Science 4 Technology – Poster Exhibition 2024

Department Polymer Engineering and Science

Chair of Polymer Processing

Table of contents

Recycling of Paper Machine Clothing

ReFibreValue

Premises and Objectives

Premises

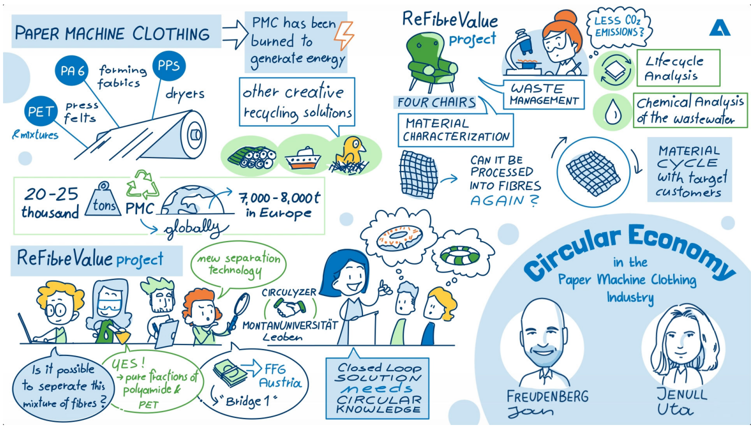
- At ANDRITZ Fabrics and Rolls GmbH several tons of textile waste are generated per year: Post industrial waste, in house waste from weaving and post consumer waste
- Delivery form: Fine fibres, finely chopped and blended
- Materials are technical plastics of high quality: PA 6 and PET

Objectives

- **Overall objective: Fibre to fibre recycling**
  - Analysis of waste flows and development of a logistics concept
  - Life cycle assessment (LCA) for the entire process
  - Investigation of different shredding technologies
  - Development of a separation technology
  - Development of a quantitative analysis method for PA 6 / PET mixtures
  - Material development for a spinnable material

Pod Cast

- Series planned over the project time
- More information on the project
- Check out the QR-code!



Industrial Partners

ANDRITZ AG

- **ANDRITZ Fabrics and Rolls GmbH**
  Locations: Reutlingen (Germany) and Gloggnitz (Austria)
- Producer of forming fabrics and felts (paper machine clothing PMC)
- **ANDRITZ Recycling Technology Center**
  St. Michael (Austria)
  Large scale trial centre for waste treatment
- www.andritz.com/group-en

Circulyzer GmbH

Circulyzer efficient separation

- Separation technology: Centrifugal Force Separator
- Spin Off from Montanuniversität Leoben
- www.circulyzer.at

University Partners

MONTAN UNIVERSITÄT LEOBEN

Waste Processing Technology and Waste Management

- Analysis of chemicals in forming fabrics and felt and in the waste water
- Legal aspects, LCA & Logistics

Material Science and Testing of Polymers

- Material characterisation

Mineral Processing

- Separation technologies

Polymer Processing

- Material characterisation
- Processing trials

Resources Innovation Center

- Project management, Dissemination

Striving for a Circular Economy

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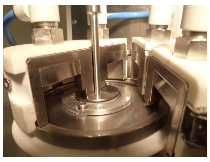
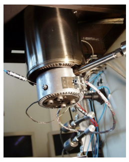
The project ReFibreValue is funded by the Austrian Research Promotion Agency (FFG)
FFG project no.: FO999895423
Start: 01.10.2022
Duration: 24 months

FFG Forschung wirkt.

Material Data Determination @ Institute of Polymer Processing



Scope of Measurements

The working group **Material Data Determination** deals with the measurement of **rheological** and **thermodynamic** material data for complete **material datasets** for **precise simulations with all simulation programs.** Furthermore we do failure analysis of polymer parts.

Rheological Measurements:

- Shear viscosity as function of shear rate, temperature and pressure (ISO 11443)
- Complex viscosity (ISO 6721)
- Transient elongational viscosity (ISO 20965)
- Extensional behaviour and melt strength (RHEOTENS)
- Magnetorheology

Thermodynamic material data:

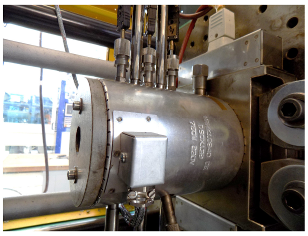
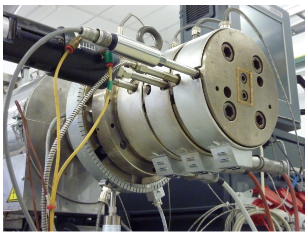
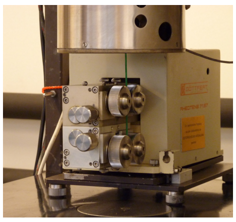
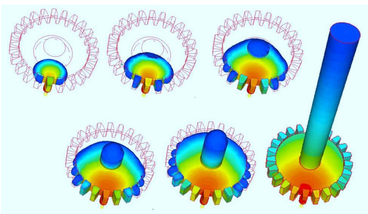
- Thermal conductivity as function of temperature (ASTM D5930, ASTM D7984) and pressure (ASTM D5930)
- Specific heat capacity (ISO 11357)
- Specific volume as function of pressure and temperature (ISO 17744)

Dynamic mechanical thermo analysis:

- Characterization of reactive or solid specimens

Materials:

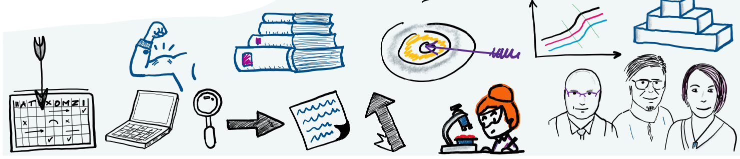
- Thermoplastics, elastomers, feedstocks for Shaping Debinding Sintering SDS (PIM, PEM, AM MEX), WPC, reactive systems, low viscous substances (food, oil…), polymer waste …

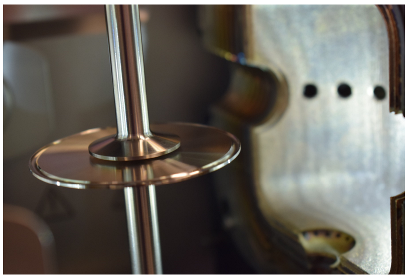





Full Service

data ⇨ analysis ⇨ interpretation ⇨ technical report with management summary

- Scientific expertise for industrial applications
- Consulting and technical support
- Tailor-made offers
- Post-project support




Equipment

- Rotational rheometer: MCR 702 MultiDrive (Anton Paar)
- High pressure capillary rheometer: RG 50, RG 2002 (Göttfert)
- Machine rheometer:
  - Leistritz inline rheometer
  - Injection moulding machine rheometer
  - PIM-injection moulding machine rheometer
- Extensional tester: RHEOTENS 71.97 (Göttfert)
- Thermal conductivity measuring device: K-System II, TCi (C-Therm)
- Differential scanning calorimeter: DSC1, Flash DSC2+ (Mettler Toledo)
- pvT-apparatus: pvT100 (SWO Polymertechnik)
- Measuring mixer: Lab Station EC, W50 EHT, W350 E (Brabender)

Complete rheological and thermodynamic material datasets for injection moulding and extrusion simulations!

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Pack2theLoop

Closing the circle of polyolefin packaging

Motivation:

- Erhöhung der Recyclingquote in Österreich

→ ~ 26 % seit ca. 15 Jahren

- Bis 2030 sollen 55 % aller Kunststoffverpackungen und 60 % der Siedlungsabfälle in den EU-Mitgliedstaaten recycelt werden.

Projektdauer: 01.07.2021 – 30.06.2024

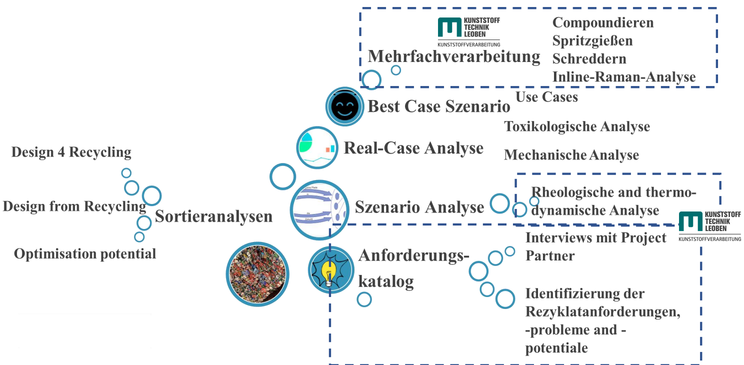
Projektträger: KC Plastics Cluster, eco plus, Co-funded by the European Union

Gefördert durch: FFG Forschung wirkt.

Projektziele:

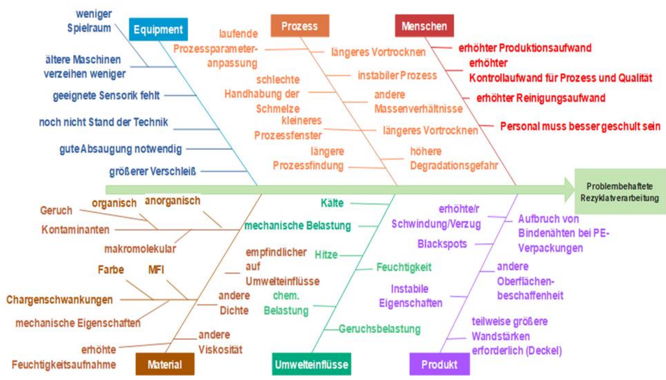
- **Entwicklung von qualitätsgesicherten Rezyklaten aus Post-Consumer-Verpackungen aus Polypropylen, Polyethylen und Polystyrol;** Sicherstellung der Verarbeitbarkeit (mechanisch), Sicherheitsbewertung (chemisch und biologisch).
- Demonstration des geschlossenen Kreislaufs mit Use Cases
- Einführung von "Design for/from Recycling" für zukünftige und wiederverwertbare Verpackungen
- Ergebnis: Handbuch mit Erfahrungsergebnissen und Durchführung eines gemeinsamen Expertentreffens mit Stakeholdern und Interessengruppen.
- Entwicklung einer gemeinsamen Sprache des Kunststoff-/Abfallwirtschafts-/Recyclingsektors durch Zusammenarbeit entlang des gesamten "Kunststoff"-Wertschöpfungszyklus.

Vorgehensweise:



Ergebnisse:

Anforderungskatalog: *Effektdiagramm – Probleme beim Rezyklateinsatz*



Mehrfachverarbeitung: *Speicher- und Verlustmodul dienten zur Ermittlung der mittleren Molmasse und mittleren Molmassenverteilung zur Bewertung der Materialdegradation der mehrfachverarbeiteten Polystyrol-Rezyklate*

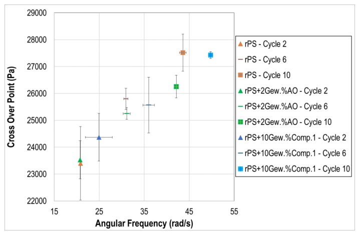


Diagramm: Kreuzungspunkt von Speichermodul G' und Verlustmodul G'' in Abhängigkeit von der Kreisfrequenz ω für eine Polystyrolschmelze bei 230 °C

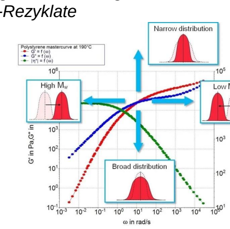
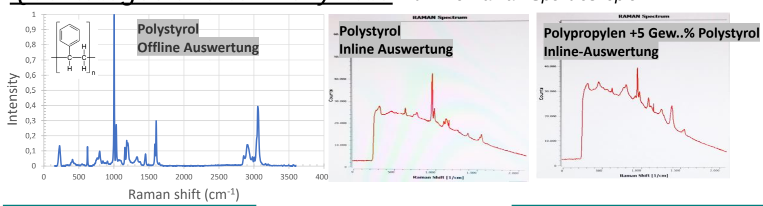


Abbildung: Speichermodul G', Verlustmodul G'' und die komplexe Viskosität |η| in Abhängigkeit von der Kreisfrequenz ω für eine Polystyrolschmelze bei 190 °C. Bildnachweis: : https://www.azom.com/article.aspx?ArticleID=20979, 28.08.2023*

→ Mit zunehmender Zyklenzahl ist eine fortschreitende Materialverschlechterung durch die nach oben und rechts verschobenen Kreuzungspunkte von G' und G'' zu erkennen, was bedeutet, dass die mittlere Molmassenverteilung enger wird und die mittlere Molmasse abnimmt

Qualitätsgesicherter Rezyklate *mit Inline-Raman-Spektroskopie:*



1. Zwei Polystyrol Schmelzestränge werden nach dem Compounder auf dem Abzugsband abgelegt.

2. Schmelzestränge werden durch die Messapparatur geführt, die am Strangabzugsband montiert ist.

3. Mit Hilfe des RAMAN Sensors und einer Software werden die materialspezifischen Spektren und Störstoffe detektiert.

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Projektkonsortium:

Research Focus:

- Mechanisches Recycling
- Kreislaufwirtschaft
- Nachhaltigkeit

WINTRUST

Wintersport Ressource Efficiency and Improved Circular Economy

Motivation:

Wie kann eine ökologische, ökonomische und sozial nachhaltige, markenübergreifende Kreislaufwirtschaft für die österreichische Wintersportbranche am Beispiel ausgewählter Schisportartikel erfolgreich implementiert und optimiert werden?

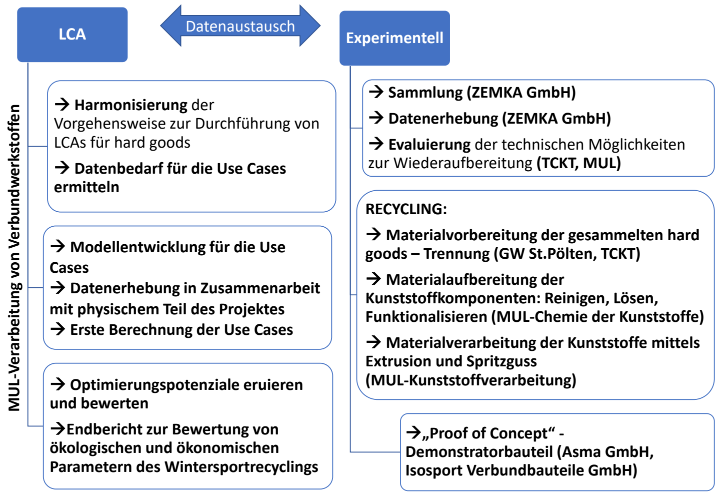
Projektdauer: 01.11.2023 – 30.10.2026

Projektträger:

Co-funded by the European Union

Gefördert durch FFG Forschung wirkt.

Vorgehensweise:



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Gemeinsam mit der österreichischen Wintersportbranche für ein effizientes Recycling!

Finde hier die Annahmestellen

BE PART OF IT

Recycling Biobased Plastics

C-PlaNeT
CIRCULAR PLASTICS NETWORK FOR TRAINING

Premise and Objectives

Premise

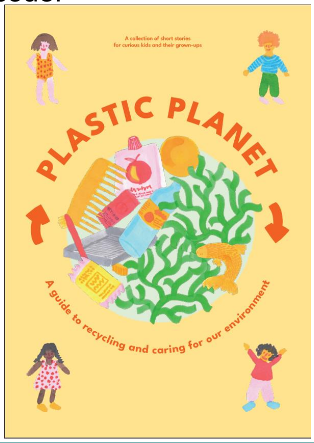
- Biopolymers are defined as polymer materials that are biodegradable, biobased or both.
- Polyhydroxybutyrates (PHBs) are biobased and biodegradable in nature with promising properties and varied applications in the market.
- Recycling becomes a desirable End of Life option for the circular economy as the amount of (bio)plastic increases.

Objectives

- **First objective: Mechanical recycling of PHBs**
  - Recycling PHB multiple times and characterization of properties in comparison to PP as an industrial standard
  - Addition of additives in different ratios and recycling modified PHB and characterization of properties
- **Second objective: Analyze the PHB food packaging potential**
  - Odour characterization of PHB in comparison to PP
  - Migration potential and barrier properties of PHB and recycled PHB films

Children's Story Book

- Plastic Planet: A guide to recycling and caring for our environment
- Open Access Link: https://zenodo.org/doi/10.5281/zenodo.8160165
- Scan QR code!



Industrial Partners

Pack4Food

- Location: Ghent University campus, Belgium
- Consortium of Flemish research centres and companies, active in the food-packaging field
- https://pack4food.be/en/

PreZero Polymers Austria GmbH

- Location: Völkermarkt, Austria
- Recycler of Polyolefins and Polystyrene
- https://prezero-international.com/polymers/

University Partners

Polymer Processing

- Processing trials
- Material characterisation
- Material development

MONTAN UNIVERSITÄT LEOBEN

Dept. Of Food Technology, Safety and Health

- Analysis of VOCs
- Migration tests and MAP potential of PHB

GHENT UNIVERSITY

Centre for Polymer and Material Technologies

- Material characterisation
- Film production

Striving for a Circular Economy

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 859885.

Start: 01.08.2020
Duration: 36 months

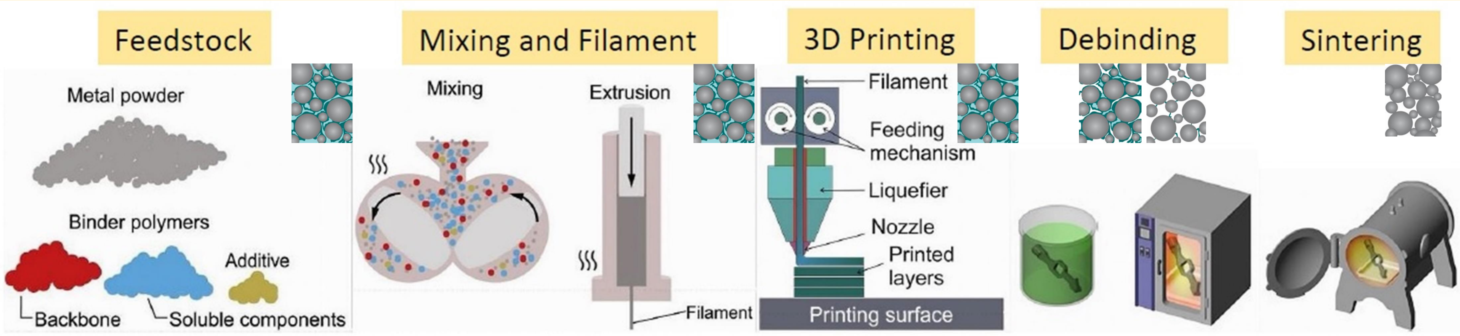
Link to C-PlaNeT: https://www.c-planet.eu/

Additive Manufacturing of Aluminium by Material Extrusion MEX

Introduction

The primary goal of the project is to develop the Material Extrusion technique MEX for the additive manufacturing of aluminium parts. This eliminates the drawbacks of existing routes for additive manufacturing of aluminium like SLM (e.g. high cost, handling of powder) and opens new design options as the production of closed cavities and multi-material parts, e.g. the combination of wear resistant and tough aluminium alloys.

Process

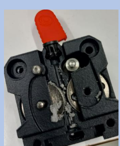


The MEX process consists of four main stages: feedstock and filament preparation, shaping (3D printing), debinding, and sintering. The feedstock, comprises a mixture of metal powder and a binder system. Binders are multi-component combinations of several polymers and additives that play a significant role in the MEX of metallic components. After the preparation of the feedstock, green parts with the desired shape are produced with 3D printing. During the debinding, all components of the binder systems are extracted from the green part gradually using different techniques (solvent and thermal). Sintering is done in the furnace by heating parts to temperatures lower than the melting point of the metal used to achieve a nearly complete density part with high mechanical properties.

Challenges

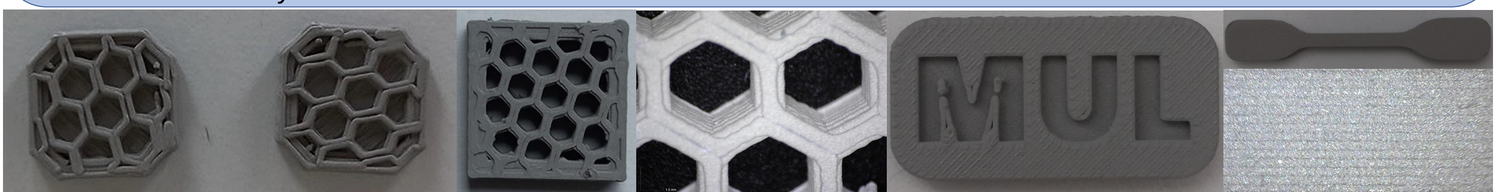
Requirements for binder system

- Homogeneity
- Flexibility
- Stiffness
- Compatibility
- Low viscosity



Processing of aluminium

- Low sintering temperature (500 - 600 °C)
- Sensitive to contamination (O and C)
- Oxide layer



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Project: ALF3

Funding: This research was funded by Austrian Research Promotion Agency (FFG), Project No.: 885128.

MONTAN UNIVERSITÄT LEOBEN

FFG Promoting Innovation.

Fraunhofer IFAM

RHP GROUP

Additive Manufacturing Material Extrusion @ Institute of Polymer Processing

Material Extrusion (MEX) is a very common Additive Manufacturing (AM) technology with low-cost printers available for home printing, as well as larger, more advanced machines used in industry. One big advantage compared to other AM processes is the huge variety of materials available and new developments are coming to market.

The use of new materials or different machine setups brings different challenges. My group is investigating materials that are highly filled (>75 wt.%) with metallic or ceramic powder (feedstock) and are processed with MEX. Afterwards some of the polymer is dissolved and the rest is thermally degraded, so that the remaining powder can sinter together and form a dense part (see Fig. 4), completely without polymers. In contrast to pure polymers, the addition of metallic powders leads to a much higher thermal conductivity and in the simulations of different printheads we can see this temperature evolution. One effect (Fig. 1) is that using a shorter PTFE insert (Fig. 1b) compared to a longer (Fig. 1c) leads to a longer melt area and therefore to a higher pressure consumption. Similar results can be seen in Fig. 1a with an all metal insert.

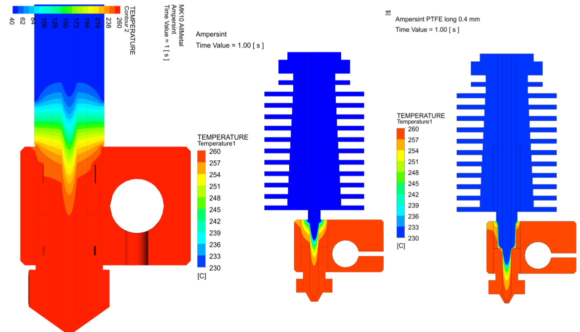


Fig. 1a Fig. 1b Fig. 1c

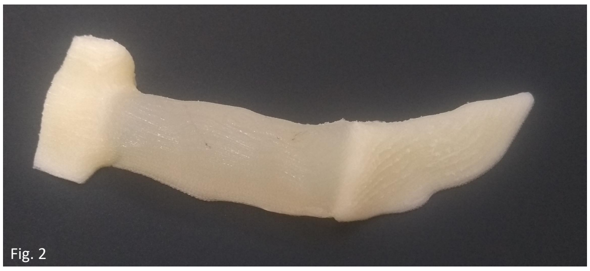


Fig. 2

The development of the feedstock, e.g. for aluminium in Fig. 3, is done together with Fraunhofer IFAM/Dresden and the company RHP/Seibersdorf. With ceramic powders the sintering temperature is so high, that all the polymer dissipates, but with Al the degradation temperature of the polymers overlaps with the sintering range of Al and thus low melting feedstocks have to be developed.

The production of patient-specific implants can lead to a better healing process and a higher level of comfort for the patient. AM is ideal for this because each geometry can be made unique without the need for expensive tools. In Fig. 2 a model of a rib can be seen. Currently rib implants are made out of metal, which is not flexible and therefore wear occurs between the screws that attaches it to the bone. The CAMed project is investigating a possible solution in which two different polymers - one flexible and one rigid - are combined and printed using the Arburg Plastic Freeformer (Figure 5). In this case not only do the polymers have to be suitable for AM, but they also have to comply with all the medical requirements. In a follow-up project we want to evaluate the processing conditions in the Freeformer to assess the degradation of the polymers using this technology and integrate the measured data into the clinic's database so that problems and deviations can be identified, solutions can be found easily and the part quality is perfect in every implant.

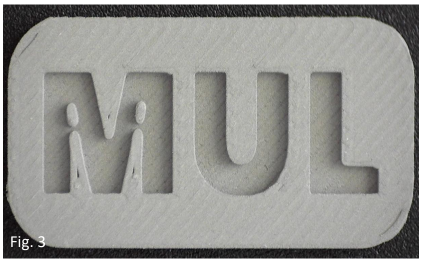


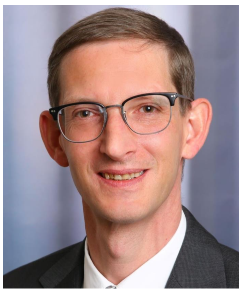
Fig. 3

AlF³ Fraunhofer IFAM RHP GROUP


Fig. 4

CAMed Clinical additive manufacturing for medical applications
Med Uni Graz
ARBURG


Fig. 5



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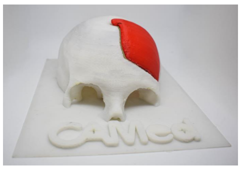
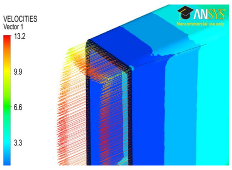
Extrusion and
Additive Manufacturing

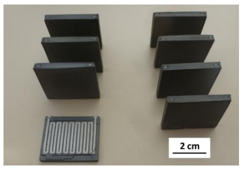
ADDITIVE MANUFACTURING

FFG Promoting Innovation.
M-era.Net

Extrusion and Additive Manufacturing @ Institute of Polymer Processing





Our service

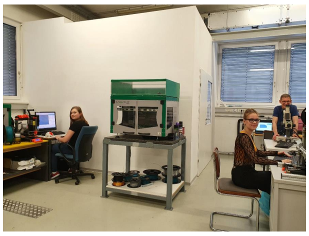
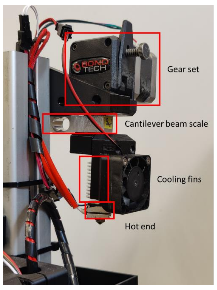
The working group **Extrusion and Additive Manufacturing** deals with extrusion related research, like simulations, practical trials and material characterization for the needed calculations. In Additive Manufacturing we are developing highly filled feedstocks and improve the understanding of the influences in Material Extrusion (MEX), which is the filament based AM method.

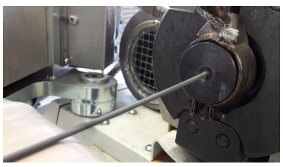
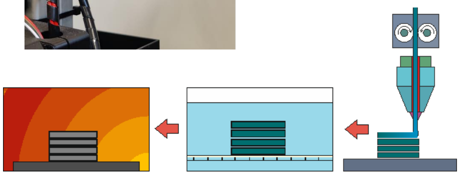
Extrusion:

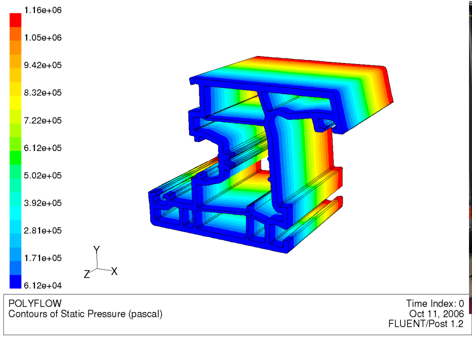
- Analytical calculation of extrusion screws and dies
- 3D-FEM Simulation of dies and screws
- Practical experiments in extrusion
- Material data for solid conveying
- Residence time determination
- Physical foaming
- Filaments for AM
- Compounding of tailor made materials

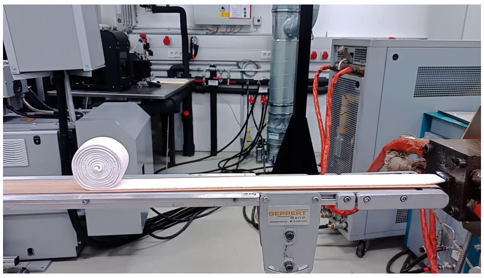
Additive Manufacturing:

- Material development for Material Extrusion Additive Manufacturing (MEX)
- Highly filled filaments with metal or ceramic powders for sintering
- Production with Material Extrusion and Arburg Plastic Freeformer APF
- Simulation and calculation of the AM process
- Adhesion on the printer bed
- Additive Manufacturing for industrial processes




Equipment

- Corotating twin screw extruder Leistritz ZSE 18 HP-48D, high temperature, wear resistant
- Single screw extruders Rosendahl, 45 mm and 30 mm, high temperature
- Filter test extruder Collin FT-E20T-MP
- Flat film line Collin up to 5 layer, 1 x 30 mm, 2 x 20 mm extruder
- Pipe Extrusion Line, Battenfeld-Cincinnati, Proton 45-28G Kuag follow-up
- Blow Molding machine Kautex
- Thermoforming machine Illig
- Arburg Plastic Freeformer 2K 3A
- Hage3D 140L, Hage3Dp-A2
- Wanhao i3, Prusa i3 MK3S+, 3Devo

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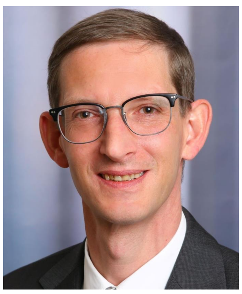


LightCycle: Upcycling of regenerates with a new Injection Moulding Compounder (IMC)

Introduction

Combining compounding and injection molding in one system may be beneficial in terms of production costs, energy, and material consumption compared to two separate systems. It also means improved material quality as it is heated only once. Twin-screw compounding allows gentler plasticizing of heat-sensitive compounds and a thorough mixing of practically any conventional filler or reinforcement.

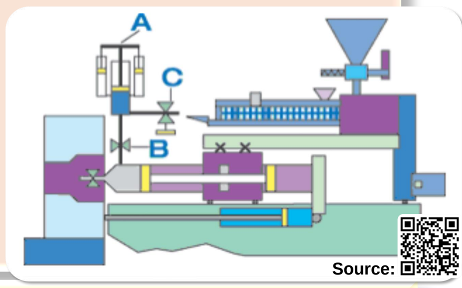
Timeline

1998

- Krauss-Maffei Kunststofftechnik GmbH jumped into the long glass fiber market at K'98, and showed an unusual machine that combines twin-screw extruder with injection molding.
- A melt accumulator stores the polymer melt and feeds the injection molding machine.

Advantages

- Actual mechanical properties of the compound
- Suitable for recyclates and long fibers
- Increased cost-effectiveness
- Suitable for the development of materials and quality control and big volume parts

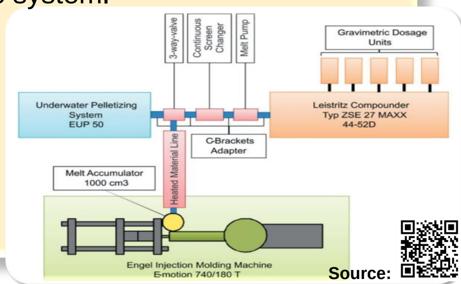


2011

- ENGEL developed an IMC for polymer nanocomposites, which is composed of a ZSE 27 MAXX Leistritz-Compounder and a 1899 kN injection moulding machine in a parallel arrangement. A 3-way valve and a melt pot increases the flexibility of the whole system.

Disadvantages

- Long flow paths and dwell times of >20 min
- Suboptimal material absorption in the melt reservoir (no first in-first out)

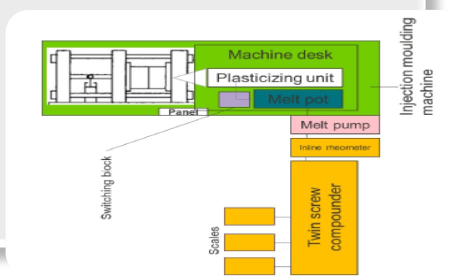


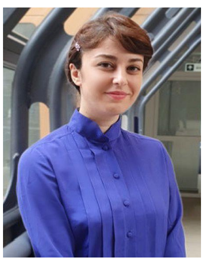
2022

- In the project **LightCycle**, MUL together with Leistritz GmbH and Engel Austria GmbH are developing a new IMC.
- The main goal is the upcycling of regenerates based on post-consumer recycled polymer and post-industrial glass fiber-reinforced polymer composite.
- An innovative connecting element (melt pot) between the compounder and the injection moulding machine with a special piston with a rheologically new and residue-free design is developed.

Advantages

- Lower residence time compared to the last model.
- Suitable for processing of recyclates and waste glass fibers composites
- Possibility to use each single machine
- Increased cost and energy effectiveness





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PROJECT: LightCycle

Funding: FTI Kreislaufwirtschaft, Austrian Research Promotion Agency (FFG), project no. FO999889913

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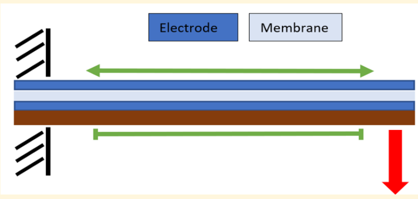
Chemitecture: Dielectric Elastomer Actuator (DEA) produced by Material Extrusion (MEX)

A Dielectric Elastomer Actuator (DEA) is a type of soft actuator, where the movement is caused by high Coulomb forces, which are the consequence of a high electric field. The electric field is appearing in the insulator ("membrane") of the actuator. This membrane is located between two electrodes, which are connected to high voltage. This work investigated the implementation of Material Extrusion (MEX) process in order to enable the manufacturing of fully 3D Printed DEAs.
The focus was on the research of potential filament materials, development of our own dielectric and electrically conductive composites and characterization of fully 3D printed soft dielectric actuators.

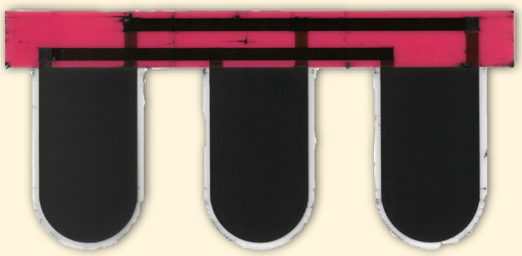
Main Actuator Design

- unimorph bending beam actuator was chosen
- This actuator design consists of an active and passive component



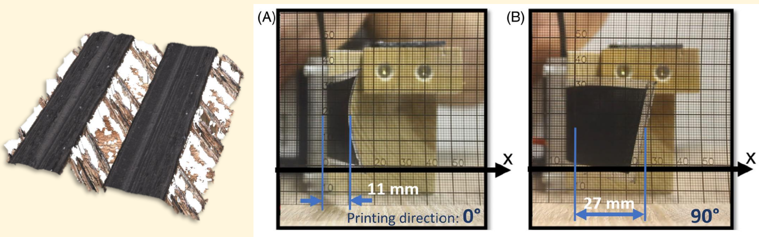
Soft dielectric assembly

- Multiple DEAs and the related wiring between them were 3D printed as only one printing job



Optimization of the 3D printed electrode

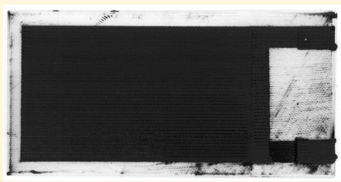
- Two main electrode infill printing directions: 90° & 0°
- The maximum actuator displacement was 42% of its freely moveable length



Own electrically conductive filament

- DEAs 3D printed out of:

Own filament
(Silver coated particles based)



Commercial filament
(carbon black based)

The MEX 3D printing process in the field of dielectric elastomer actuators was successfully implemented. The fully 3D printed soft actuator achieved quite high displacements. As a show case example, the fully 3D printed soft actuator assembly was presented. The fully 3D printed soft dielectric assembly shown in this work represent one step ahead in the direction of fully 3D printable robots.

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