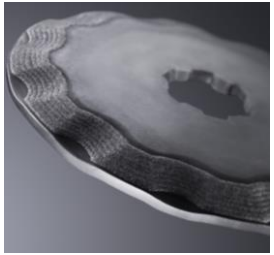




# Main Application Fields and Examples

## Cladding

1

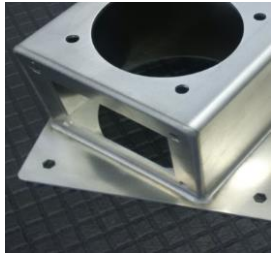


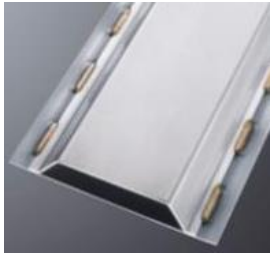
## Repair

3

## Joining / Welding

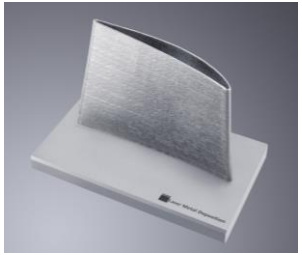
2





## Additive Manufacturing

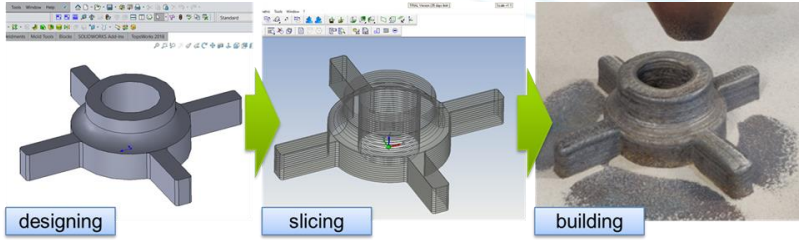
4

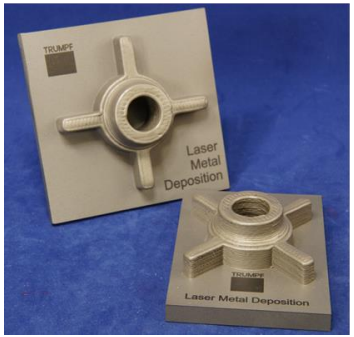


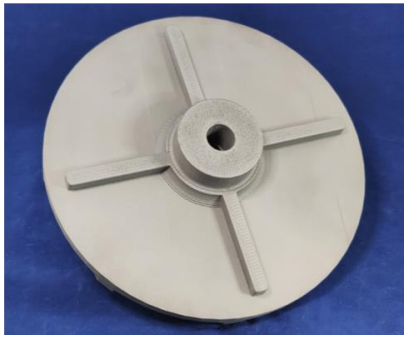
# LMD Application Field Additive Manufacturing

- Good for large scale components with simple shapes.
- A strength of the AM LMD process is adding material to existing components.
- If parameters are within a stable process window, process can easily be scaled.
- Post processing for final finish and mechanical properties might be needed.
- General workflow:

  1-CAD design  2-Slicing and Toolpath Planning 3-Building
- Important for a successful build:
  - Component design (keep it simple)
  - Only support structure is the part itself
  - Stable layer height and
  - Reliable process parameters



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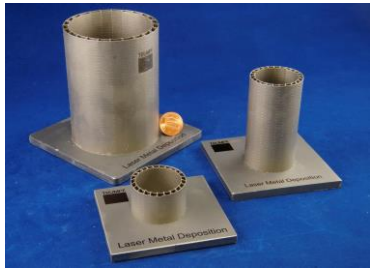
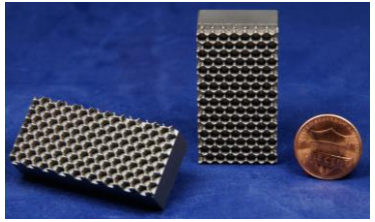
# AM LMD Examples and Build Strategies

## Fast scanning

- Very thin walls -500 µm



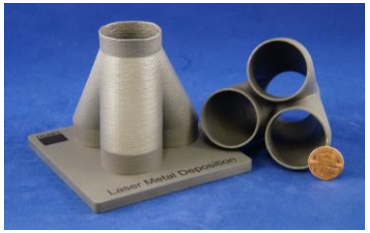



## Continuous Spiral

- Hollow structures with matching spot size and wall thickness

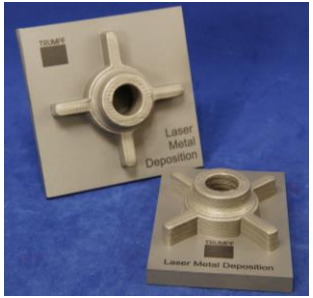
## Single Layer

- Complex hollow structures or wall thickness larger than laser spot size

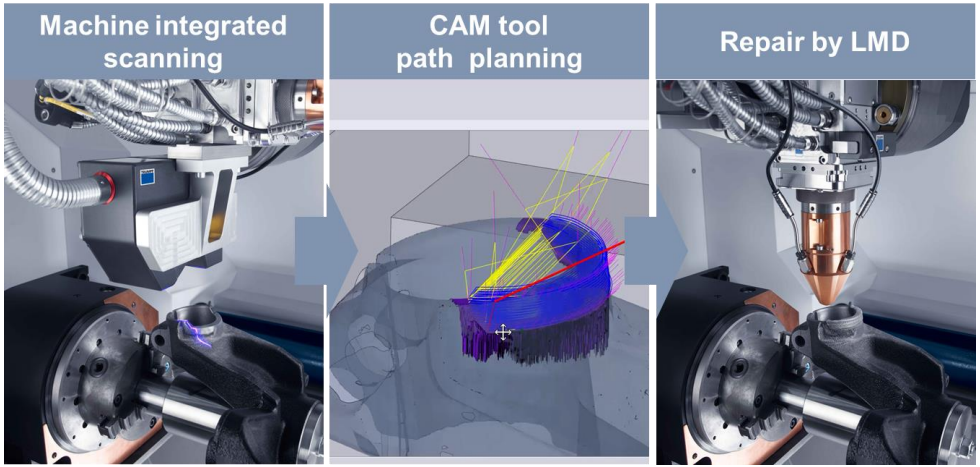


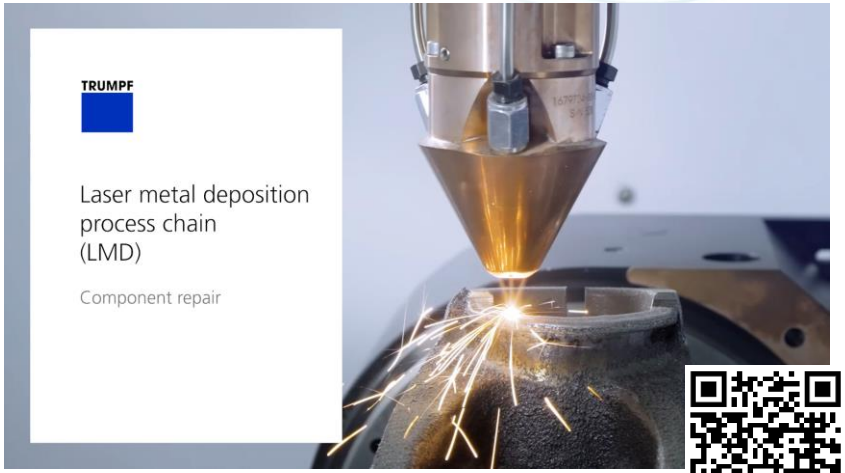

## Filled Single Layer

- Large scale solid parts
- Contouring + Fill



# Machine integrated laser scanner for component repair

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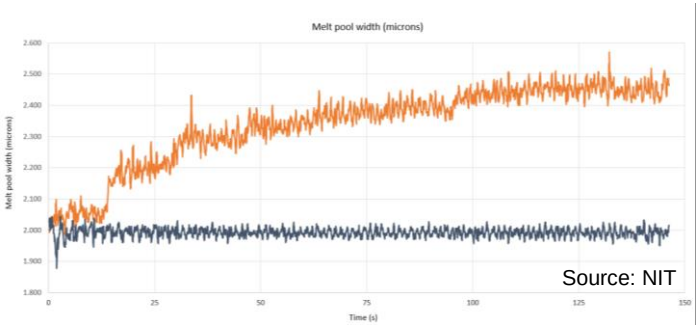
- Adaptive preparation of damaged area by milling
- Digitalization of workpiece with a machine integrated laser scanner
- CAM software tool path planning and simulation
- LMD Repair

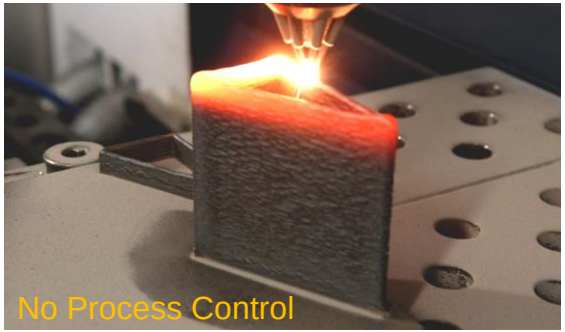
Software solution: lasertools by netvision

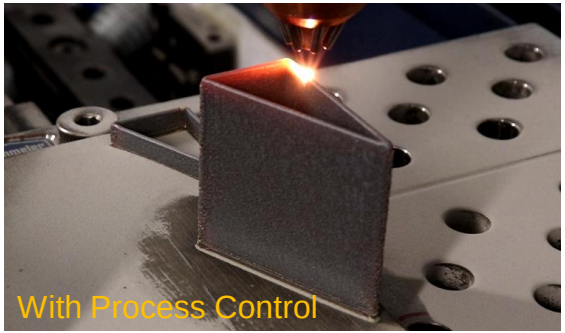
# Process Control Camera for Melt Pool Monitoring

- Closed loop process control
- Real time melt pool monitoring and laser power control
- Reduces part overheating, increases geometrical accuracy and improves surface finish




Melt pool size uncontrolled (orange) vs. melt pool size controlled (blue)



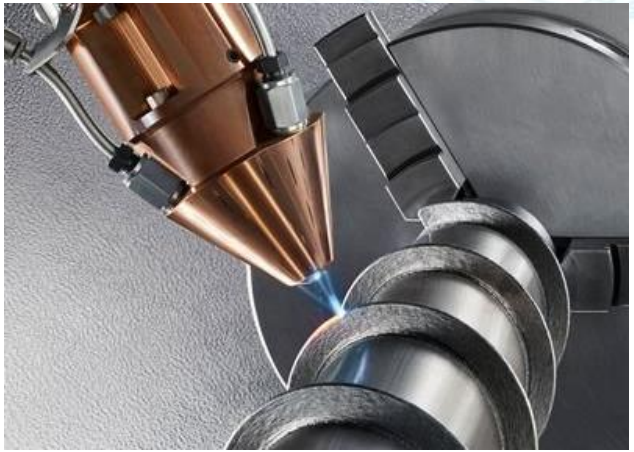





CLAMIR NIT New Infrared Technologies

**Ulli Kraske**
Senior Laser Applications Engineer, TRUMPF Inc.
laser.applications@us.trumpf.com

Thank you for your attention!

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# THANK YOU!

rapid + tct

THE NEXT LEVEL