Symposium on ADDITIVE MANUFACTURING AND INNOVATIVE TECHNOLOGIES 2018
September 27 – 28, 2018
Museum Arbeitswelt
Wehrgrabengasse 7, 4400 Steyr (AT)
www.addit2018.org

From Continuous Fiber Composite 3D-Printing to Video Enhanced Learning Applications (VELA)

FH-Prof. Mag. DI Dr. Bernhard Heiden, MBA b.heiden@fh-kaernten.at
Hannes Oberlercher BSc MSc h.oberlercher@fh-kaernten.at

Steyr, Museum Arbeitswelt, 28. Sep. 2018, Parallel Session II Material Development I 11:00-12:30

REPUBLIKA SLOVENIJA
SLUŽBA VLADE REPUBLIKE SLOVENIJE ZA RAZVOJ IN EVROPSKO KOHEZIJSKO POLITIKO
Interreg SLOVENIJA - AVSTRIJA
Evropska unija | Evropski sklad za regionalni razvoj
KWF Kärntner Wirtschaftsförderungs Fonds

**„Menschen, die miteinander arbeiten, addieren ihre Potenziale.
Menschen, die füreinander arbeiten, multiplizieren ihre Potenziale“**

Steffen Kirchner

FH-Prof. Mag. DI Dr. Bernhard Heiden, MBA

Professor for Production Engineering

FH-Prof. DI Dr. Roland Willmann

Professor for Industrial Management

FH-Prof. DI Dr. Erich Hartlieb

Degree programm leader Industrial Engineering
Professor für Innovation- und Technologymanagement

Mag. Dr. Petra Hössl

Senior Researcher
Start Up Initiative

Mag. Dr. Patrick Holzmann

Senior Researcher
Start Up Initiative

FH-Kärnten Wirtschaftsingenieurwesen Studiengang WING & IEM

FH-Prof. Dr. Joachim Werner

Professor for Business Adrministration

DI Dr. Josef Tuppinger

Senior Researcher

DI (FH), Mag. (FH) Michael Roth

Scientific Employee

Mag. (FH) Thomas Saier

Scientific Employee

Alexandra Reithofer

Administration

DI Reinhard Tober

Laboratory Engineer
Smartlab

Monika Decleva, BSc

Scientific Employee

Joris Löschnig

Student Staff Member
Smartlab

Tamara Penker

Administration

The CUAS-Interdisciplinary Team for Additive Manufacturing (AM)

FH-Prof. DI Dr. Robert Hauser

Professor for Physics
Head of Mechanical Engineering & Light Weight Construction Studiengang
Focus: Sensors

FH-Prof. Mag. DI Dr. Bernhard Heiden, MBA

Professor for Production Engineering
Focus: Manufacturing

FH-Prof. DI Dr. Franz Riemelmoser, MBA

Professor for Mechanical Engineering
Focus: Light Weight Materials

AM Team:
- Hannes Oberlercher, BSc MSc (FH)
- Bushati Jona

Actual Projects
- MMO3D – Development of a Robot Cell for AM, Interreg
- GENFEROS 4.0 – Qualifizierungsnetz FFG – Spreading of AM-technology knowledge for the industry
- Planned: Metal 3D-Printing for the Industry

Overview

(1) Continuous Fiber Composite 3D-Printing

(2) Video Enhanced Learning Applications (VELA)

(1) PW- Experimental Setup (1)

*

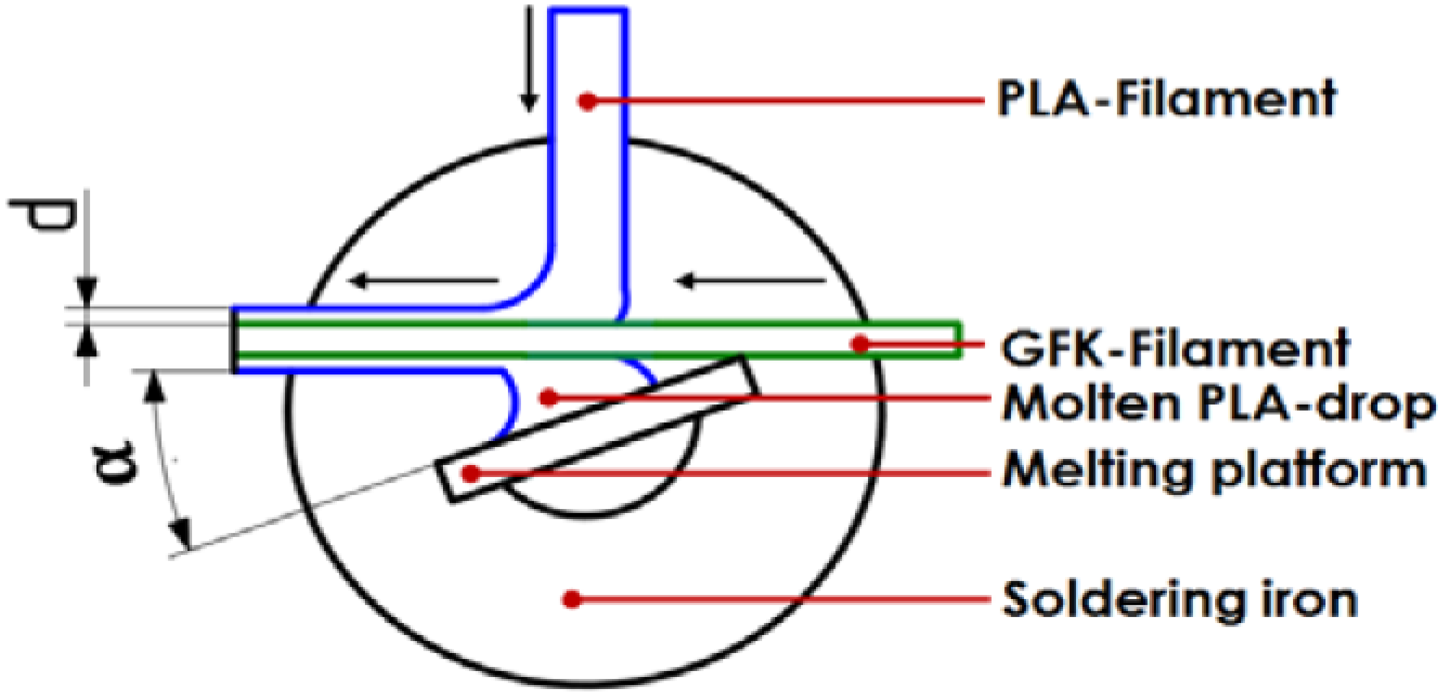


Fig. 1: Coating concept – principal process layout; The GFK-fiber is coated with the PLA-filament with coating

*[LeU16] ,** [HeB17]

(1) PW-Best working concept

*

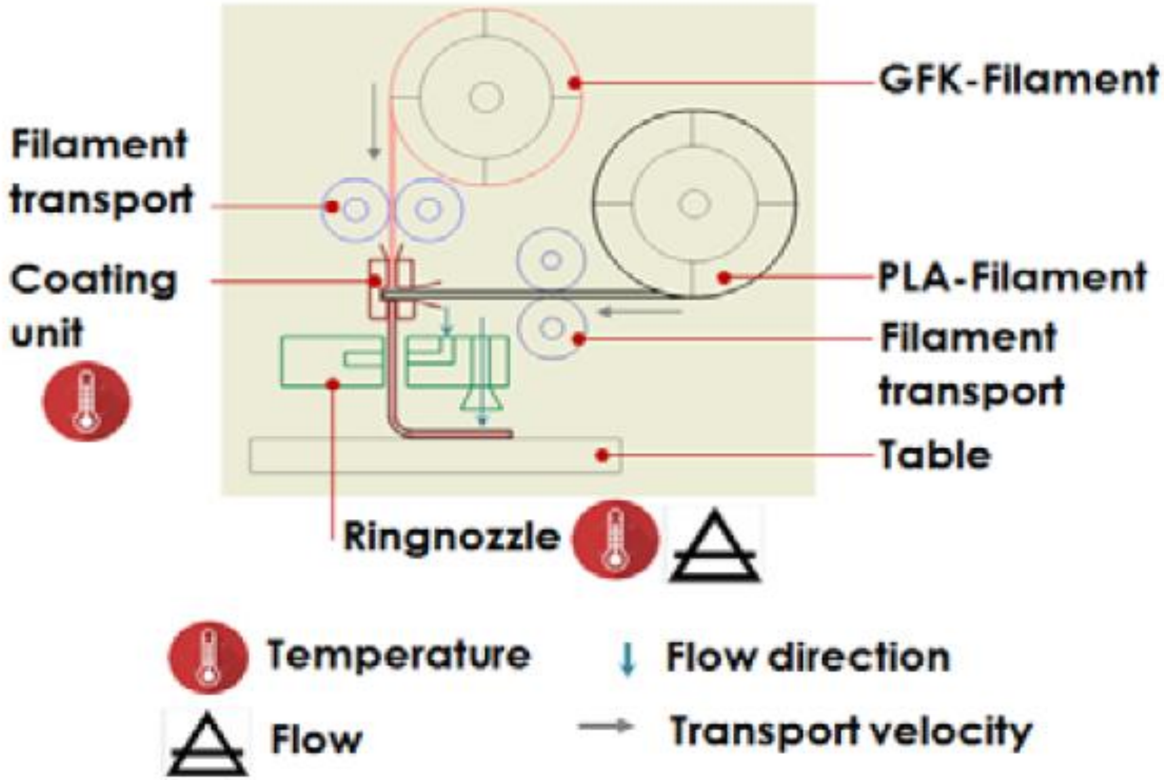


Fig. 2: AM concept for coated fibers *,**

*[LeU16] ,** [HeB17]

(1) MMO3D (1)

Status 2017 – Printing Head Concept:

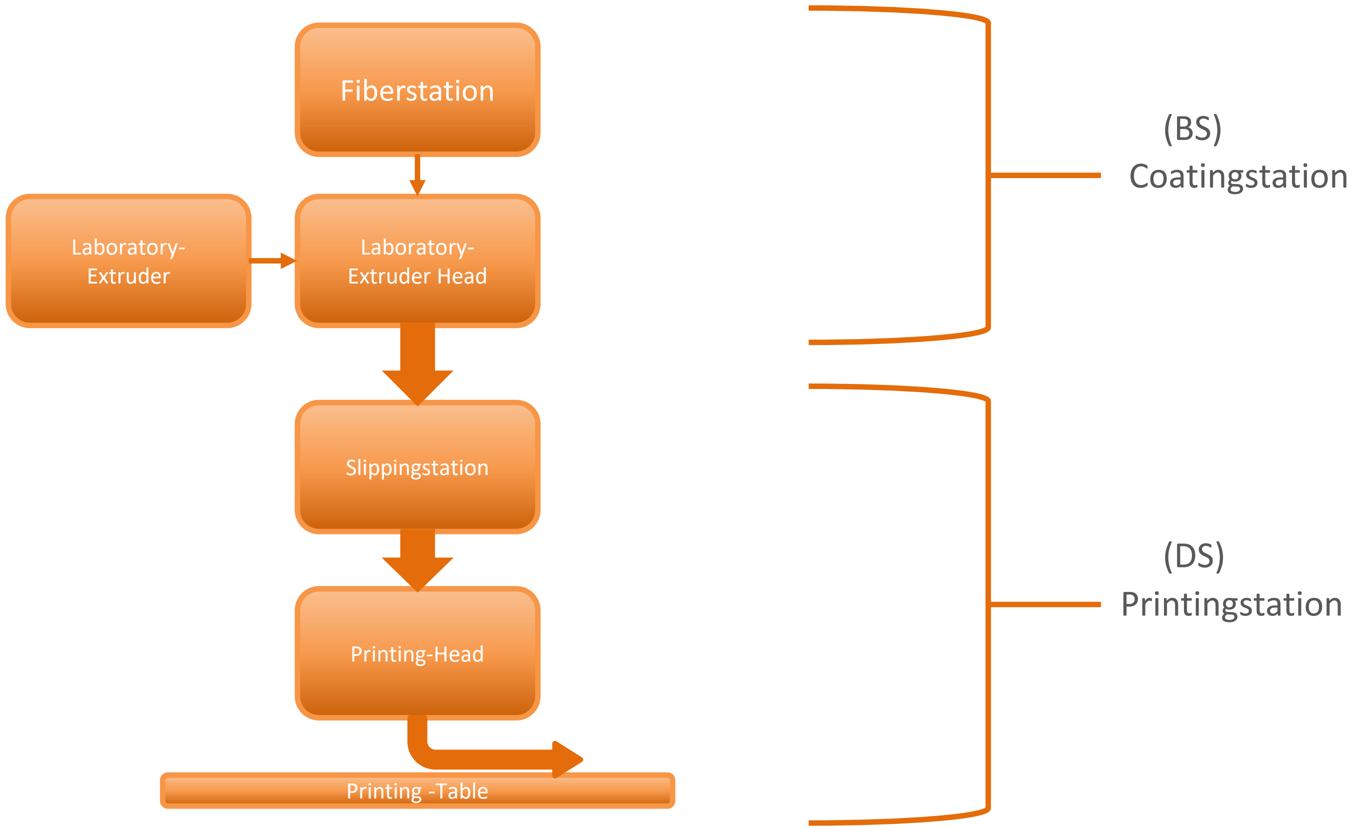


Fig. 3: MMO3D - printing head concept, state September 2017

(1) Project description / consortioum / activities

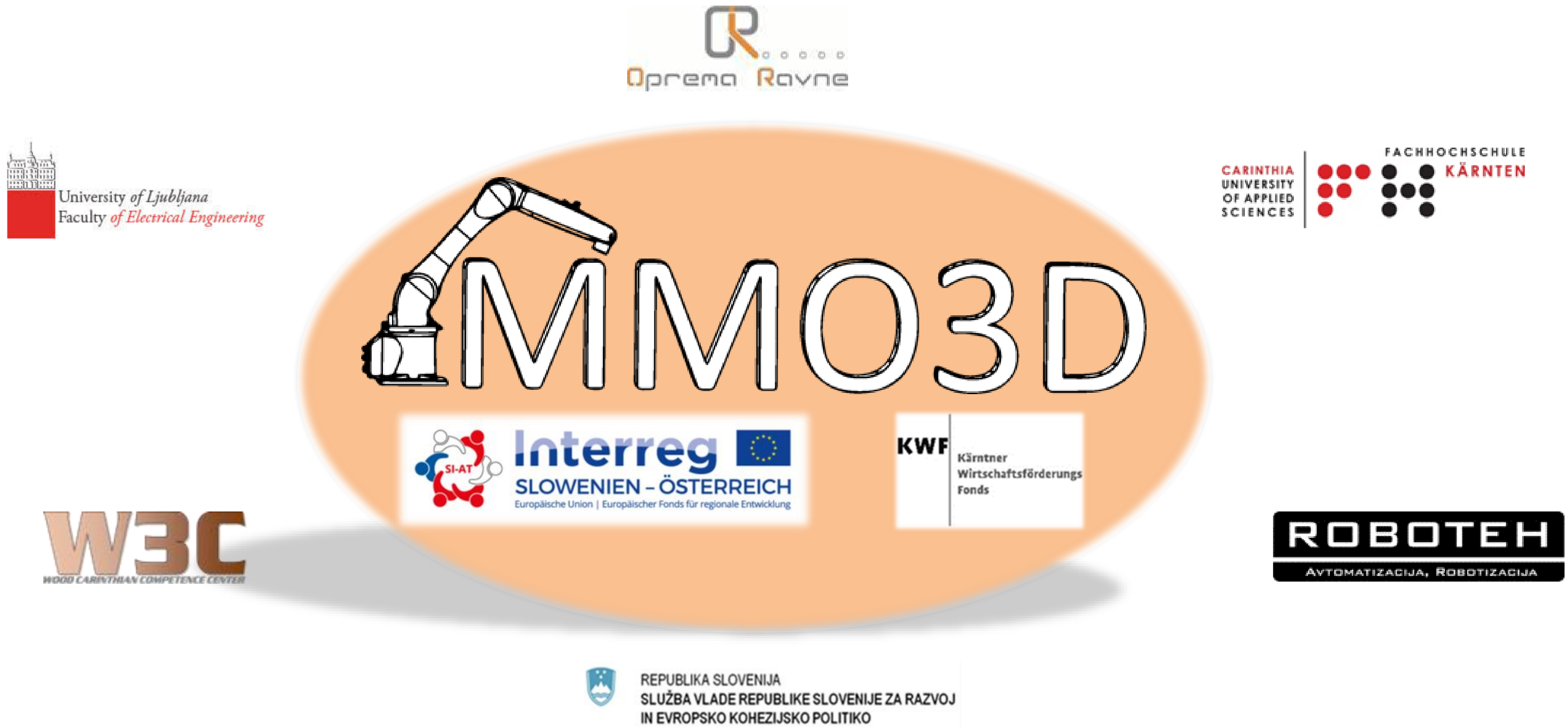


Fig. 4: Consortium for MMO3D

(1) Agenda

- Project goals
- Basics of continuous fiber printing
- Trajectory strategy MarkForged
- FEM-Simulation with continuous fiber
- Testbench MMO3D
- Application concept

(1) Project goals

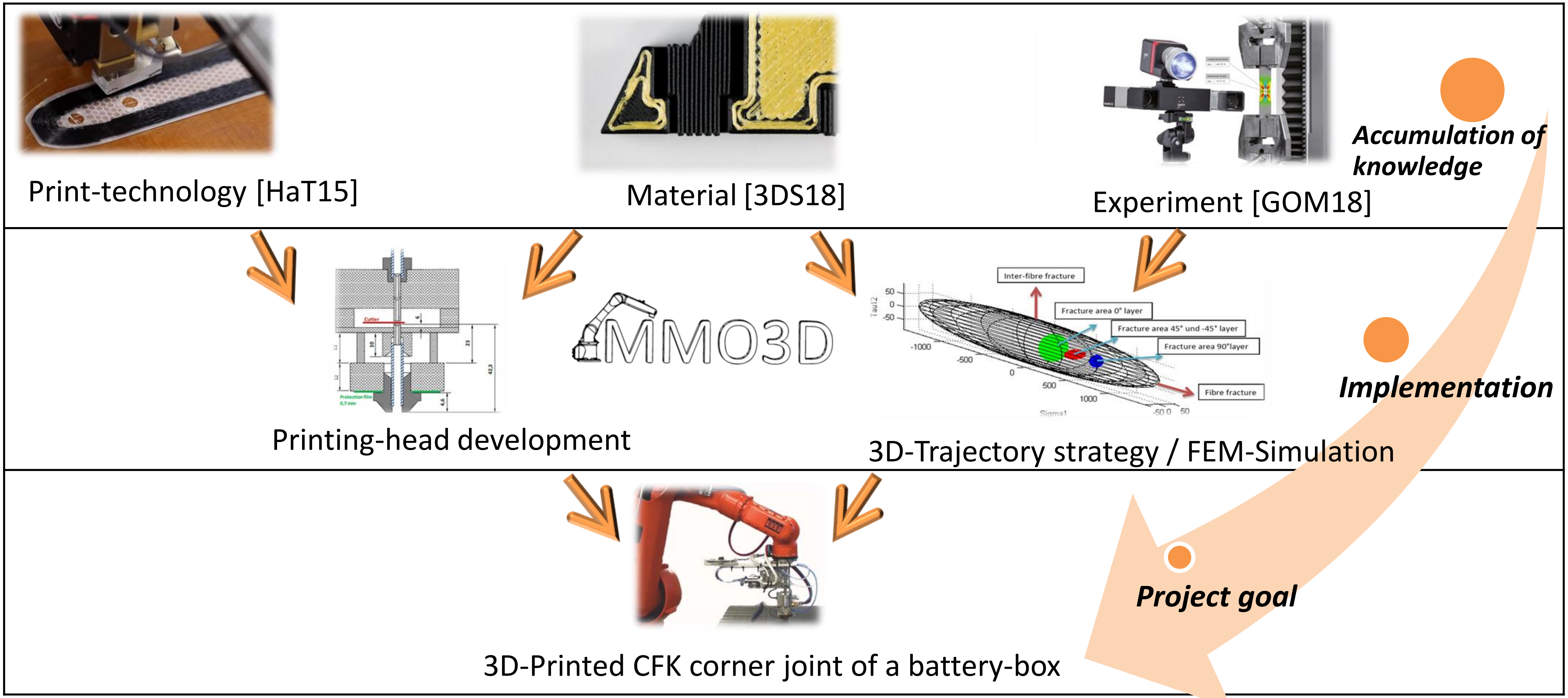


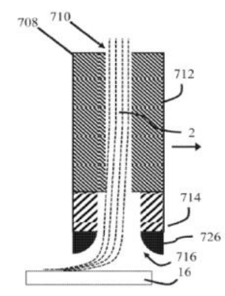
Fig. 5: Project goals for MMO3D

Interreg SLOWENIEN – ÖSTERREICH
REPUBLIKA SLOVENIJA
SLUŽBA VLADE REPUBLIKE SLOVENIJE ZA RAZVOJ IN EVROPSKO KOHEZIJSKO POLITIKO
KWF Kärntner Wirtschaftsförderungs Fonds
Oprema Ravne
Carinthia University of Applied Sciences
ROBOTEH
W3C

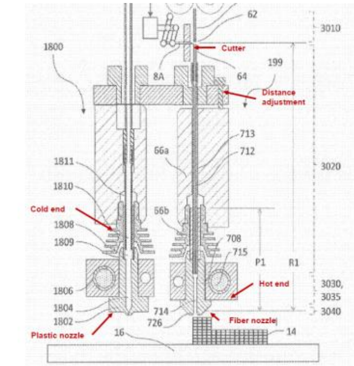
Printing-Head Construction

- A cutting mechanism must be considered
- The filament must be guided through a heated channel, then it exits the nozzle
- The flange of the nozzle flattens the filament and adds the compaction pressure
- A flat section (“flange”) at the nozzle tip to achieve sufficient compaction time (~ 15 mm/s) when the filament is welded to the part surface
- Due to circular symmetry, the nozzle can move and print in any direction, without turning the print head

Nozzle [MaG16a]

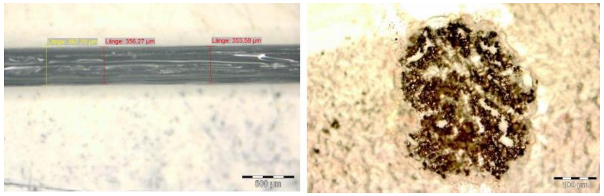


PH MarkOne [MaG16]



Continuous-Fiber-Filament

- Carbon fiber / polyamide
- Diameter of about 0,35 mm
- Fiber volume fraction of about 34 [%]
- 1 K roving (1000 single carbon fibers)



Printing process

- The print speed must be higher than the filament drive speed
- Compaction pressure must be defined by calibration of the distance nozzle to surface

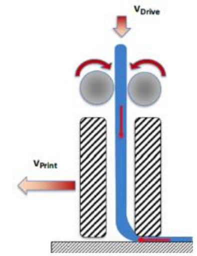


Fig. 6: Basics of continuous fiber printing

(1) Trajectory strategy MarkForged

Printing process and trajectory strategy:

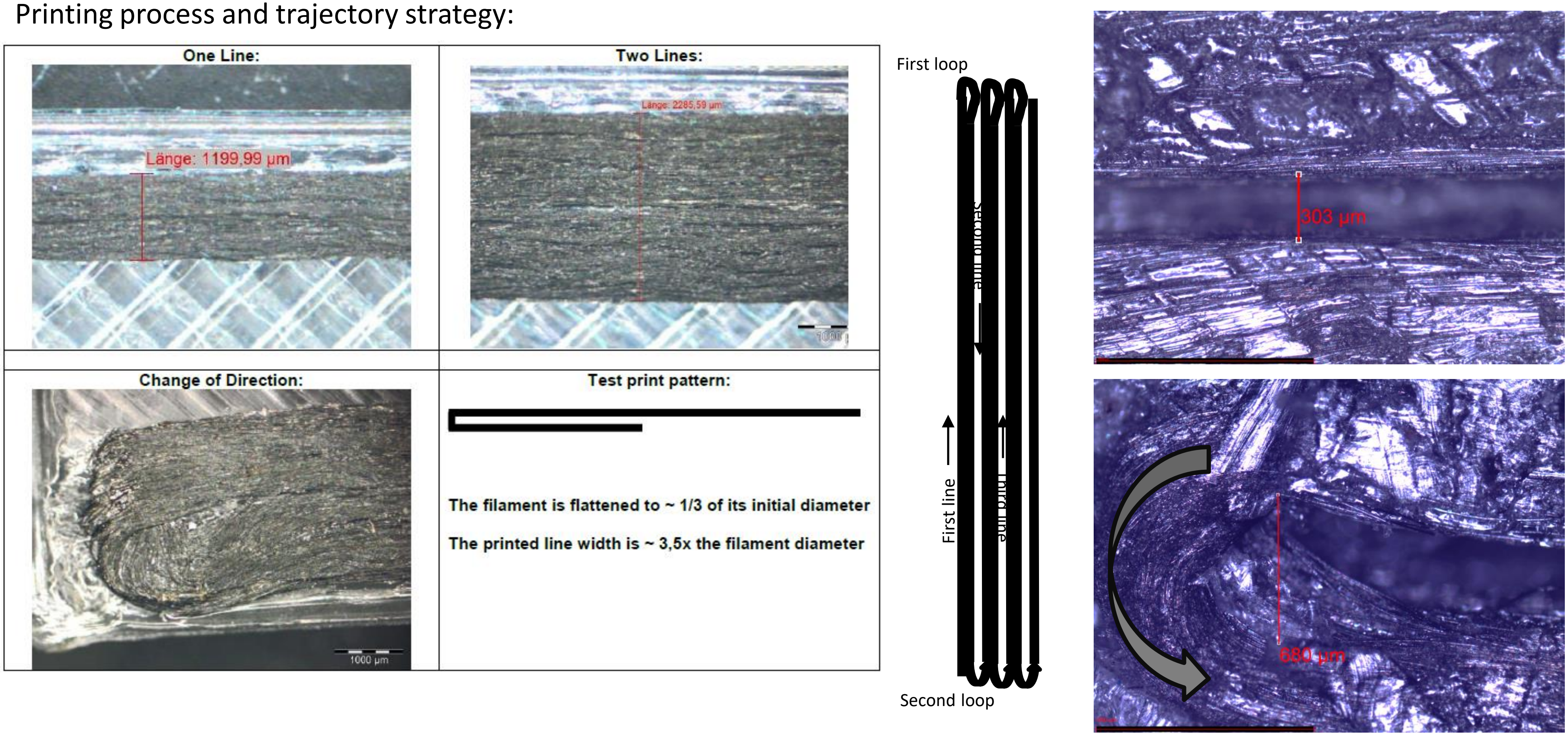


Fig. 7: Printing process and trajectory strategy

Heiden B. & H. Oberlercher, 2018, From Continuous Fiber Composite 3D Printing to Video Enhanced Learning Applications (VELA), Add+iT 2018, www.addit2018.org, Symposium on Additive Manufacturing and Innovative Technologies, Sept. 27.-28. 2018, Museum Arbeitswelt, Steyr, Austria

(1) FEM-Simulation with Continuous Fiber 1

EXPERIMENTAL

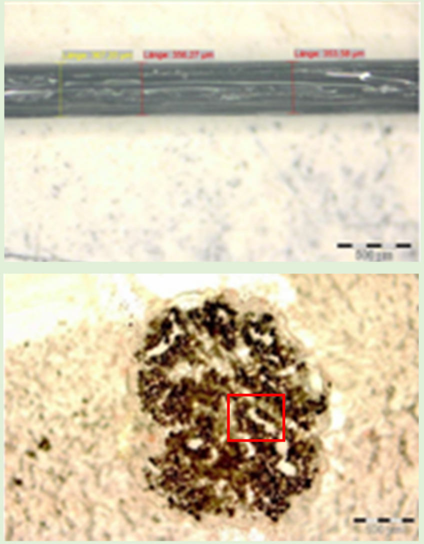


Fig. 8: Cross-section of fibre reinforced 3D-printed component

ANALYTICAL

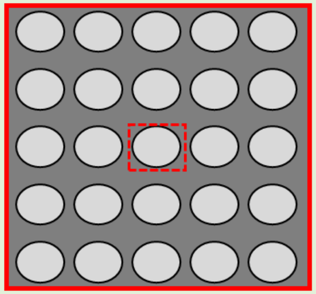


Fig. 9: Idealized fibre square array

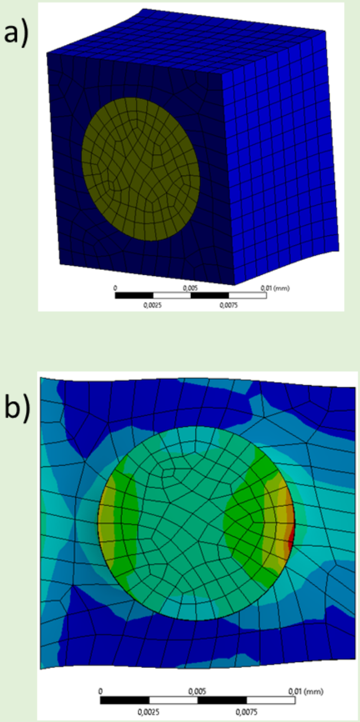


Fig. 10: Unit cells under load
a) longitudinal; b) transversal

(1) FEM-Simulation with Continuous Fiber 2

FACHHOCHSCHULE KÄRNTEN

EXPERIMENTAL approach

- Tensile test of reinforced specimen
- Shear test of reinforced specimen

- Tensile test of matrix material
- Tensile test of fibre material

ANALYTICAL approach

- Obtain material parameters
- Use of (inverse) rule of mixture (IROM/ROM) or Halpin-Tsai
- Calculation of unknown material parameters

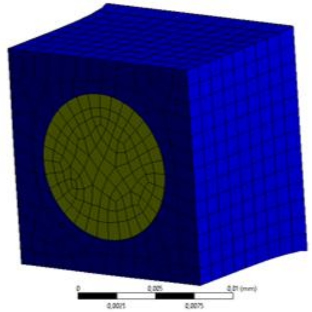


Fig. 11: Longitudinal unit cell under load

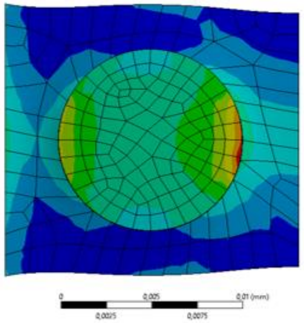


Fig. 12: Transversal unit cell under load

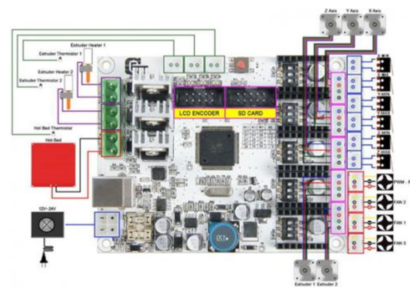
In comparison

Experimental data		Simulation data	
Longitudinal Youngs Modulus	Transversal Youngs Modulus	Longitudinal Youngs Modulus	Transversal Youngs Modulus
25608 MPa	1415 MPa	26096 MPa	4068 MPa

(1) Testbench MMO3D

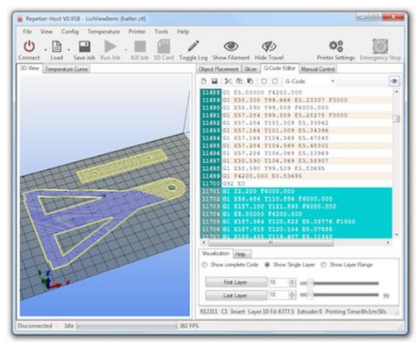
Controller Board

- Designation GT2560
- Controll 2 printing heads (Feeding, Heater, Thermistor,…)
- Controll 3 steppdrives, touch-sensitive switch (X-,Y-,Z-axis)
- Controll 2-3 fans
- Controll 1 servo drive with PWM(Cutter for CFK-fiber)
- Controll 1 Hot-Bed (optional)



Slicer Software

- Generate G-Code
- Manipulation of G-Code for Trajectory path
- Implementing the cutting sequence in the G-Code
- Edit the parameters



Testbench at FH-Kaernten

MMO3D

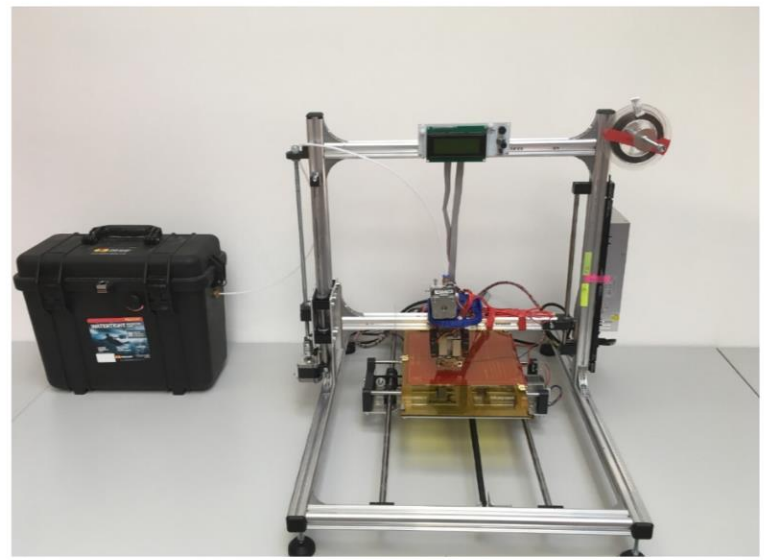
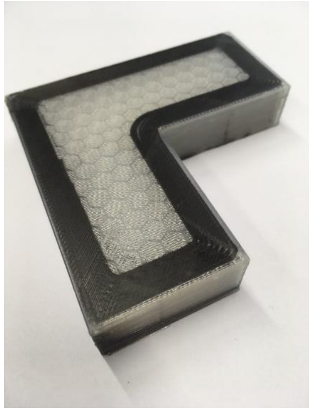


Fig. 13: Testbench for MMO3D printing head at CUAS – October 2018

(1) Application concept of 3D-printed fibers in the MMO3D project

- Concentric orientation of the reinforced fibers allow a derivative of the forces.
- Honeycomb structure for good energy absorption.



- L-profile in housing. Housing protects laminate from impacts.
- Is stuck to the housing.

Concept corner joint

MMO3D

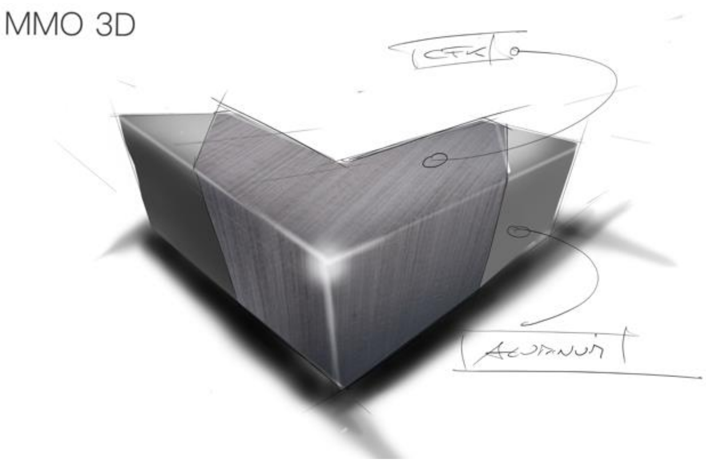


Fig. 14: Application concept of 3D-printed fibers for the reinforcement of edges in the MMO3D project

(2) Video Enhanced Learning Applications (VELA) 1

4th Main Sentence of Thermodynamics*:

Energy Forms have different orders:
→ more ordered Energy Forms can more broadly be used

* Heiden, B. & U. Leitner, Additive Manufacturing – a system theoretic approach (approved) 2018/10/11, Conference ICAT 2018, Maribor, Slovenja [HeB18]

(2) Video Enhanced Learning Applications (VELA) 2

→ AM*
→ VEL**

→leads to democratisation

* Additive Manufacturing
** Video Enhanced Learning

(2) Video Enhanced Learning Applications (VELA) 3

$$E=m*c^2$$

Informationprocessing:
(1)Machining
(2)How to use machine?
→ learning

Materialprocessing:
→Additive Manufacturing (AM)
→ physically building objects

Theorie of Value Enhancement*:

- The more „things“ are connected, the more the value increases

→ **Semantical Density**

→ Information Density=Sum of single information**/Content

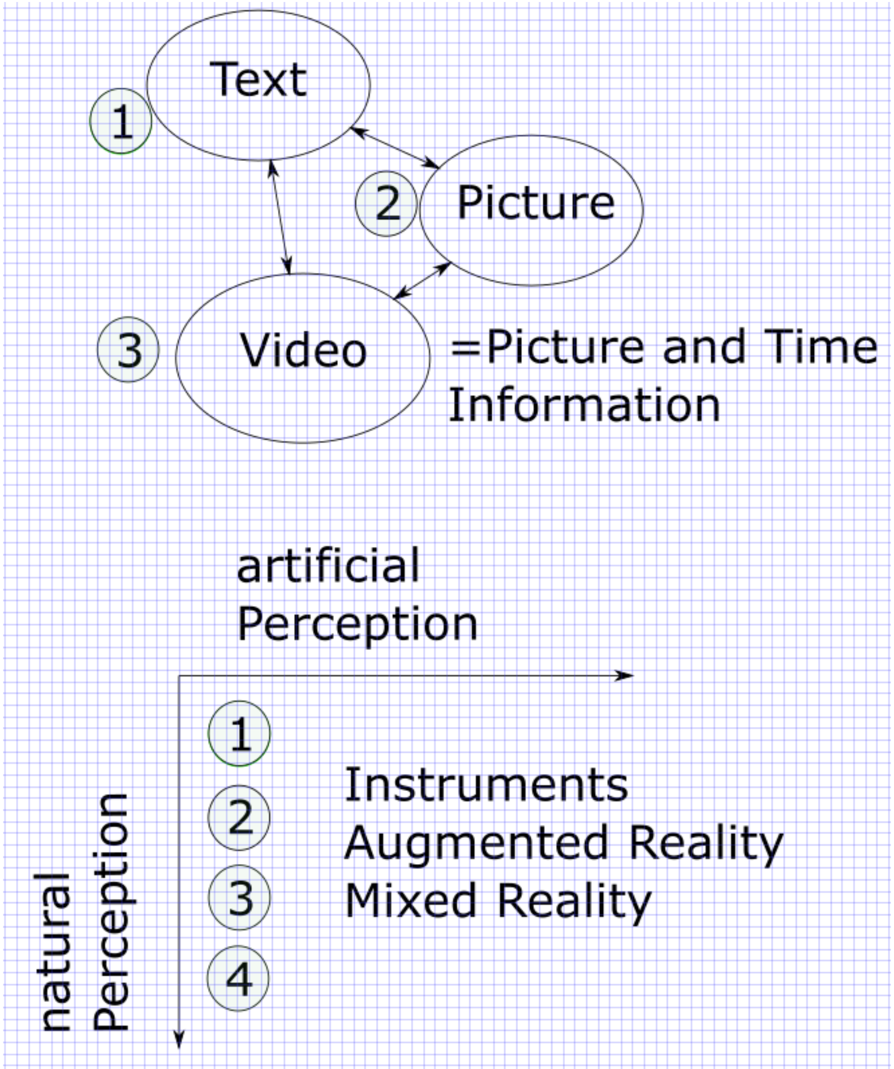
Example: (Perception of Text+Perception of Picture Sequence)/Perception of one Video → the „same“ information can be perceived by different perceptions (redundancy)

→ As it is not exactly the same → new information is generated = value add

* See also [HeB17] ** eg. sum of number of information – in general the sum of a measure of order; in this case the order is „one information **unit**“

/ ... can also refer to the word or meaning „per“

FACHHOCHSCHULE KÄRNTEN



1..4..n: Perception Chanels

Fig. 15: Block diagram structure with couplings for perception chanels and „dimensions" of natural and artificial perception as an indicator for semantical density generation

Heiden B. & H. Oberlercher, 2018, From Continuous Fiber Composite 3D Printing to Video Enhanced Learning Applications (VELA), Add+iT 2018, www.addit2018.org, Symposium on Additive Manufacturing and Innovative Technologies, Sept. 27.-28. 2018, Museum Arbeitswelt, Steyr, Austria

(2) Video Enhanced Learning Applications (VELA) 6

- Polygenferos 4.0 Project:

  → Learning Application for 3D-Printing:

    - EVOTECH
    - FLEX

  → Consideration of the Concept of Video Enhanced Learning to

    - increase semantical density (e.g. timely word insertions)
    - Learn specific content
    - Learn process sequence of AM
    - built in a modular concept

Summary

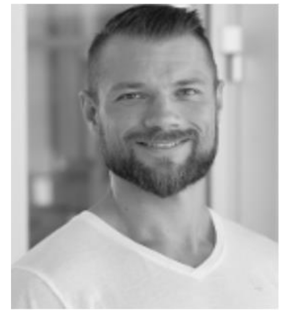
(1) Continuous Fiber Composite 3D-Printing

- Development of a AM method for lightweight applications
- Printing Head Construction
- Testbench at CUAS (Carinthia University of Applied Science)

(2) Video Enhanced Learning Applications (VELA)

- General learning method
- applied to AM technologies and in industrial companies in the field

Herzlichen Dank für die Aufmerksamkeit!



FH-Prof. Mag. DI Dr. Bernhard Heiden MBA & Hannes Oberlercher MSc BSc

Professor for Production Engineering
b.heiden@fh-kaernten.at

Research Assistant
h.oberlercher@fh-kaernten.at

PS.: The presentation you will find soon also at: http://www.dr-heiden.com/Vortraege.htm

Literature AM Recommendation & Presentation 1

[3DS18] 3DSL, 2018, Markforged Mark Two Enterprise 3D Printer, product description, https://www.3dsl.com.au/shop/markforged-mark-two-enterprise-3d-printer/, retrieved 2018/10/02

[HaT15] Halterman TE, 3DPRINT, 2018, 3HTi Signs Deal with MarkForged to Sell the Mark One 3D Printer, https://3dprint.com/45660/3htimarkforged-partnership// publication date 2015/02/15, retrieved 2018/10/02

[HeB16] Heiden B., 2016, Wirtschaftliche Industrie 4.0 Entscheidungen - Mit Beispielen - Praxis der Wertschöpfung, AV Akademikerverlag

[HeB17] Heiden B. & U. Leitner, 2016, Additive Manufacturing with coated materials - First experimental investigations and design considerations, Paper & Presentation, ICAT2016, Nürnberg, Germany

[HeB18] Heiden B. & U. Leitner, 2018, Additive Manufacturing – a system theoretic approach (approved) 2018/10/11, Conference ICAT 2018, Maribor, Slovenia

[GeA14] Gebhardt A., 2014, 3D-Drucken, Grundlagen und Anwendungen des Additive Manufacturing (AM), Carl Hanser Verlag, München

[GOM18] GOM, 2018, ARAMIS 3D Camera, Product Description, https://www.gom.com/de/messsysteme/aramis/aramis-3d-camera.html, retrieved 2018/10/02

[GiI15] Gibson I. et al., 2015, Additive manufacturing technologies, 3D printing, rapid prototyping, and direct digital manufacturing, Springer Verlag

[LeU16] Leitner U., 2016, 3-D Druck von Verbundwerkstoffen - Erstellung eines Prozesskonzeptes für glasfaserverstärkten Kunststoff (GFK), Bachelorthesis, Carinthia University of Applied Sciences, Villach

[MaG16] Mark G.T., Woodruff R. B., Parangi A. L., Benhaim D. S. and B. T. Sklaroff, 2016, Multiaxis fiber reinforcement for 3D printing, US Patent 2016/311165 A1

[MaG16a] Mark G. T. and A. S. Gozdz, 2016, Three dimensional printer with composite filament fabrication, US Patent 2016/0200047 A1

[ZaS17] Zapletal S., 2017, Vorarbeit zur Entwicklung eines MMO Faserverbundwerkstoff 3D Druckkopfes, Bachelorthesis II, Carinthia University of Applied Sciences, Villach, Austria