High Resolution Imaging for Inspection of Laser Beam Melting Systems

Joschka zur Jacobsmühlen\textsuperscript{a)}, Stefan Kleszczynski\textsuperscript{b)}, Dorian Schneider\textsuperscript{a)}, and Gerd Witt\textsuperscript{b)}

\textsuperscript{a)} Institute of Imaging and Computer Vision
RWTH Aachen University
Aachen, Germany

\textsuperscript{b)} Institute for Product Engineering
University of Duisburg-Essen
Duisburg, Germany
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control
What is Laser Beam Melting? An Introduction

- "3D printing"
- Layer-based, iterative (additive manufacturing)
What is Laser Beam Melting? Build Process

1. Powder Deposition
   - X-Y Scanner
   - Laser
   - Inert Gas
   - Powder reservoir
   - Recoater
   - Created part

2. Layer Creation
   - X-Y Scanner
   - Laser
   - Laser window
   - Powder overflow reservoir

3. Lowering
   - Lowerable building platform

Joschka zur Jacobsmühlen
What is Laser Beam Melting? Parts

High density metal parts with excellent mechanical properties

Quality?

Flawless?
Quality Control for Laser Beam Melting Processes

Non-destructive inspection difficult
Can't X-ray thick metal parts!

Inspect each layer after creation
Quality Control for LBM Processes: the Idea

Inspect each layer after creation

all layers correct?
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
  - Setup
  - Resolution Measurement
- Sample Build Images
- Applications in Quality Control
Image Acquisition Setup

LBM machine: EOS EOSINT M 270
Camera

- 29 megapixels, large sensor (36 mm x 24 mm)
  - Usable pixels
- Tilt and shift lens to reduce perspective distortion

Hartblei Macro 4/120
TS Superrotator

SVS-VISTEK
SVCam-hr29050
Resolution Measurement

Assess properties of optical system
Resolution sufficient for small details?

- Use modulation transfer function (MTF): resulting contrast for spatial frequency
Modulation Transfer Function

Magnitude of complex optical transfer function (OTF)

$$\text{DFT } \text{psf}(x) \xrightarrow{\text{OTF}} \text{OTF}(f) = \text{MTF}(f) \cdot \theta(f)$$

(point spread function)

Compute by slanted-edge method [Burns2000, ISO12233]
Resolution Measurement: Target

(neither dark nor bright regions are saturated in full-scale image.)
Resolution Measurement: Result

limiting resolution at least $\xi_0 = 50 \text{ lp/mm} \ [90 \text{ lp/mm}]$ (on sensor) for FOV 180 mm x 120 mm able to resolve details of 50 $\mu$m $[28 \mu$m]
Example Image

Weld Seams: 90 µm

1 pixel: 25...35 µm
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
  - Documentation Format
  - Images
- Applications in Quality Control
High Resolution Imaging for Inspection of Laser Beam Melting Systems

Documentation Format

Many images and associated metadata

Hierarchical Data Format (HDF5)

- Documentation of entire process in one file

[www.hdfgroup.org]
Sample Build

Laser scan velocity

- 20%
- 40%
+ 20%
+ 40%

Laser power

- 20%
- 40%
+ 20%
+ 40%

Hatch distance

- 20%
- 40%
+ 20%
+ 40%

○: Increased energy input
○: Decreased energy input
Sample Build: Hatch Distance

-20 %

+20 %

-40 %

+40 %
Sample Build: Elevation of Contour Regions

Power +40 %

Power -40 %
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control
Applications in Quality Control

Process documentation

Detect and learn from errors

HDF5 file

Cause?
Applications in Quality Control

Detect non-optimal parameter values

Laser power -40 %

Laser power +40 %
Applications in Quality Control

Link surface images to mechanical part properties

(low energy input critical for ultimate tensile strength)

(tensile strength, energy density)
Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control
- Summary
Summary

- What is Laser Beam Melting? An Introduction
  - "print" complex metal parts
  - no complete process documentation, yet

- Our Imaging System
  - MTF for resolution measurement
  - resolution at least 50 µm [28 µm]

- Sample Build Images
  - different surface quality visible in images

- Applications in Quality Control
  - documentation
  - flaw detection: energy input, elevated regions
High Resolution Imaging for Inspection of Laser Beam Melting Systems

Joschka zur Jacobsmühlen\textsuperscript{1)}, Stefan Kleszczynski\textsuperscript{2)}, Dorian Schneider\textsuperscript{1)}, and Gerd Witt\textsuperscript{2)}

1) Institute of Imaging and Computer Vision
   RWTH Aachen University
   Aachen, Germany

2) Institute for Product Engineering
   University of Duisburg-Essen
   Duisburg, Germany
References