Coperion Extrusion Days 2018

COMPOUNDING OF WATER SOLUBLE SUPPORT MATERIAL FOR ADDITIVE MANUFACTURING

iwk INSTITUTE FOR MATERIALS TECHNOLOGY AND PLASTICS PROCESSING

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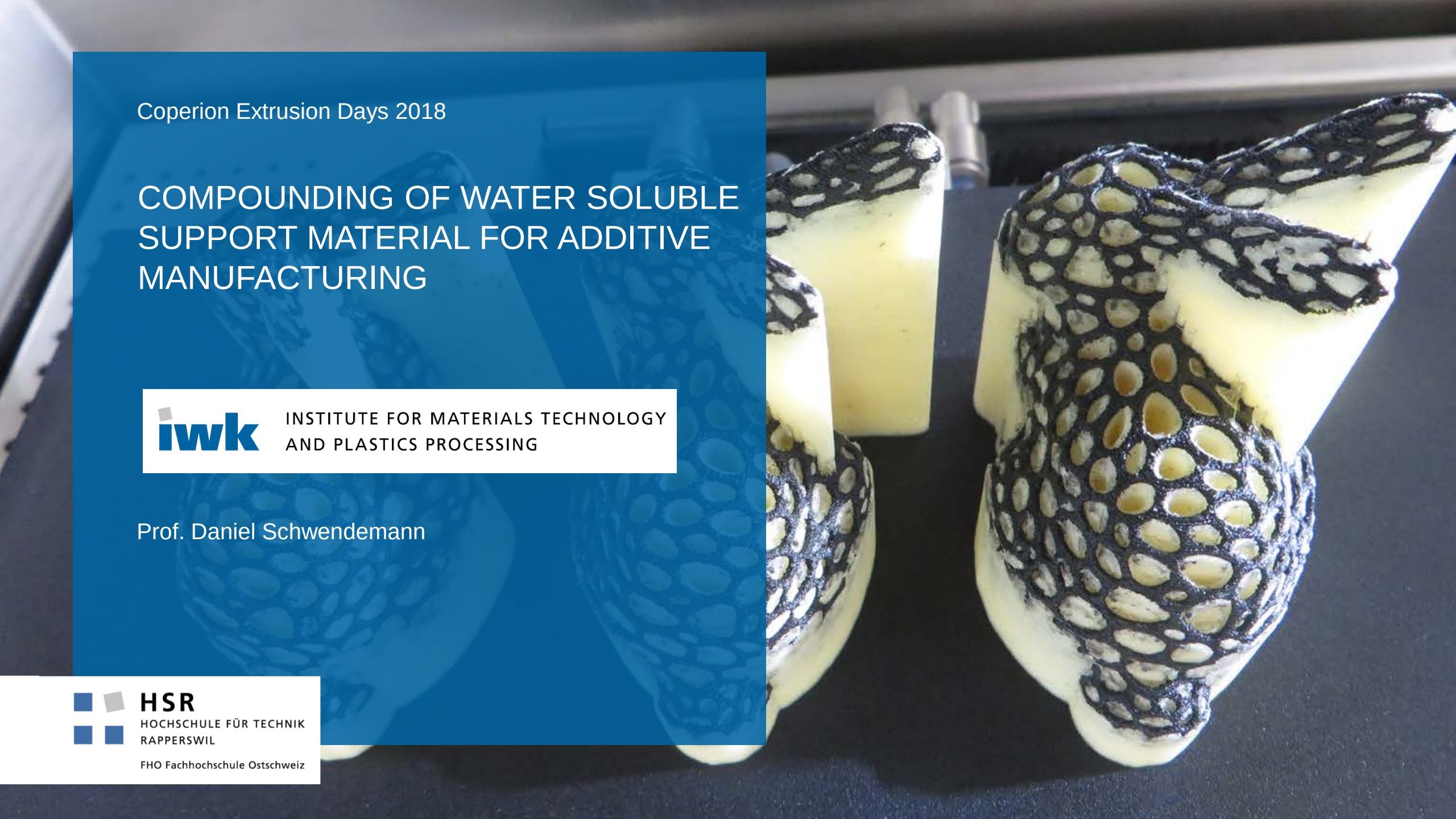
HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL
FHO Fachhochschule Ostschweiz



Outline

- **HSR/ IWK**
- **Additive Manufacturing**
- **FFF (Fused Filament Fabrication)**
- **Compounding**
- **Applications and Results**

University of Applied Sciences Eastern Switzerland
HSR Hochschule für Technik Rapperswil

Introduction IWK: 6 research groups in different fields of innovation

Mechanics/
Kinematics
(2005)

Composites/
Light weight
construction
(2015)

Light weight
construction

Integration of
functions and
processes

Simulation

Hybrid technology

Fields of Innovation

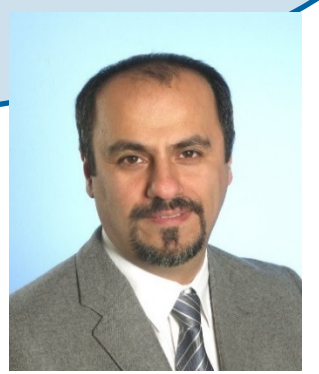
3D Printing/AM

Polymerengineering

Interfaces and surfaces

Injection Moulding/
Polyurethane
(2005)

Biopolymers/
Recycling



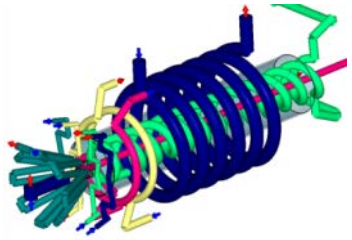
Bonding
technologies
(2015)

Compounding/
Extrusion (2010)

Metal Processing
(2016)

Introduction IWK: Support along the whole value-added chain

Compoundierung

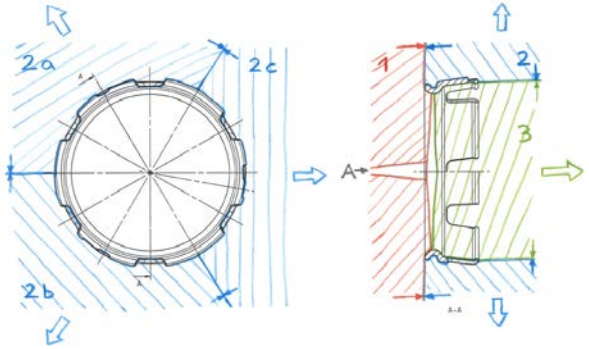


Filling simulation

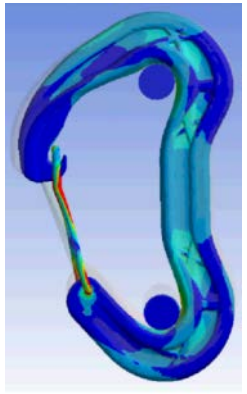
Integration of illumination

Electro leight weight car

Material Development → Part Design → Part Development → Mould Technology → Process Technology → Prototyping Pilot runs → Part Testing

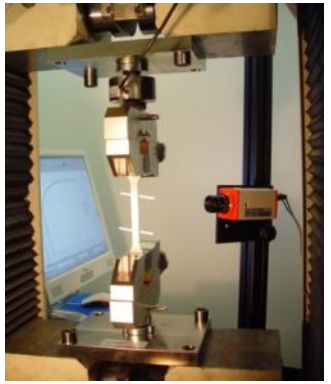


Development of concepts



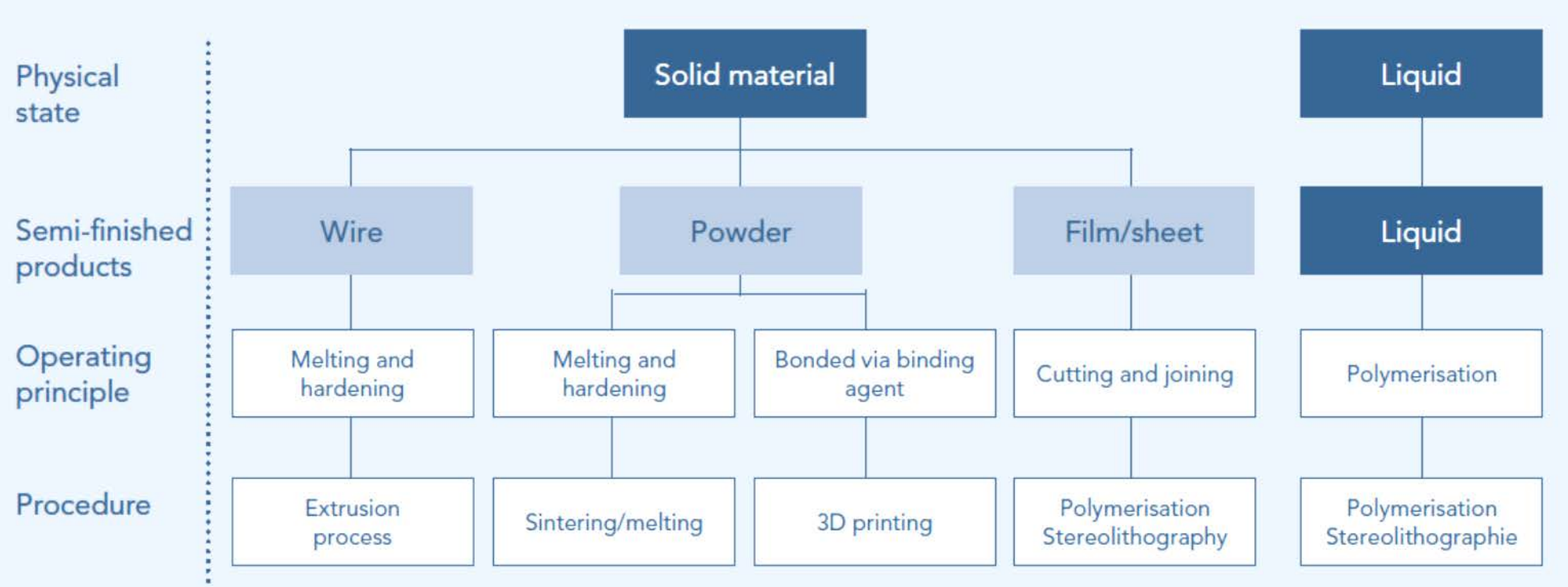
Structural analysis

Special Processes



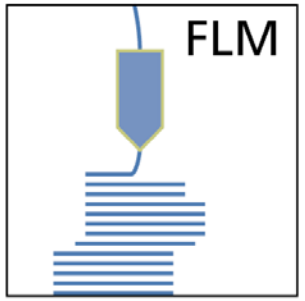
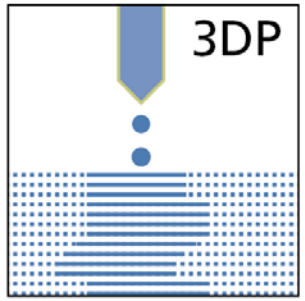
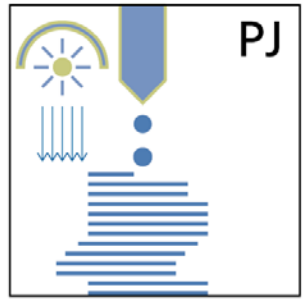
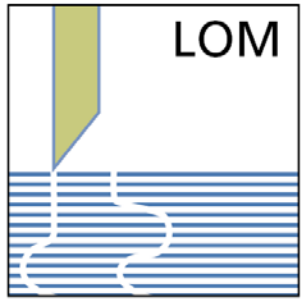
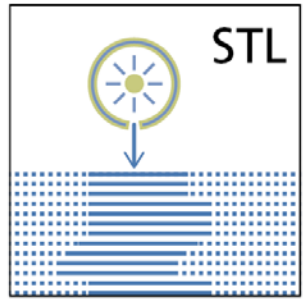
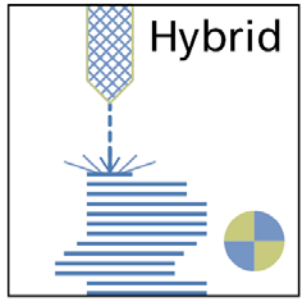
Material parameters

Additive Manufacturing Process Overview

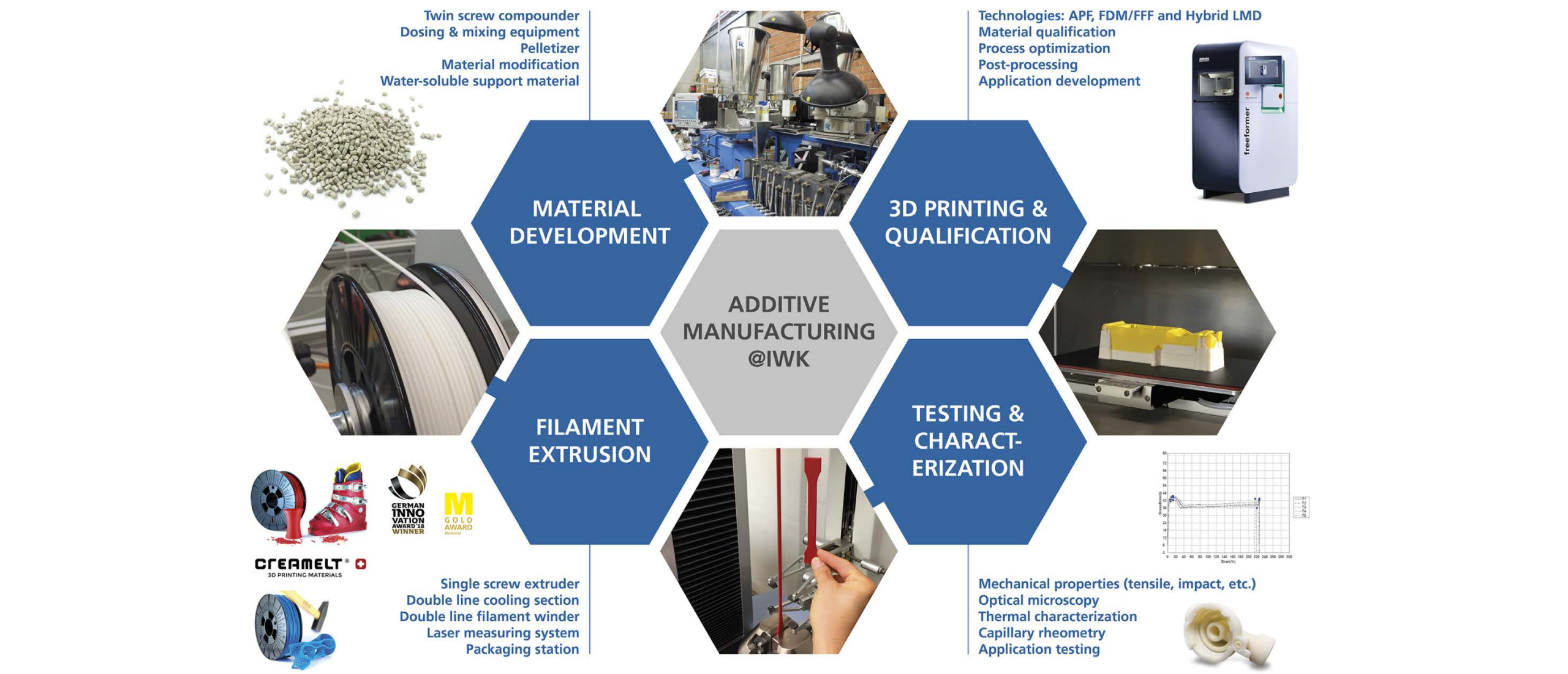


The fundamental principles of additive manufacturing processes (Source: based on: Gebhardt, A.: Generative Fertigungsverfahren: Additive Manufacturing und 3D Drucken für Prototyping – Tooling – Produktion. München, Wien: Carl Hanser Verlag, 4. Auflage, 2013)

Overview of possible additive manufacturing processes

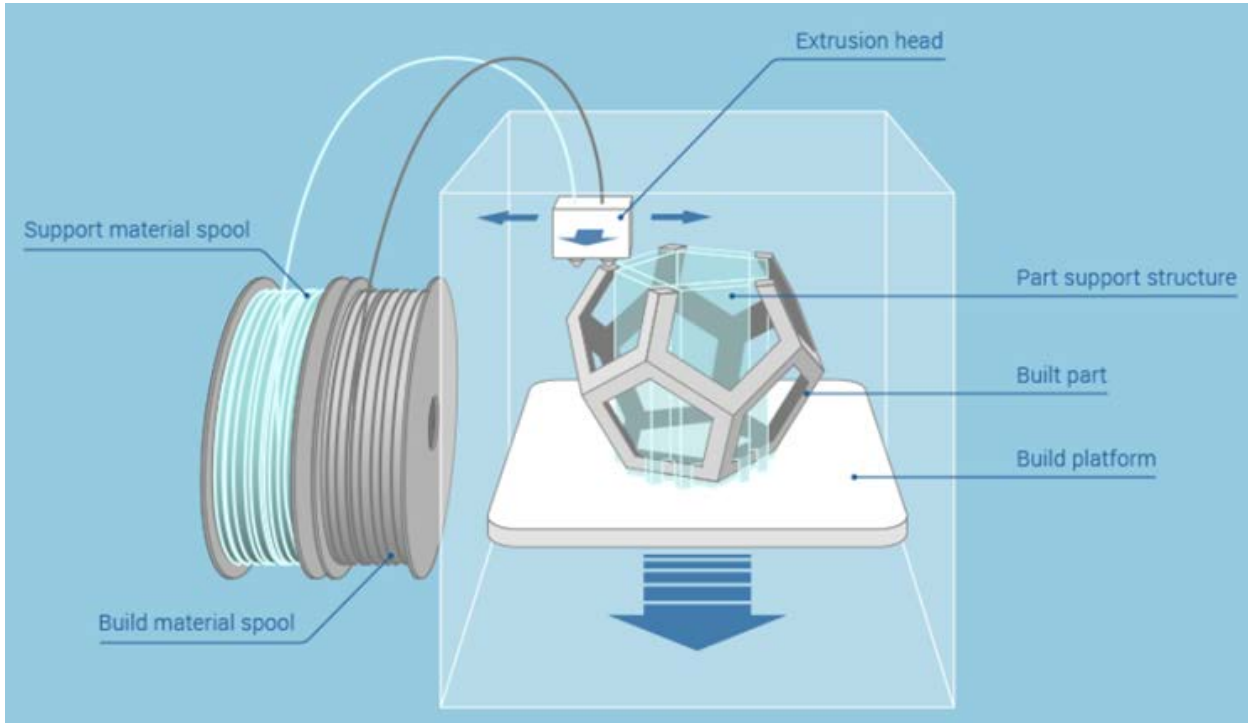
						
Fused Layer Modeling / Freeformer / Multi Jet Modeling (FDM, FLM, AKF)	**Selective Laser Melting / Sintering** (SLM, SLS, EBM)	**3D-Printing** (3DP)	**Polyjet Modeling** (PJ, PJM)	**Laminated Object Modeling** (LOM, LLM)	**Stereo-lithography** (SL, STL, DLP)	**Hybrid Machines**
plastics (+ filler material)	metals (SLM), plastics or similar	quartz, metals, plastics	photopolymers, waxes	paper, plastics, carbon fiber	photopolymers (+ filler material)	metals
models, prototypes, consumer goods	prototypes, small batch series, repairs, tools	models, prototypes, casting molds	models, prototypes, casting molds	models, casting molds	models, prototypes	repairs, single parts, small batch series

3D-Printing activities at IWK



Fused Deposition Modelling (FDM) / Fused Filament Fabrication (FFF)

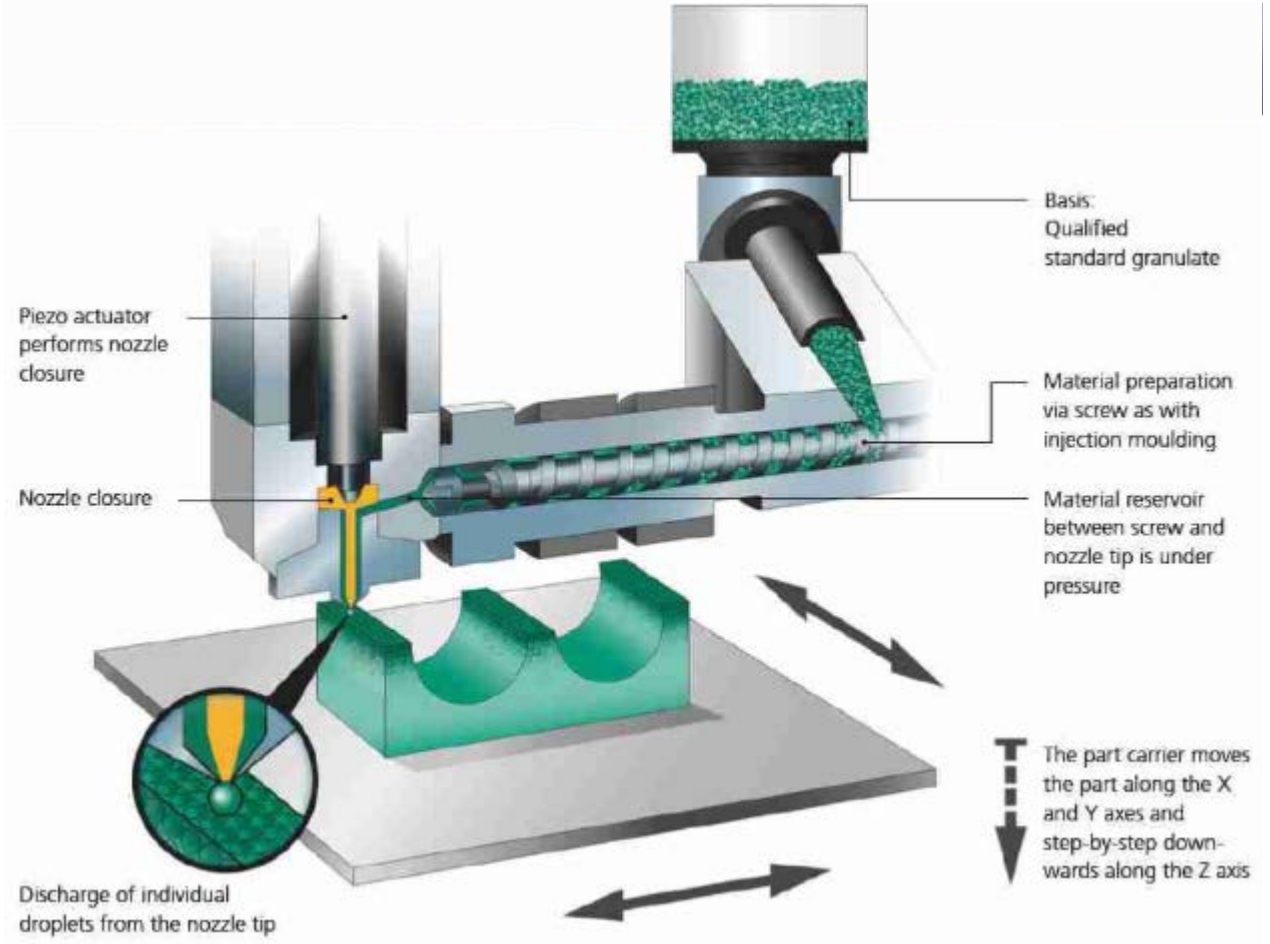
- **Building material:** thermoplastic filament on a coil
- **Mode of action:** Heating up in an extrusion head and cooling down on a building platform (like extrusion)
- **Possible materials:**
  - ABS, PLA, PC, PET, PA12, PA6, PP, TPU, etc.
- **Characteristics:**
  - Layer thickness between 0.05 and 0.4 mm
  - Sometimes support structures are needed (on big overhangs)
  - Possible distortion
  - cheap acquisition costs
  - large variety of possible materials
- **Related procedures:**
  - Arburg Plastic-Freeforming (AKF)



Picture source: additivly.com

Arburg Plastic-Freeforming (APF)

- **Building material:** thermoplastic granules
- **Mode of action:** Heating up through plasticizing (like injection moulding) and droplet formation with a
  piezo actuator and a gate nozzle
- **Possible materials:**
  - Commercial plastic granules: ABS, PC, PA12, PLA, PP, TPU, etc.
- **Characteristics:**
  - Commercial plastic granules
  - large variety of possible materials
  - Precise material discharge
  - 70-80% of the mechanical strength compared to injection moulding



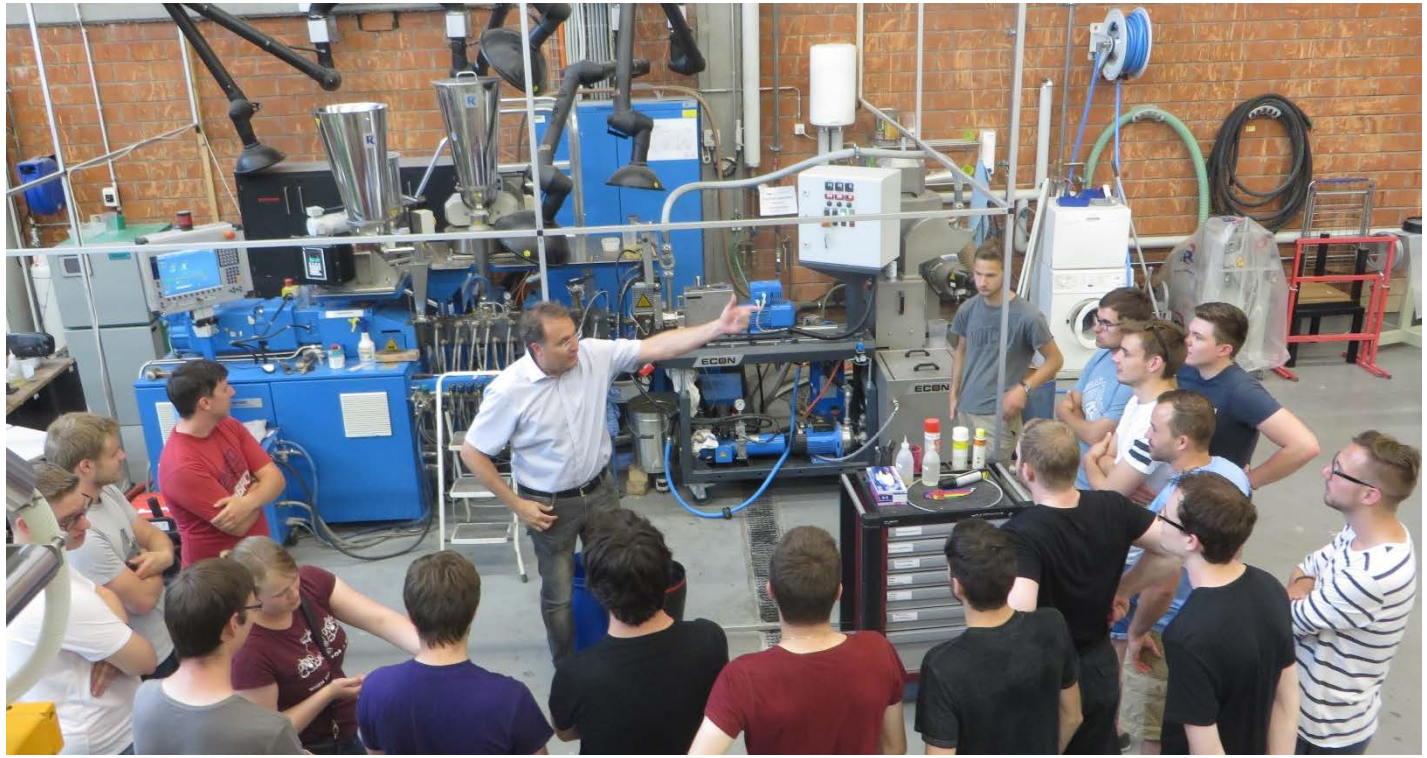
Bildquelle: ARBURG

Requirements for Support Material (for Arburg Freeformer)

- Additive Manufacturing with plastic materials
- Thermoplastic processing with a die diameter of 0.2mm is mandatory
- Water soluble with a weight loss around 0.5 gram per hour
- Good adhesion to the building platform
- Good adhesion to different building materials for the desired parts
  - Without visible residues
- Good mechanical properties, so that no support material can break during the building process
- Good heat resistance for an optimal support effect at building room temperatures from 80°C to 110°C
- Dissolved material should be able to be disposed of via sewerage
- Optimal form of the granules

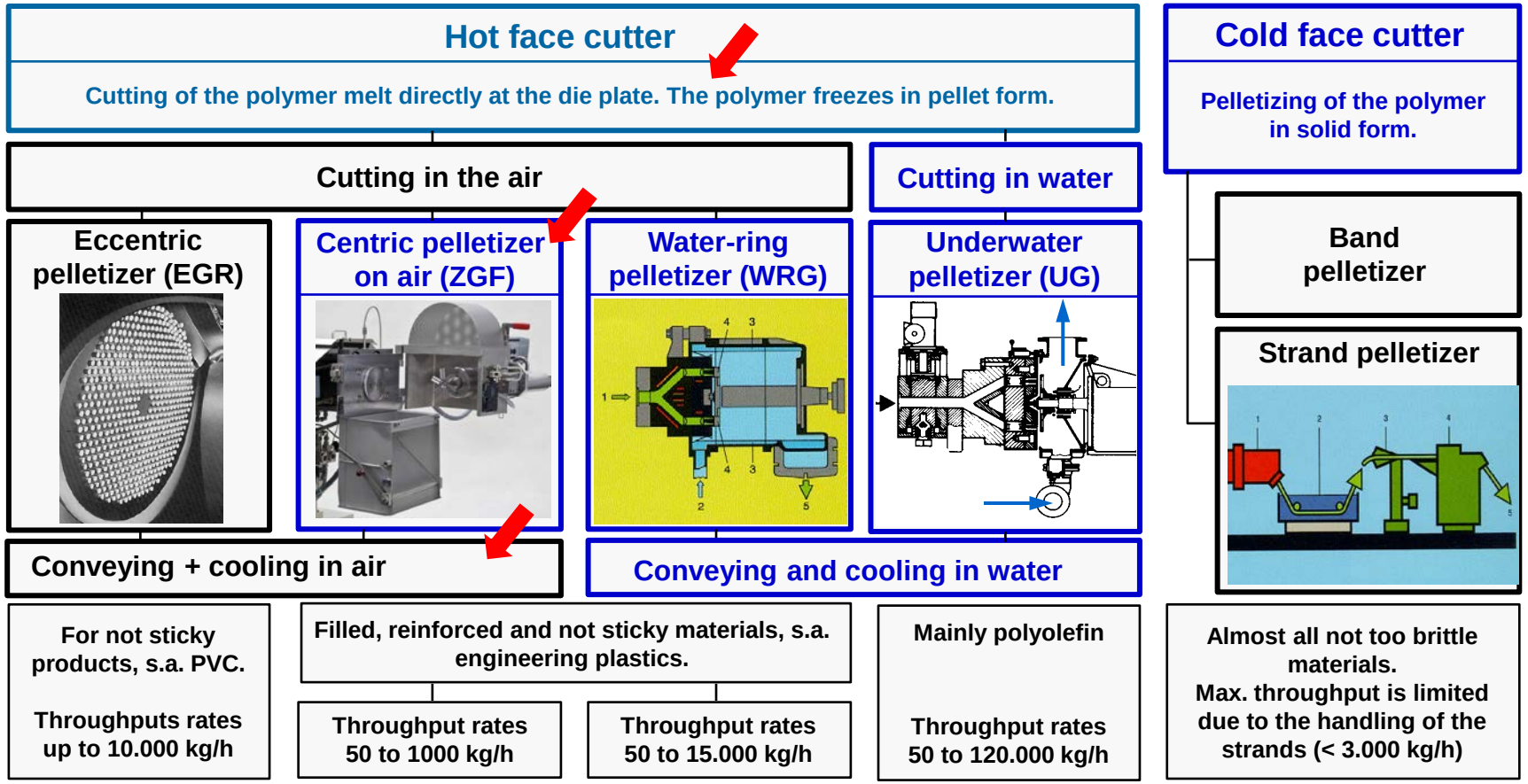
Infrastructure at IWK for material development: Compounding

- **Compounder Coperion ZSK 26**
  - Co-rotating twin-screw extruder (Ø26mm)
  - Processing length 44xL/D
  - Modular and flexible process part design/ screw configuration
  - Side feed and side degassing
  - Gravimetric dosing and volumetric feedings systems for liquids
  - Strand, underwater and air pelletizing systems



Plastics processing: Pelletizing

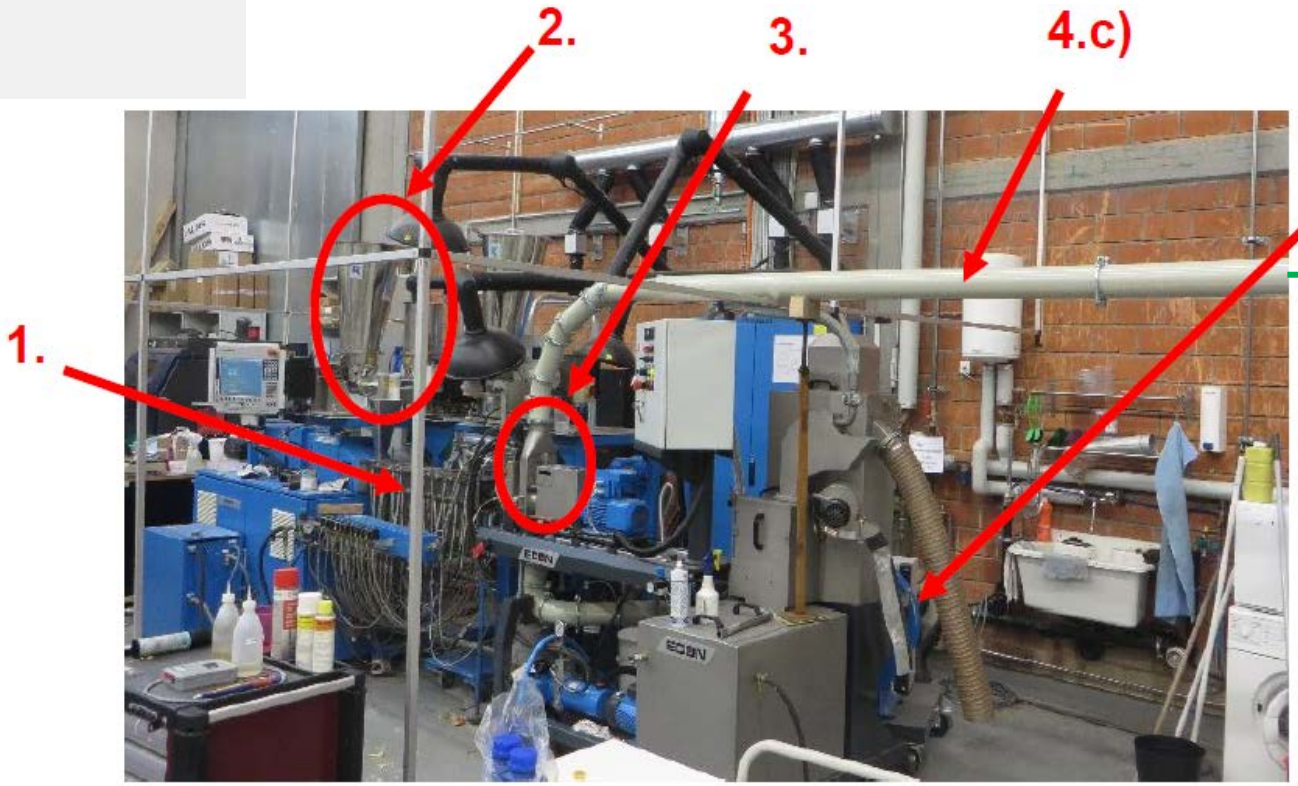
- Different types of Pelletizing systems



Because of the water soluble behavior of the material, the Pelletizing has to be a hot face cutter with the cooling in the air stream (red arrows).

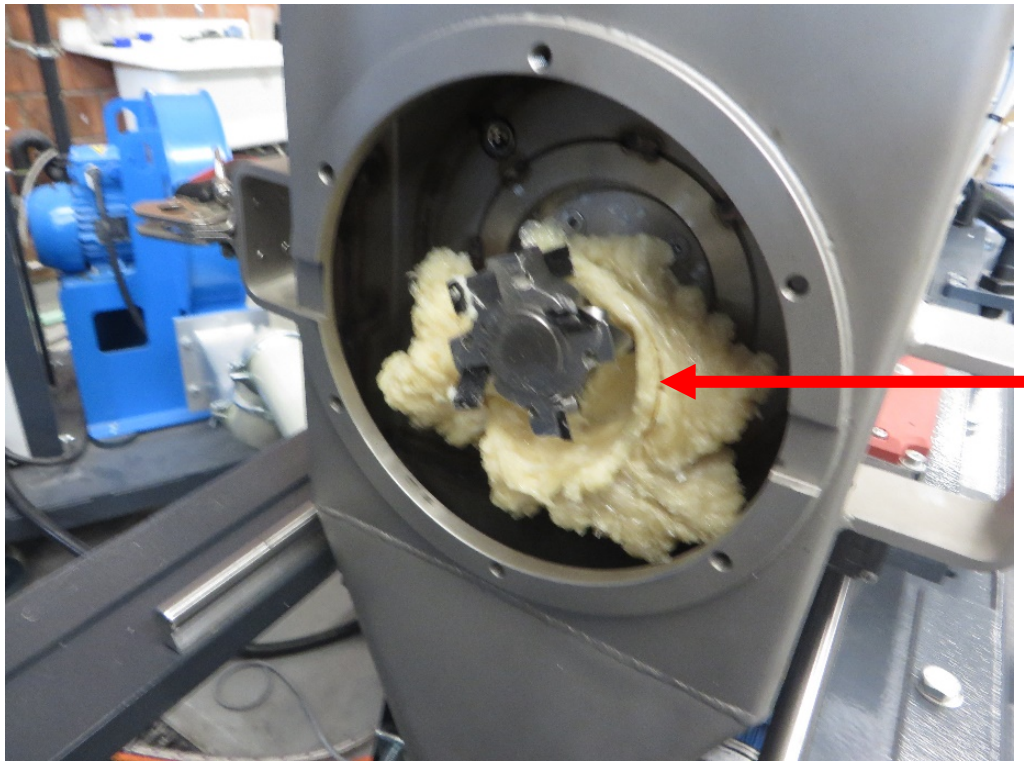
Source: Coperion (modified)

Compounding of water-soluble support materials



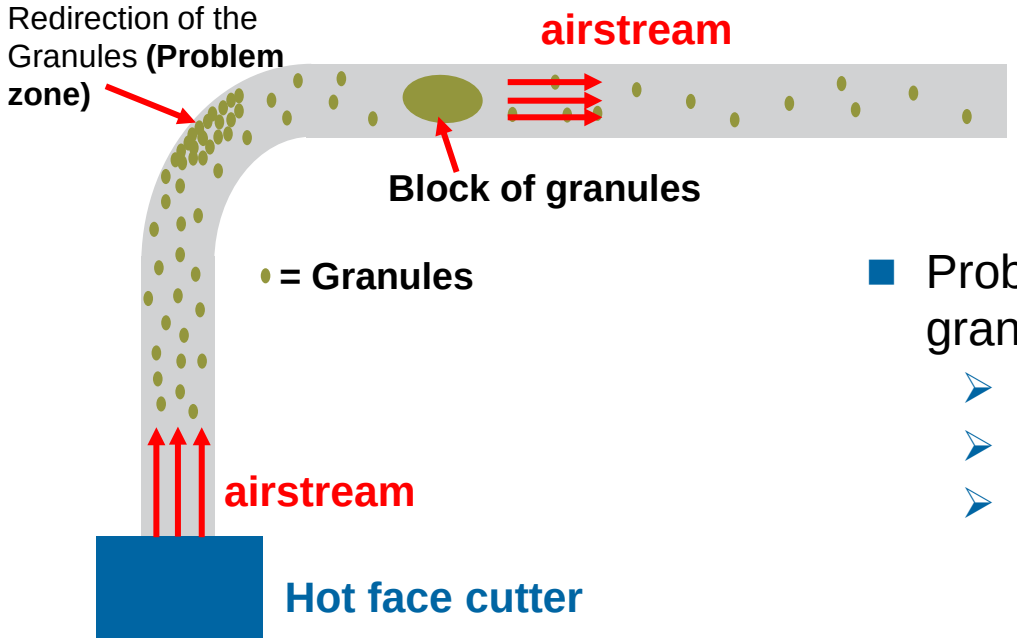
1. Co-rotating twin-screw extruder ZSK 26
2. Gravimetric feeding system
3. Knife-rotor-pelletizer (hot face cutter)
4.a) Fan
4.b) Discharge cyclone
4.c) Air conveying system(cooling section)
5. Drip tray for the granules to cool down

Problems with hot face cutter (knife-rotor-pelletizer) on air



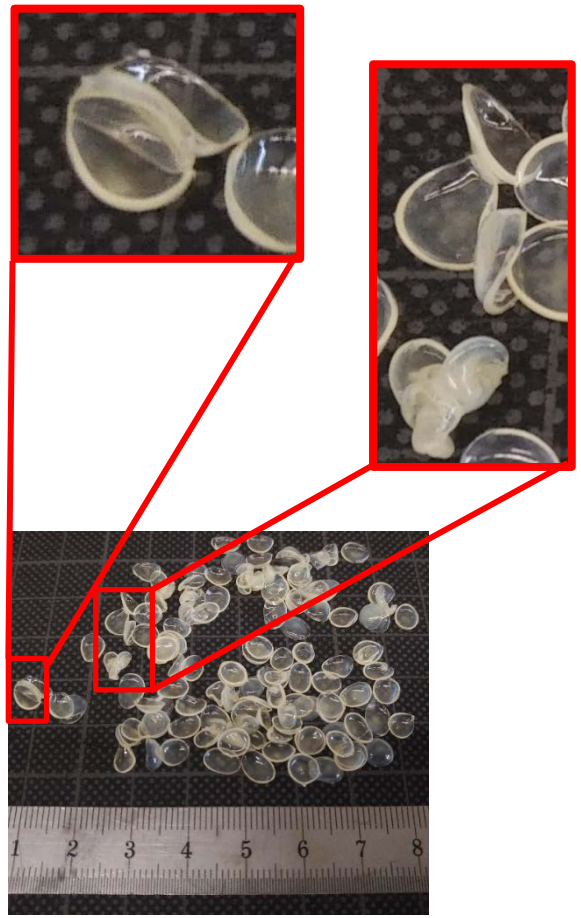
- Bad cutting because of:
  - Low viscosity
  - Blurred cutting edges
- Hot granules can glue together immediately because of the high adhesiveness of the material.
- The result is shown in the picture left.
  - Big blocks of granules which increase the torque on the shaft of the cutting knife.
  - Blockade of the air discharge of the granules and the cutting knife.
  - Stop the whole process

Problems with the pneumatic conveying system

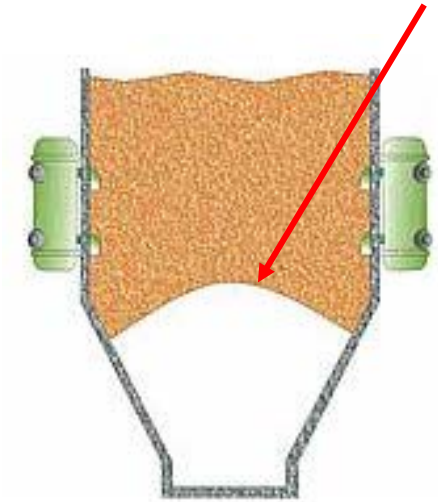


- Problematic zone in the bend, because of the redirection of the granules in the radius
  - In this zone, the granules are heated up by friction on the wall.
  - Therefore the hot granules can glue together.
  - The result of this are big blocks of granules, that are discharged through the cyclone as its shown in the picture above. Also named “shin pads” in the conveying “world”.

Problems with glued granules and agglomerates



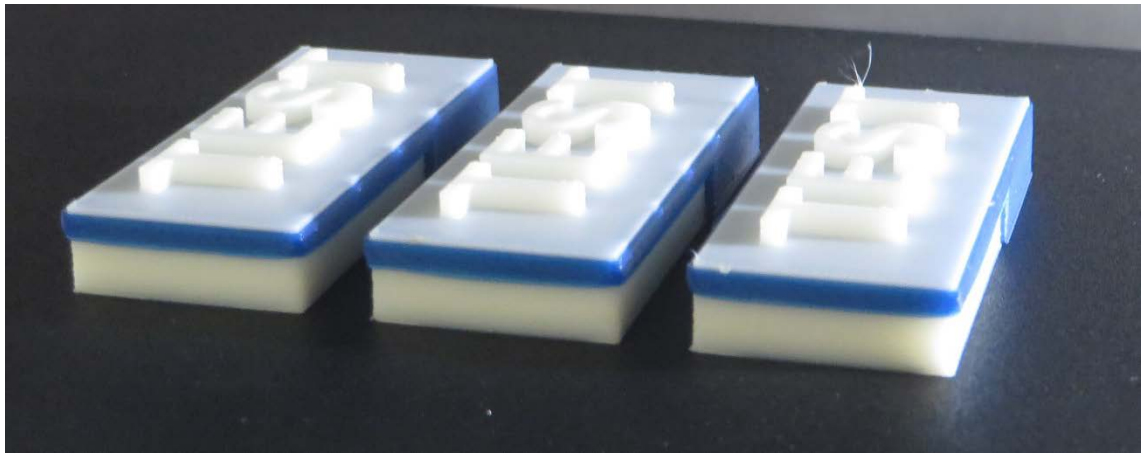
- Because of the used hot face cutter, the single granules are very hot and are cooling down slowly.
- So there is a possibility that single granules stick together and create some agglomerates.
- These agglomerates lead to problems in the feeding section of the Freeformer because of the «bridge building» effect



Optimization of the process

Actually the following optimization steps were done:

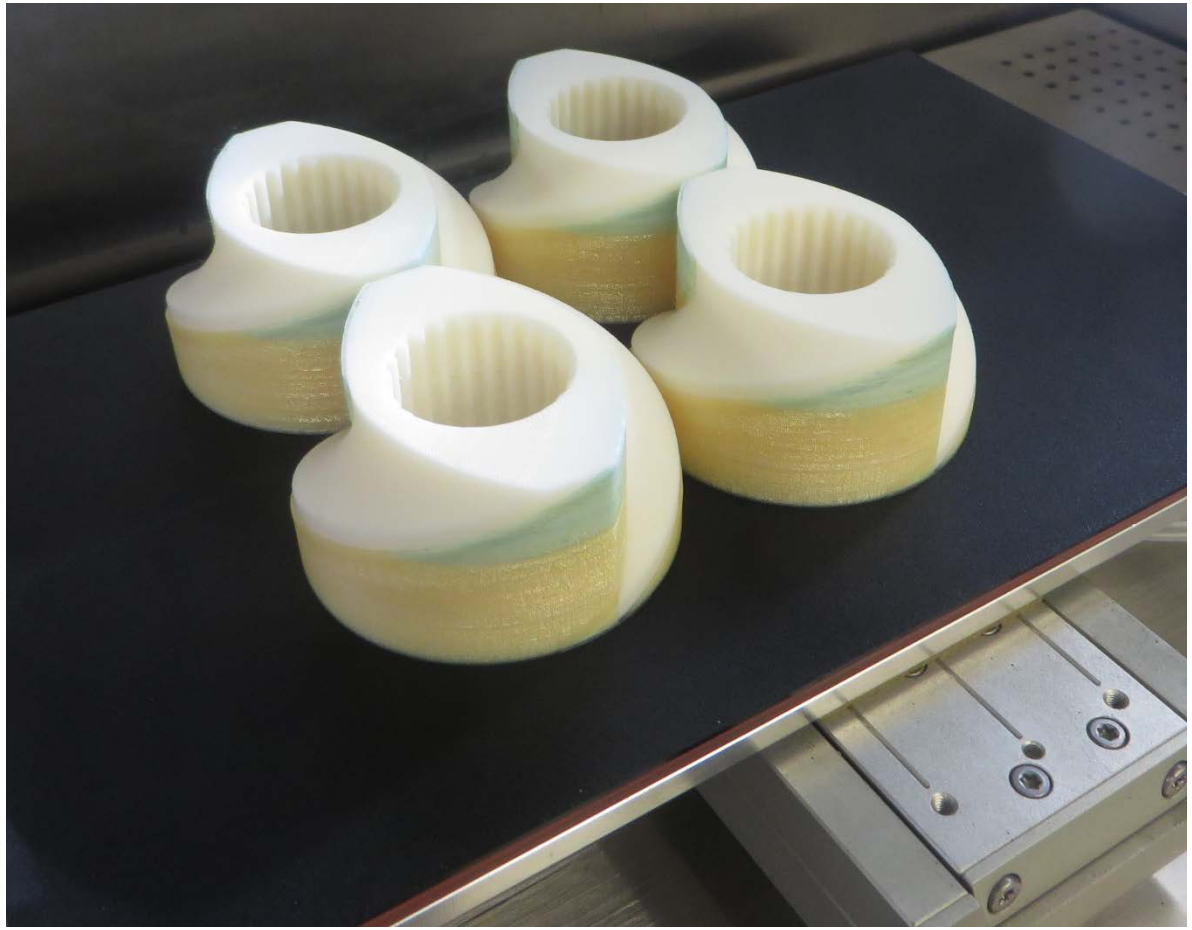
- Change the nozzle to minimize the strand expansion of the compounded material, so that the granules getting smaller.
  - Smaller granules = faster cooling of the single granules (less agglomerate) and more globular shape
- Use coated knifes on the granulator (sharper cutting edges)
- Vary the air flow rate to reduce warming of the granules through wall slide.
- Vary the speed of the knifes to produce smaller granules.



Applications

Special Application

Screw Elements for a transparent process section of a co-rotating twin screw



Project Team - development of water soluble support material

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THANK YOU VERY MUCH FOR YOUR ATTENTION

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