Joining Sub-Platform

Industrial trends and demands for Arc Welding in AM Technologies

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3. Study on industrial trends for Arc AM
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Technische Universität Ilmenau - Germany

facts and figures

- founded in 1894
- about 7000 students
- 5 faculties (<100 professors)

Production technology group

Team is consisting of 23 research assistants, 7 technical employes and 1 full professor

Research topics are
- welding of light weight materials, laser material processing
- solid state welding, cladding and chipping (milling and turning)
- additive manufacturing (plastics as well as metals)
Motivation for Additive Manufacturing

Limits of conventional Production Technologies

- Complexity
- Light weight construction
- Undercuts
- Individualization

Additive Manufacturing as an enabling Technology
Study on potentials and development

Technische Universität Ilmenau was appointed from German welding society (DVS e.V.) to perform a study and to depict potentials and research topics for arc based additiv manufacturing

Start in September 2017
End in December 2017

Study is divided in
- a part regarding depicting of the development and state of the art (printed media, internet etc.)
- a part performing interviews with experts in Germany (20-25)
Arc Technologies for AM

Wire Arc Additive Manufacturing (WAAM)
- GMAW and TIG processes
- feeding of wire
- low priced technical setup
- Deposition rates up to 5 kg/h and over
- little material loss compared to powder based technologies

Plasma Deposition Manufacturing (PDM)
- Plasma and μ-Plasma processes
- feeding of powder or wire
- Deposition rates up to 10 kg/h
- Powder availability and over spray
Arc Technologies for AM

Number of Publications for Arc AM
(Database Elsevier / ScienceDirect)

Number of Publications

Year


Increase by Factor 10 since 2010

[Elsevier Oct. 2017]

2018 Forecast
Arc Technologies for AM

Content of Publications for Arc AM

- **Feasibility Studies**
e.g. [Spe98, Zha03, Son05]

- **First attempts with CMT (Fronius) ColdArc (EWM)**

- **Materials, Parameters, Properties**
e.g. [Wan04, Cla08, Alm10, Bau11, Wag13, Wan16]

- **Process Control**
e.g. [Bon11, Xio14, Xio16]

- **Process Automation**
e.g. [Din15, Din16, Din17]
## Arc Technologies for AM

### Examples of ongoing Projects for Arc AM within the EU

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<tr>
<th>University / Coordinator</th>
<th>Project / Runtime</th>
<th>Content</th>
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<tr>
<td>ESA (European Space Agency) and 26 Academic and Industrial Partners</td>
<td>Project AMAZE 2013 - 2017</td>
<td>AM aiming towards Zero Waste &amp; Efficient Production - New approaches to design, materials, automation, finishing</td>
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<td>University Delft / MX3D, Netherlands</td>
<td>Various projects since 2015</td>
<td>3D printing of various structures and materials with WAAM (bridges, sculptures etc.)</td>
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<td>etc.</td>
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Arc Technologies for AM

Commercially available systems for Arc AM

Mutoh Value Arc MA5000-S1 (2015)
working space - 0,125 m³
Additional subtractive Manufacturing

GEFERTEC GTarc 800-5 (2017)
working space - 0,8 m³
Additional subtractive Manufacturing
Arc Technologies for AM

Industrial applications and markets of Arc AM

"Norsk Titanium to build world’s first industrial-scale aerospace Additive Manufacturing plant in New York"

Aerospace Industry

Energy Industry

Oceanic / Offshore Industry

"Norsk Titanium wins award for ist Rapid Plasma Deposition 3D printing technology"
Interview on Industrial Trends for Arc AM

Survey based on analytic pattern concerning the following topics:

- Potentials of Arc AM
- Industrial Requirements for Arc AM Structures
- Software Integration
- Standardization
- Network Integration in context of Industry 4.0
Interviews on Industrial Trends for Arc AM

Preliminary results of the study (ongoing interviews)

„Why do powder based AM process have a higher popularity compared to Arc AM processes?“

„What are the main potentials of Arc Additive Manufacturing processes?“

Benefits of Powder Additive Manufacturing

- Near Net Shape: 43%
- Availability of Technology: 29%
- Fine Structures: 14%
- No Wire Handling: 14%

Potentials of Arc Additive Manufacturing

- Deposition Rate: 43%
- Large Geometries: 14%
- Handling Benefits: 14%
- Process Efficiency: 29%
Interviews on Industrial Trends for Arc AM

Preliminary Results of the Study (ongoing interviews)

„Please rank the following criterias for Arc AM“

Statements of the interviewed companies:

„...process time is not important due to large parts“

„The most important criteria for Arc AM is the realization of homogeneous mechanical properties.“
Interviews on Industrial Trends for Arc AM

Preliminary Results of the Study (ongoing interviews)

„Which requirements need to be conformed in order to apply Arc AM in your company?“

Industrial Requirements

- Availability of Commercial Arc AM System
- Material Database
- Software (CAD/CAM)
- Availability of Various Materials
- Process Control
Preliminary conclusions

Topics

- Part volume is a benefit
  ➔ machinery / process control

- Material properties and homogeneity of the parts
- Distortion
  ➔ high heat input (compared to laser)
Preliminary conclusions

Way 1: temperature controlled process

\[ t_1 \leq t_2 \leq \ldots \leq t_n \]

- Defined interlayer temperature
- Total time is depending on cooling time
- Higher total processing time
- Microstructure can be modelled over the part

Way 2: time controlled process

\[ T_1 \leq T_2 \leq \ldots \leq T_n \]

- Defined interlayer holding time
- Total time is depending on holding time
- Shorter total processing time
- Microstructure
Cooling or heating?

Material (summarised from literature)

Unalloyed steels
High alloyed steels
Tool steels
...
Ni-Alloys
Ti-Alloys
Al-Alloys
Cu-Alloys

...can be processed, but:

→ size effects (wall thickness, part volume)
→ mass distribution effects

are not fully described!

GMAW processing „tower“
Deposition Rate: 4 kg/h
Material: unalloyed steel (G4Si1)
Preliminary conclusions

Ding et al., (2015), Int. Journal of advanced manufacturing technologies

Robot path

CAD/CAM

Distortion prediction and control

Microstructure prediction
Summary

Process development

- i.e. arc / material interaction, arc set up, material properties

Process control and monitoring

- i.e. temperature, geometry...

Experts' final remark: Reliable technologies and machinery for producing big volume parts with known material properties

CAD/CAM Simulation and modelling (simple and low sensitive)

- i.e. distortion ...
Outlook

Processing Chain of future industrial Additive Manufacturing

Connecting machinery to each other in order to reduce time, data waste

CAD / CAM → Additive Manufacturing

Data → Finishing (e.g. milling)

Data → Heat Treatment

Data → Assembly

Data → Welding

Data → Forming etc.

Simulation (e.g. distortion) → Additive Manufacturing
Thanks for your attention

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<td>Reference</td>
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<tr>
<td>Xio16</td>
<td>Forming appearance control of arc striking and extinguishing area in multi-layer single pass GMAW based additive manufacturing.</td>
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<tr>
<td>Zha03</td>
<td>Fundamental study on plasma deposition manufacturing.</td>
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