BIO-UPTAKE

Injection Moulding of Bio-Based materials

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MOSES Productos

moses
advanced materials

- Company activity starts in 2018
- Spin off from Aitiip technological centre
- Core activity
  - Rotational moulding
  - Injection moulding
  - Recycling
  - R&D → 13 active projects

MISSION

- Provide innovative plastic products, enhancing and improving performance and end of life, reducing in this way plastic's impact into the environment

VISION

- Become an expert in transforming plastic components for industrial use and recycling high-technology polymers. Using the most suitable material for the particular application

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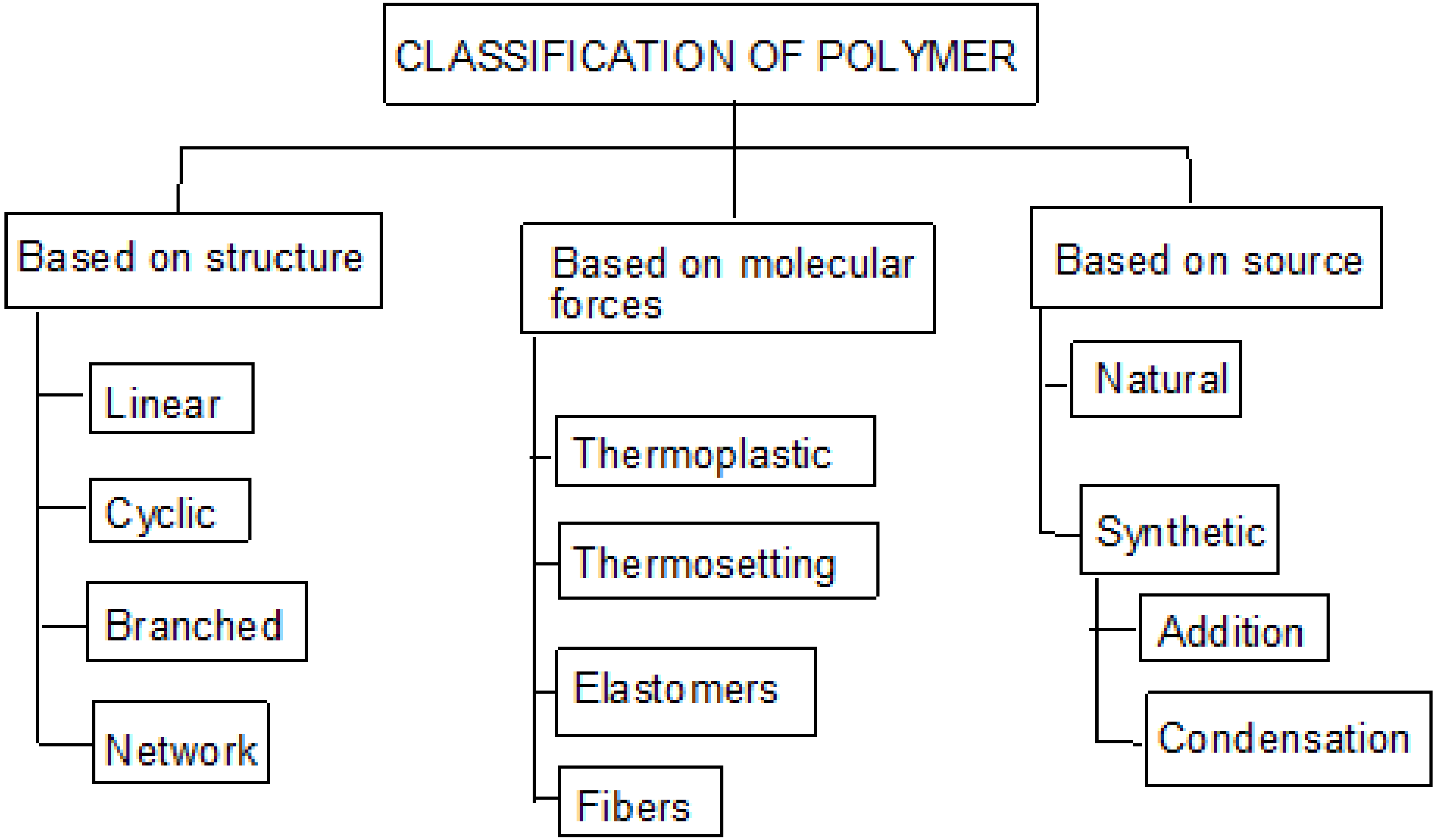

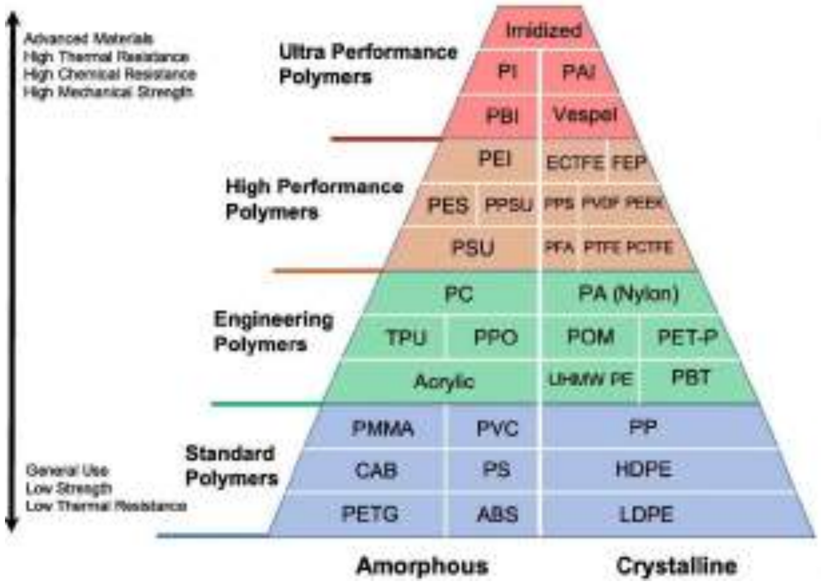

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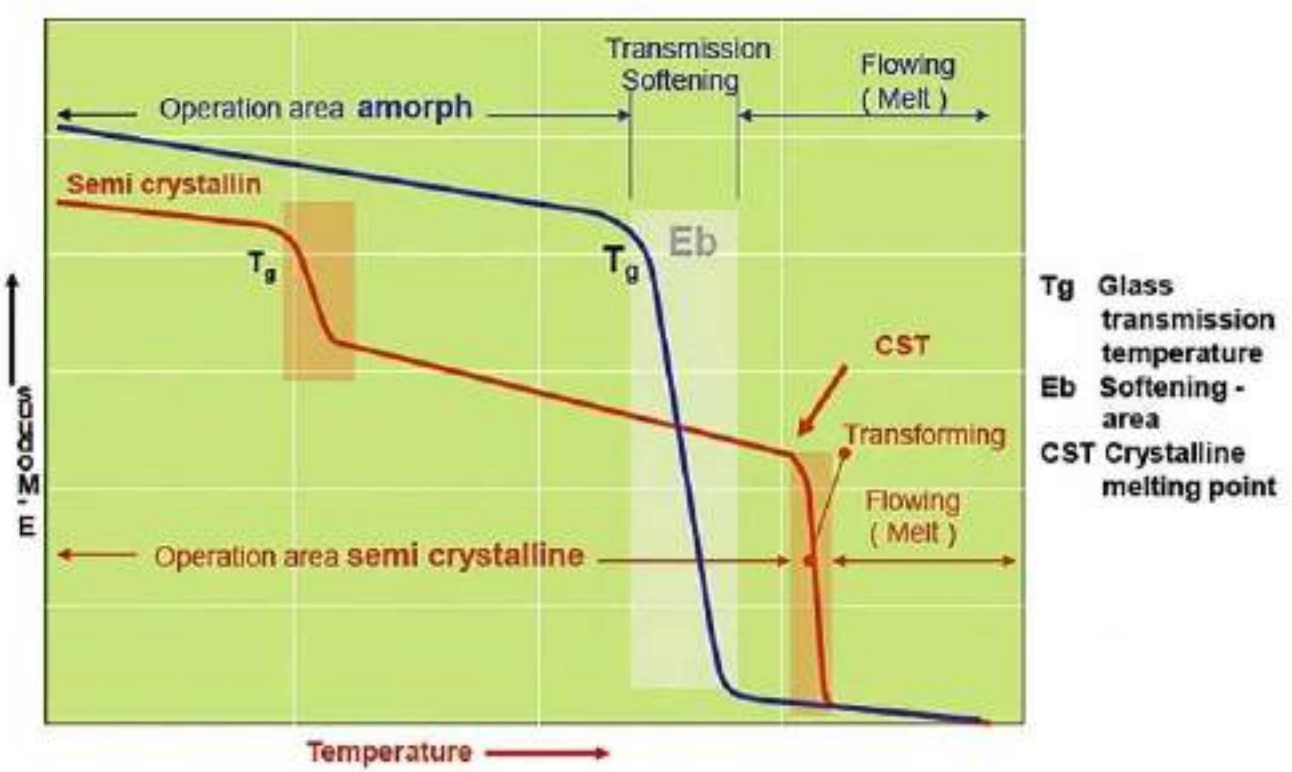

Polymer	Tg (°C)	Density (g/cm ^{3})
High density polyethylene (HDPE)	−125	0.94–0.97
Low density polyethylene (LDPE)	−130	0.91–0.93
Polypropylene (atactic)	−20 to −5	0.85–0.94
Polyethylene terephthalate (PET)	70 to 80	1.34–1.39
Polytetrafluoroethylene (PTFE)	120 to 130	2.2
Polyvinyl alcohol	80 to 90	1.19
Polyvinyl chloride (PVC)	65 to 85	1.16.1.20
Polypropylene (isotactic)	100	0.92
Polystyrene (PS)	90 to 110	1.04–1.09
Polyurethane (PU)	120 to 160	1.2
Poly(methyl methacrylate)	85 to 105	1.18
Polyacrylamide	160 to 170	1.11
Polyamide (Nylon 6,6)	50 to 60	1.13–1.15

Data adapted from Perkinelmer (2019) and Sundt et al. (2014).

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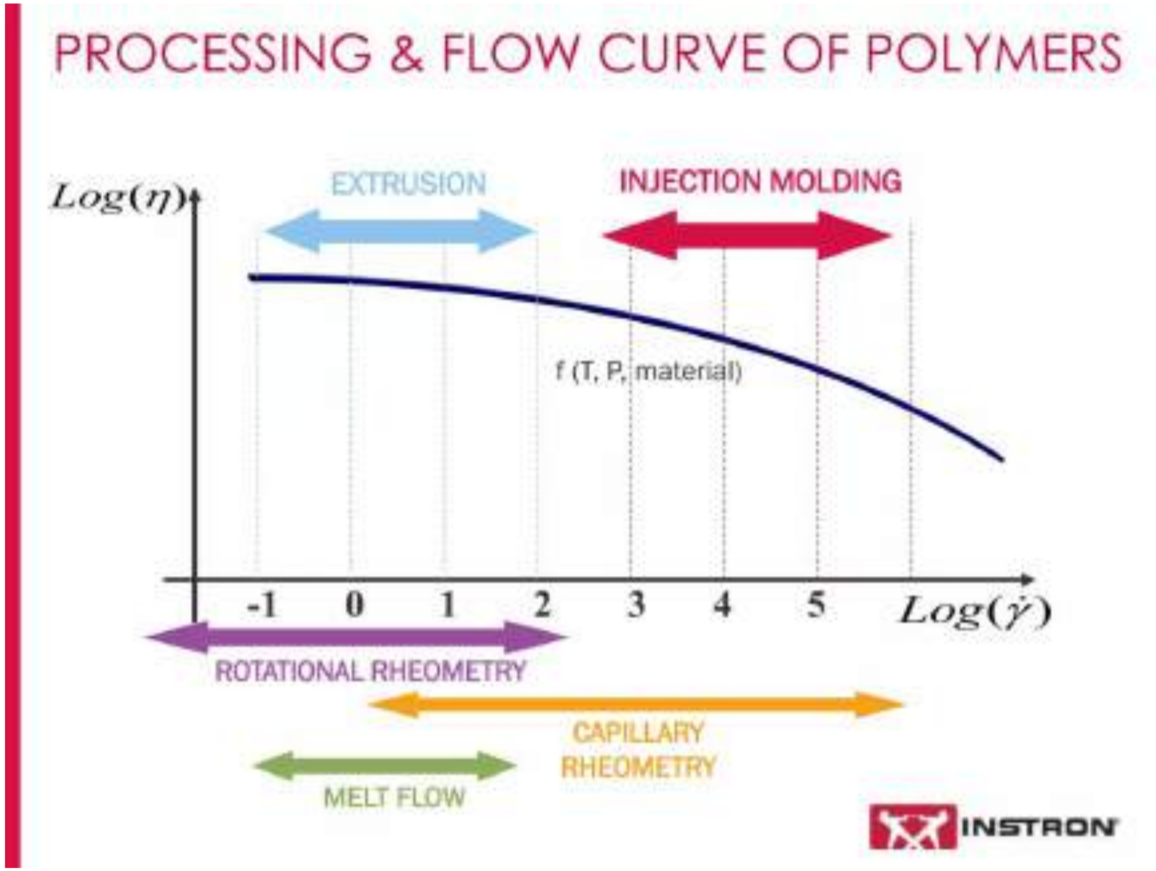

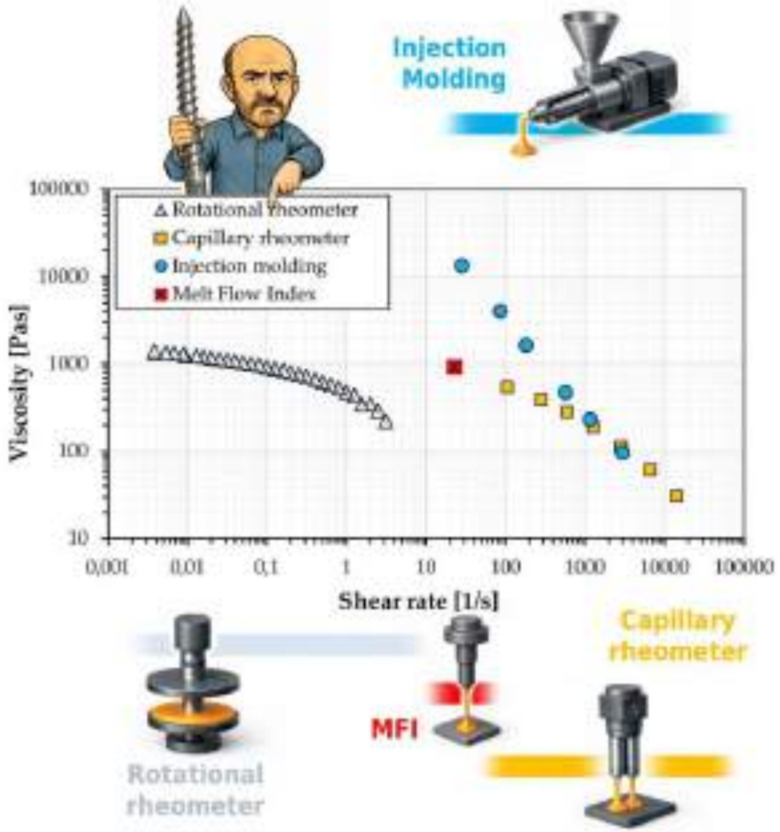

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Other advantages of plastics include:
•Design freedom ("anything is possible," finishes, colors)
•Low specific weight
•Reduced process costs for large-scale production
•Integration of functions and components
•Potential for environmental resistance (especially corrosion resistance)
•Low thermal and electrical conductivity (insulating properties)
•Enhanced passive safety
•Transparency capabilities
•Ability to manufacture custom materials

The drawbacks of plastics include:
•Service temperature limitations
•Tooling costs for short production runs
•Tolerances
•Limited structural responsibility
•Service life
•Complexity of manufacturing processes
•Inexperience of design teams
•Engineering challenges in defining proper boundary conditions.

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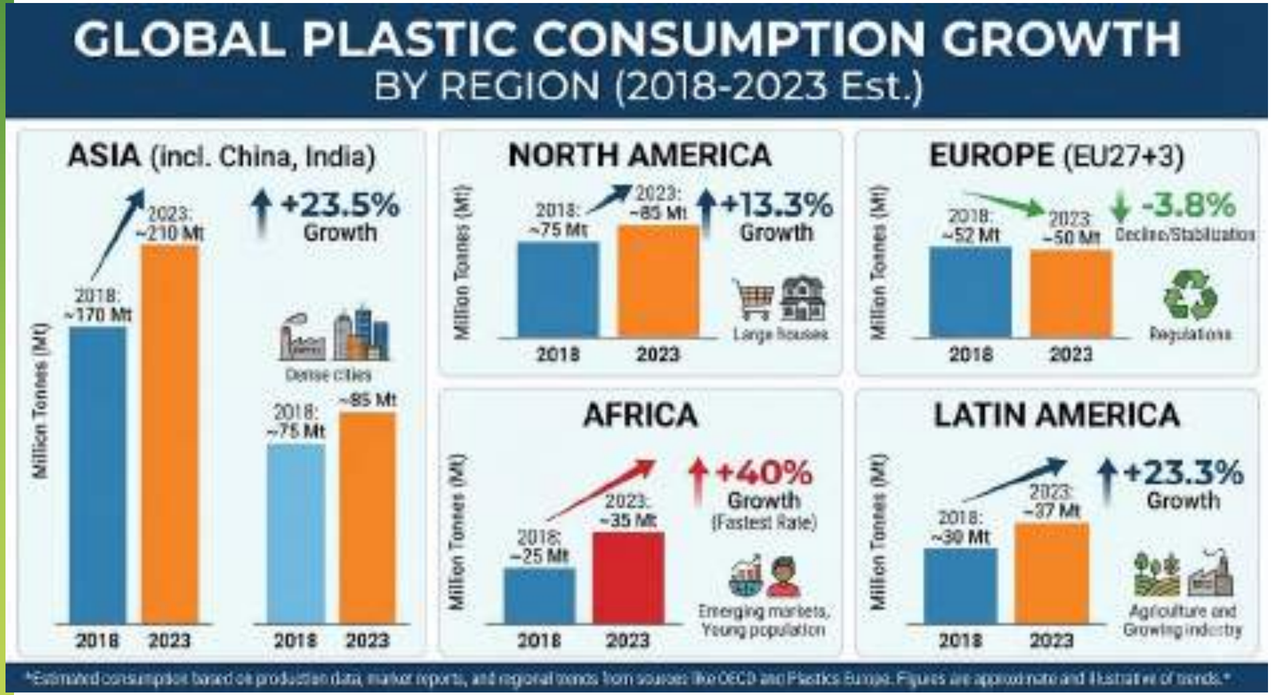

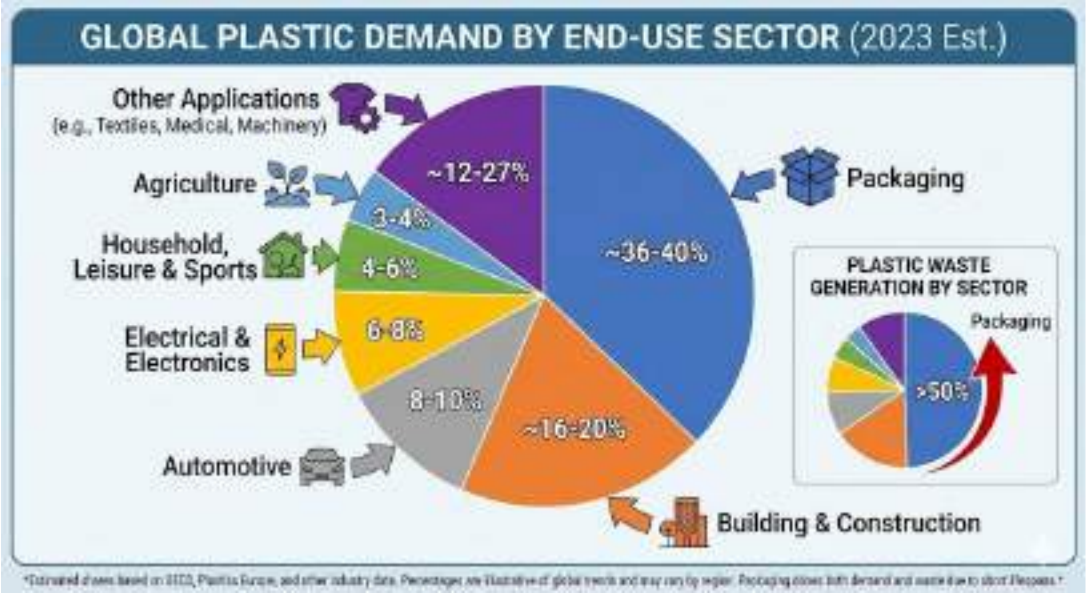

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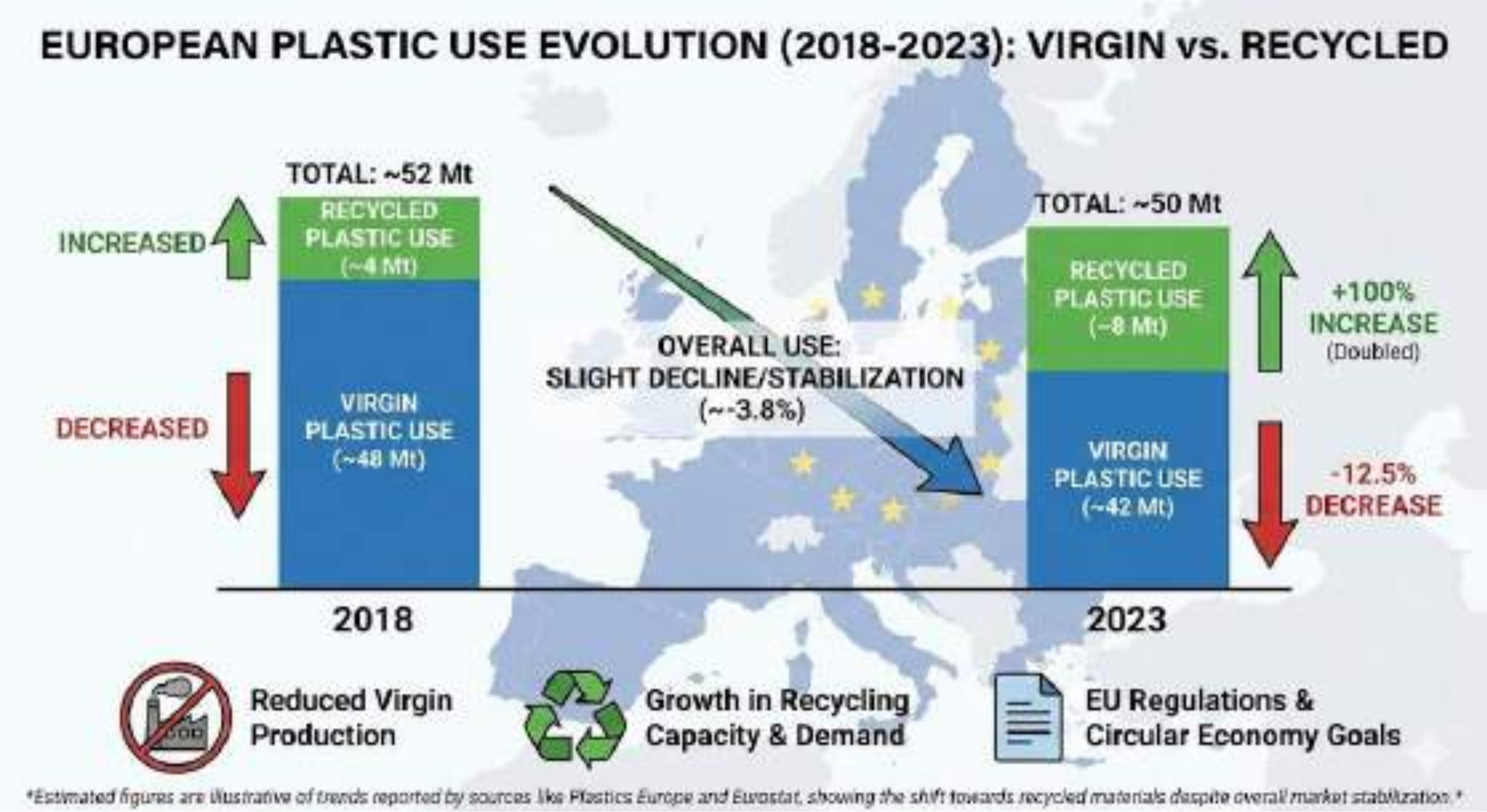

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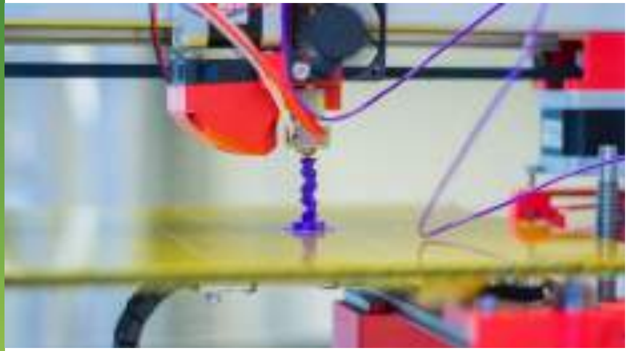
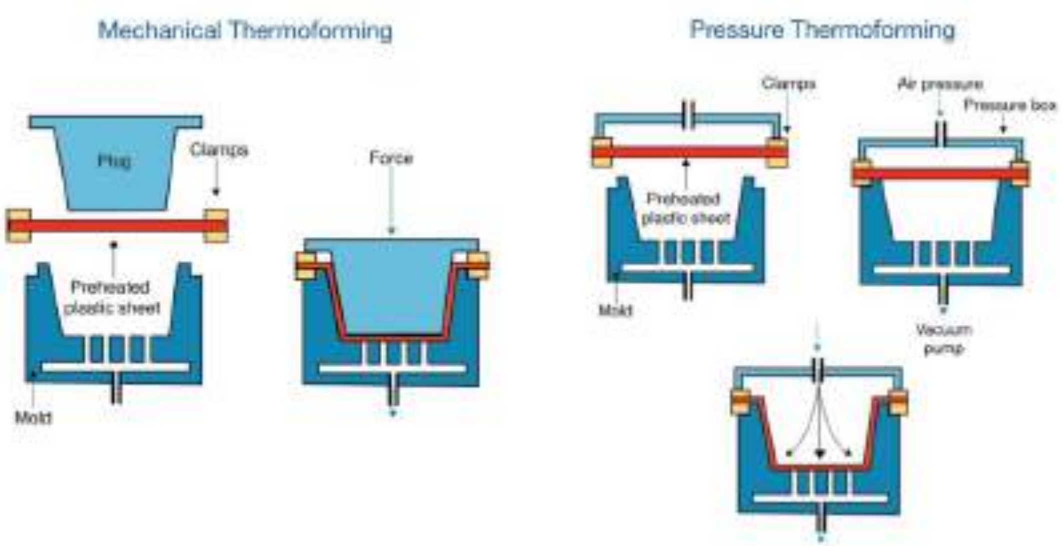
Plastic processing technologies





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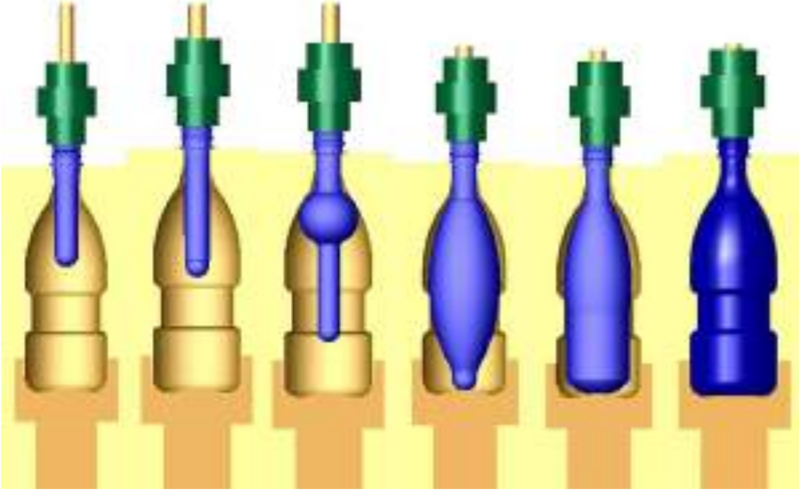
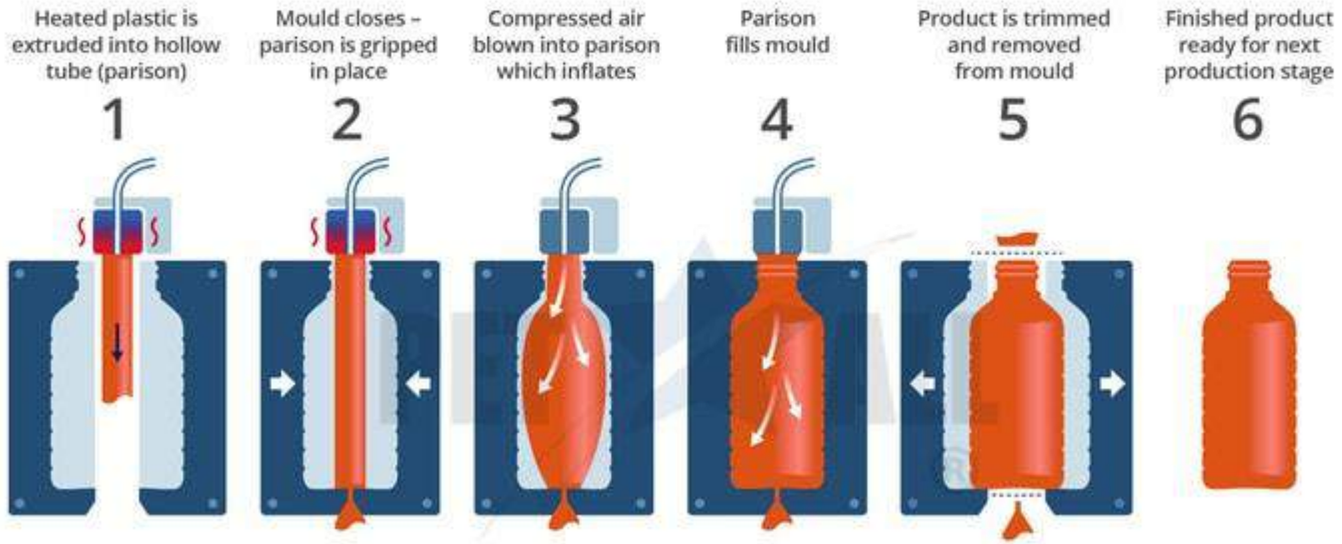
Plastic processing technologies





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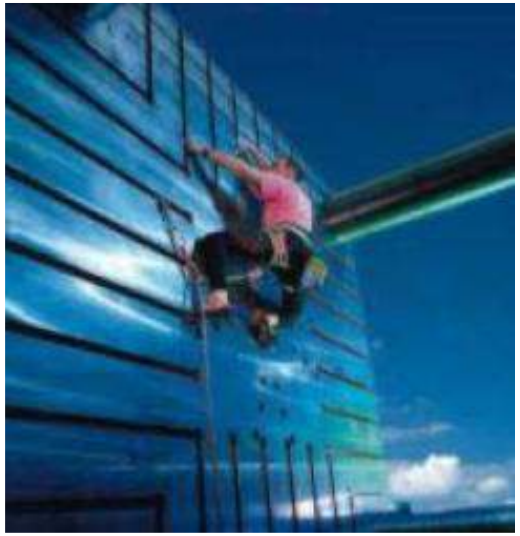
Machinery



Working ranges:
- 10 to 5,000 tons of clamping force
- 1 gram to 100 kg of shot weight
- 1 to 3 meters

Injection machine manufacturers:
1. Engel
2. Arburg
3. Krauss Maffei
4. Husky Injection moulding Systems
5. Sumitomo (SHI) Demag
6. Nissei Plastic Industrial
7. Haitian International
8. JSW Plastics Machinery
9. Milacron
10. Toshiba Machine

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Limitations in injection moulding

1. **Clamping Force**: The clamping force of an injection machine determines the maximum force it can apply to hold the mould closed during the injection process. It typically ranges from a few tons to several thousand tons. Common ranges include 10 tons to 5000 tons or more.
2. **Shot Weight**: The shot weight refers to the amount of molten plastic injected into the mould cavity in a single shot. It can range from a fraction of a gram to several kilograms. Common ranges include 1 gram to 10 kilograms or more.
3. **Injection Volume**: The injection volume is the maximum capacity of the injection unit to deliver molten plastic. It is measured in cubic centimeters (cc) or grams of plastic. Typical ranges vary from a few cc to several thousand cc.
4. **Mould Size**: The size of the mould that can be accommodated by an injection machine depends on its clamping force and dimensions. Injection machines can handle moulds ranging from small parts to large components. The mould size can vary from a few centimeters to several meters.

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Plastic products in injection moulding








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Injection process

The current production process depends heavily on the injection molding sector. From consumer goods to medical gadgets, a diverse range of products are made using it. A flexible process, injection molding can create complicated structures with excellent repeatability and precision. Like many industries, injection molding is continually changing due to shifting consumer needs, advancing technology, and environmental concerns.

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Automation

Although automation and robotics have long been a component of the injection molding business, recent developments are having a big impact. Automation and robots can increase manufacturing effectiveness while lowering labor costs and raising product quality. The newest trend is the deployment of collaborative robots, or cobots, which assist human operators in tedious or hazardous jobs. Today, robotic systems are becoming more user-friendly and cost-effective as more companies enter the market. In fact, the industrial robotics market is predicted to have a CAGR of 7.2% until 2033.

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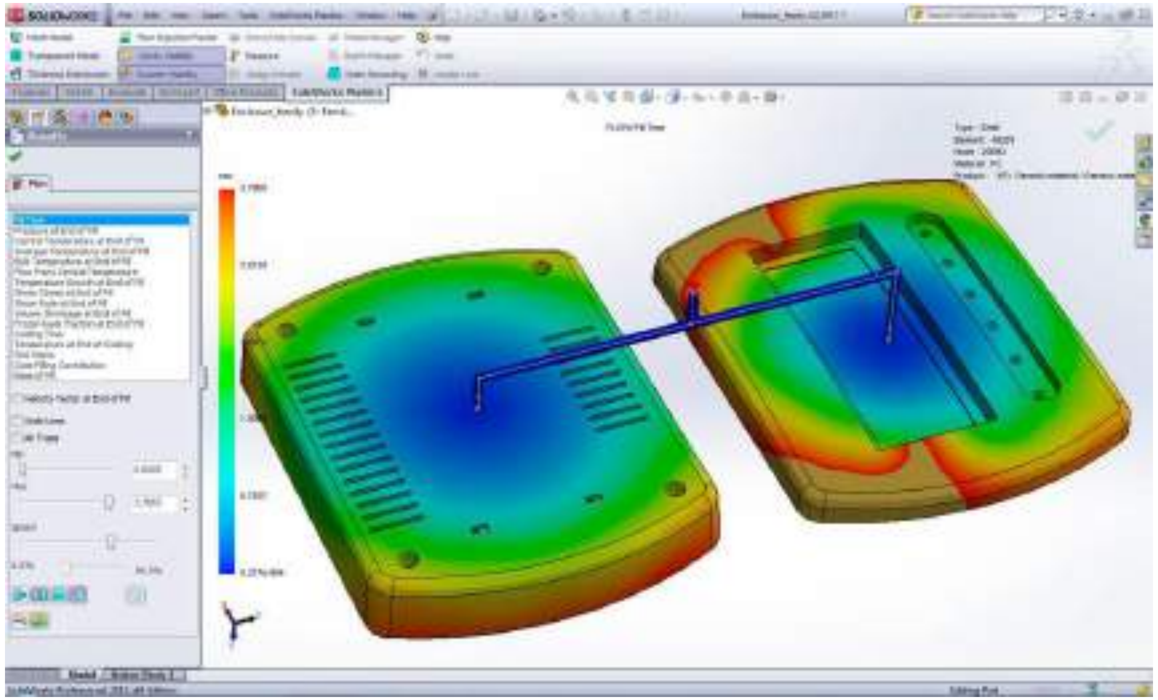
Simulations

Toolmaking is still one of the biggest cost drivers in injection moulding, the development of new moulds, their production and necessary optimisations in the course of series production sometimes significantly squeeze the margins of a project. With new, innovative simulation software, tools can be optimised even before production. The software also makes it possible to provide detailed information on process parameters, such as filling times, flow behaviour of the plastics in the tool or temperatures. In combination with computer-aided component analyses, precise assessments of the readiness for series production of injection-moulded parts are thus possible, without even removing a chip from the future tool.



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Sustainable alternatives

Concerns over how their purchases affect the environment are growing among consumers. As a result, there is a growing trend toward using sustainable materials in injection molding. Biodegradable, compostable, and recycled materials are examples of sustainable materials. Increasing demand for sustainable products, which has driven companies to incorporate plastics that can be recycled or are biodegradable, such as PLA or bio-PET materials, into their offerings.

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Lightweight materials

Another development in the injection molding sector is the use of lightweight materials. Lightweight materials can increase energy efficiency, enhance product performance, and lower transportation costs.

High performance materials

The injection molding industry is also seeing a trend towards the use of high-performance materials that are designed to meet specific performance requirements, such as high strength or heat resistance. Examples of high-performance materials include engineering plastics and thermoset materials.

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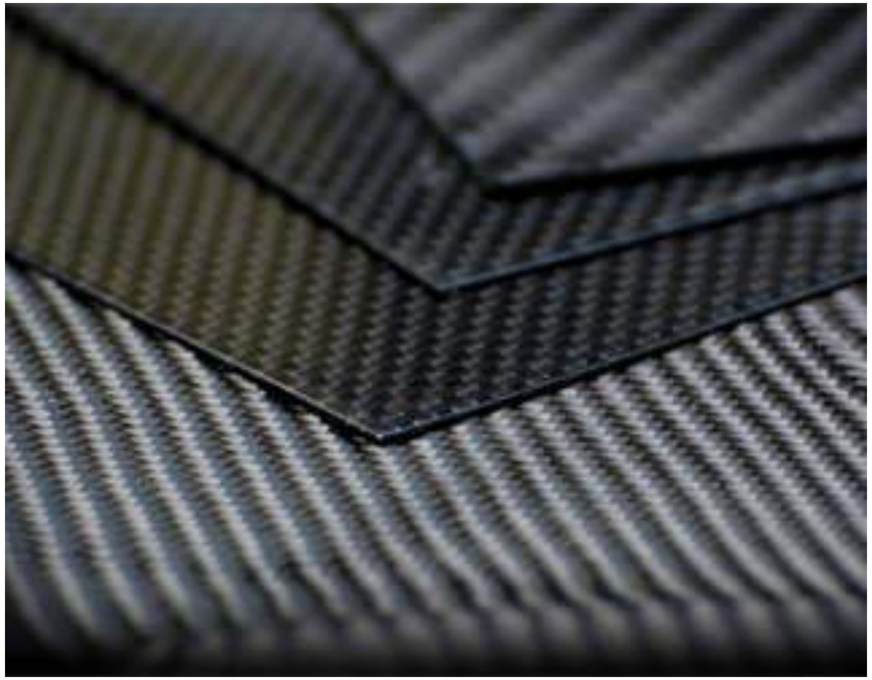
Reinforced materials

In order for injection-moulded parts to exhibit particularly high strength, they can be enriched with fillers or fibres. Injection-moulded composite materials offer excellent mechanical properties combined with low weight, which attracts particular interest from the automotive and aerospace industries. In this way, insulating materials can be made conductive – which opens up completely new fields of application, for example in the area of electromagnetic shielding of technical components. Even though the high-tech materials cannot yet be used economically in series production, research is focusing strongly on that development.



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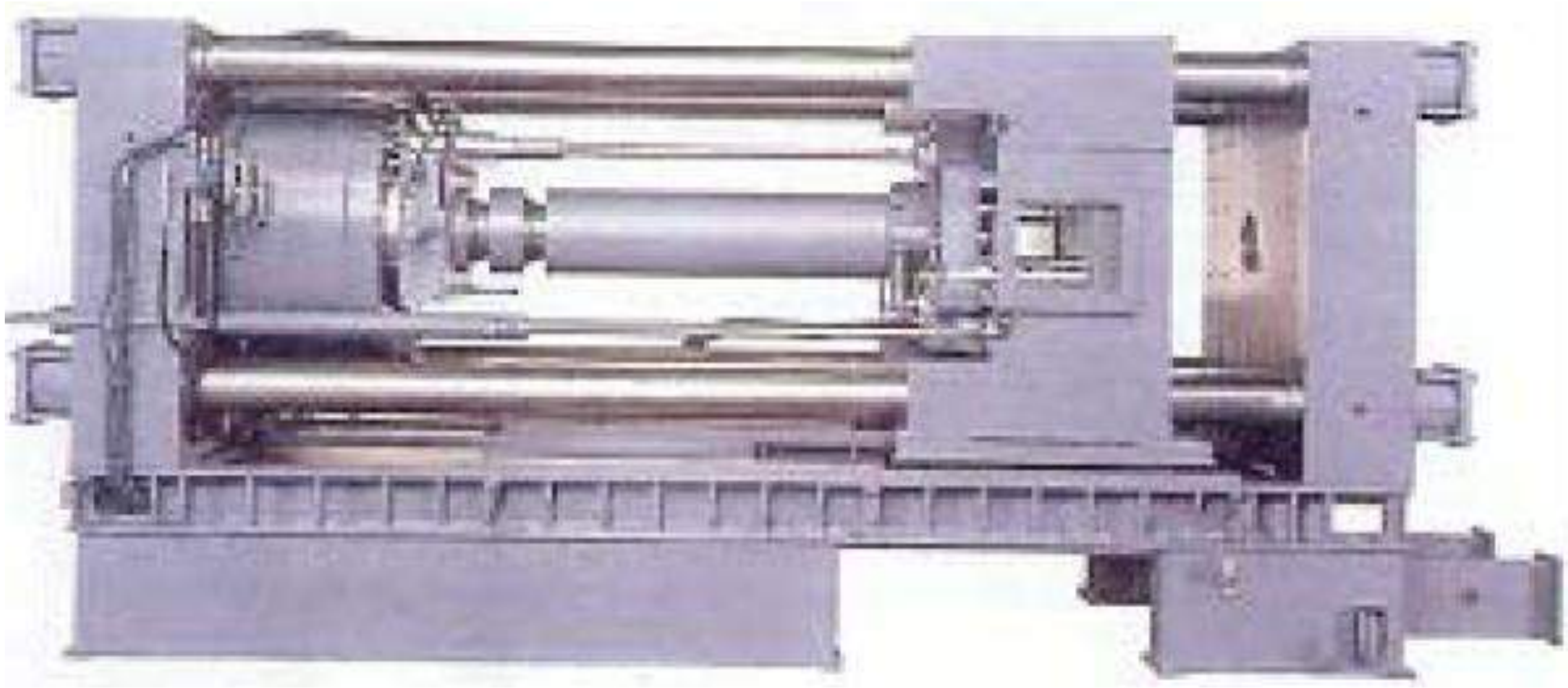
Injection machine

Injection unit

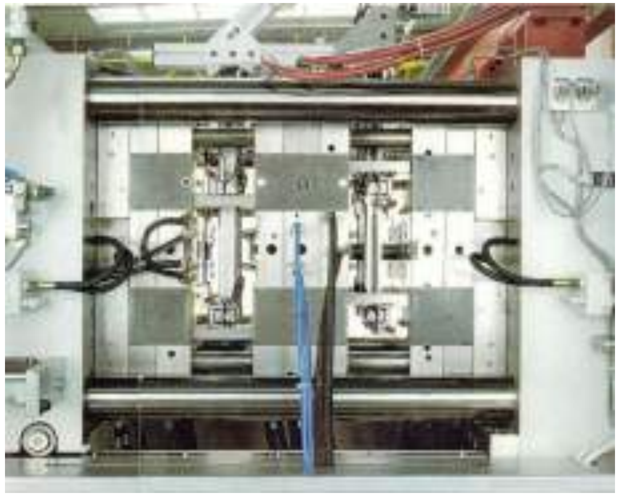
Injection Unit

Clamping unit

Clamping Unit



Clamping unit



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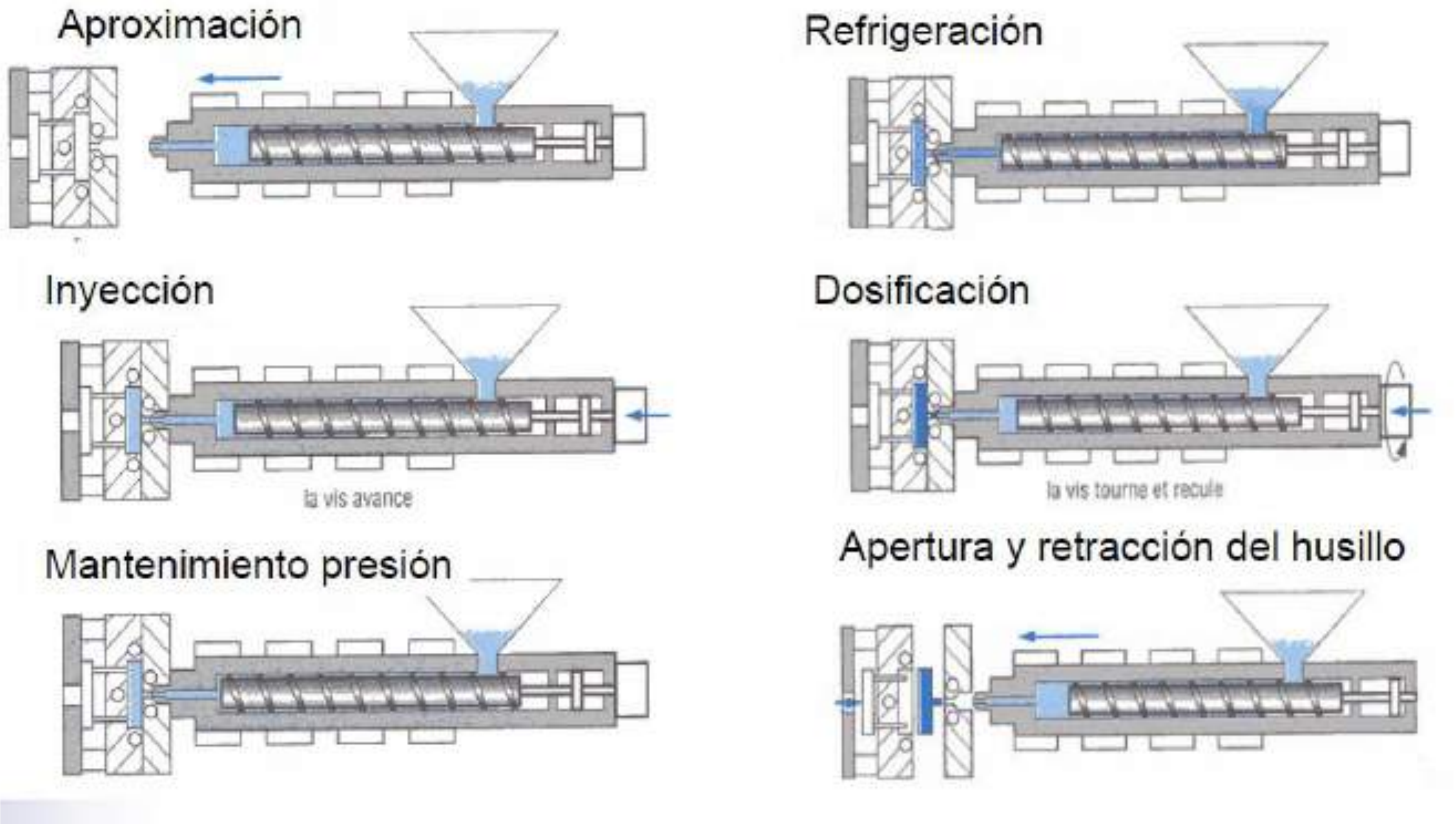
Injection cycle



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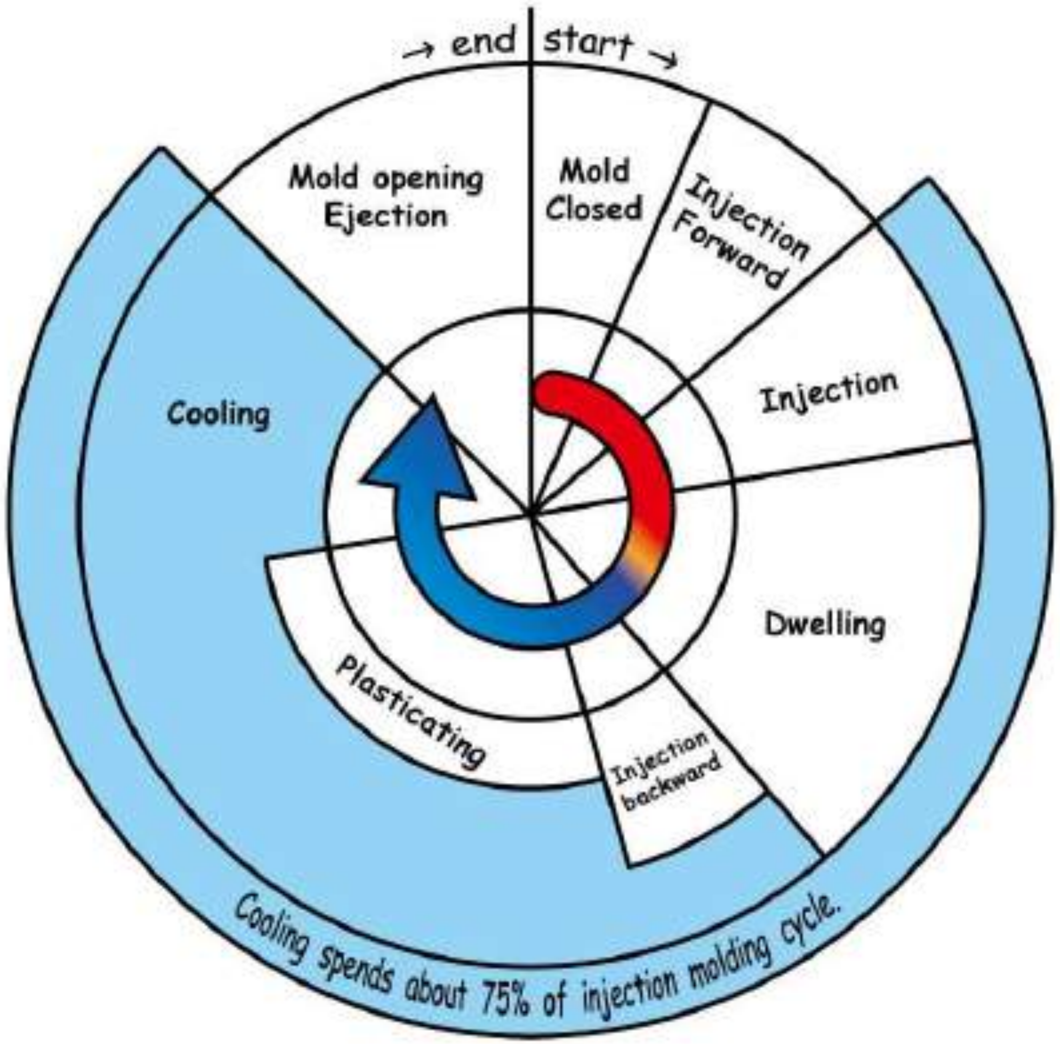
Injection cycle



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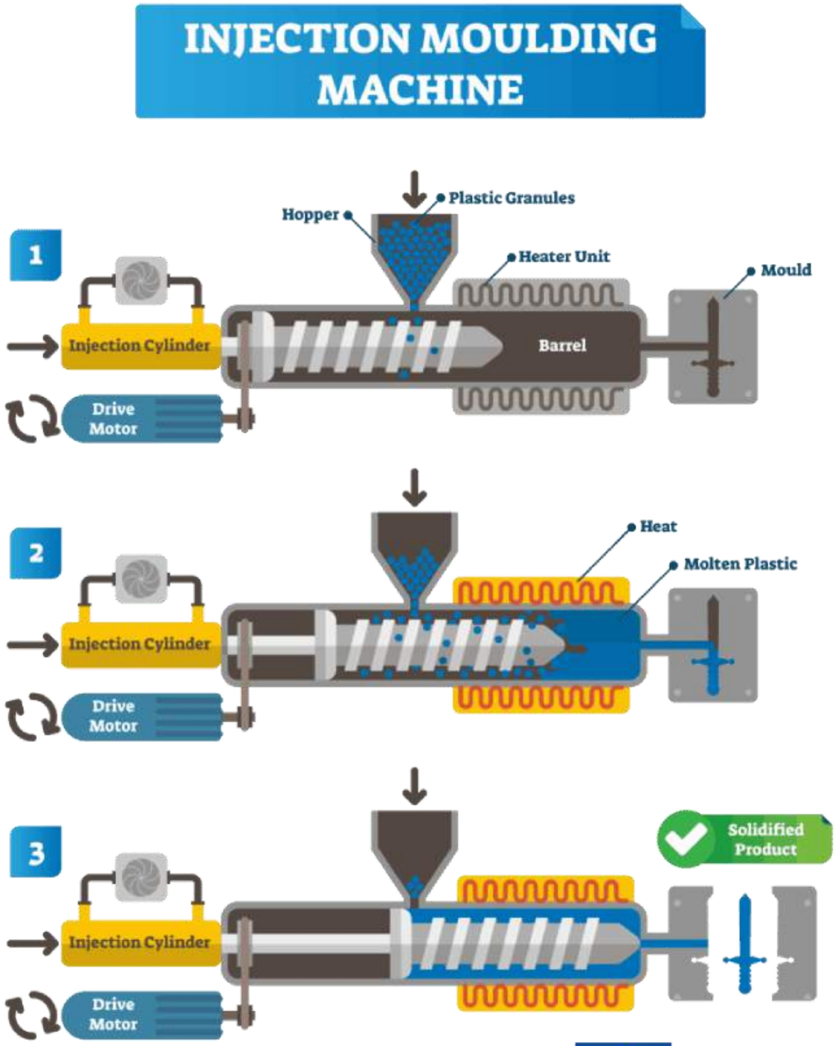
Injection cycle



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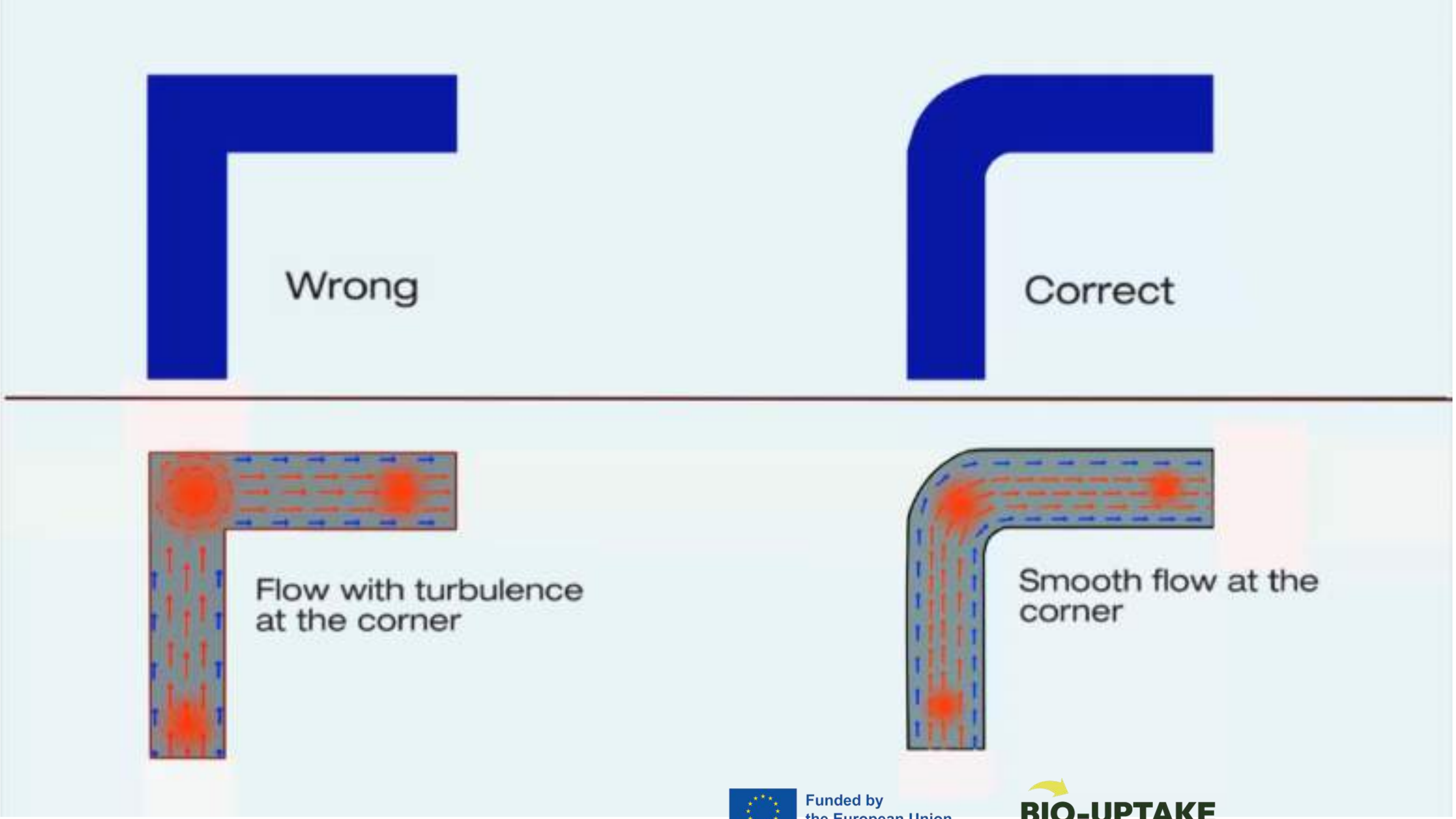
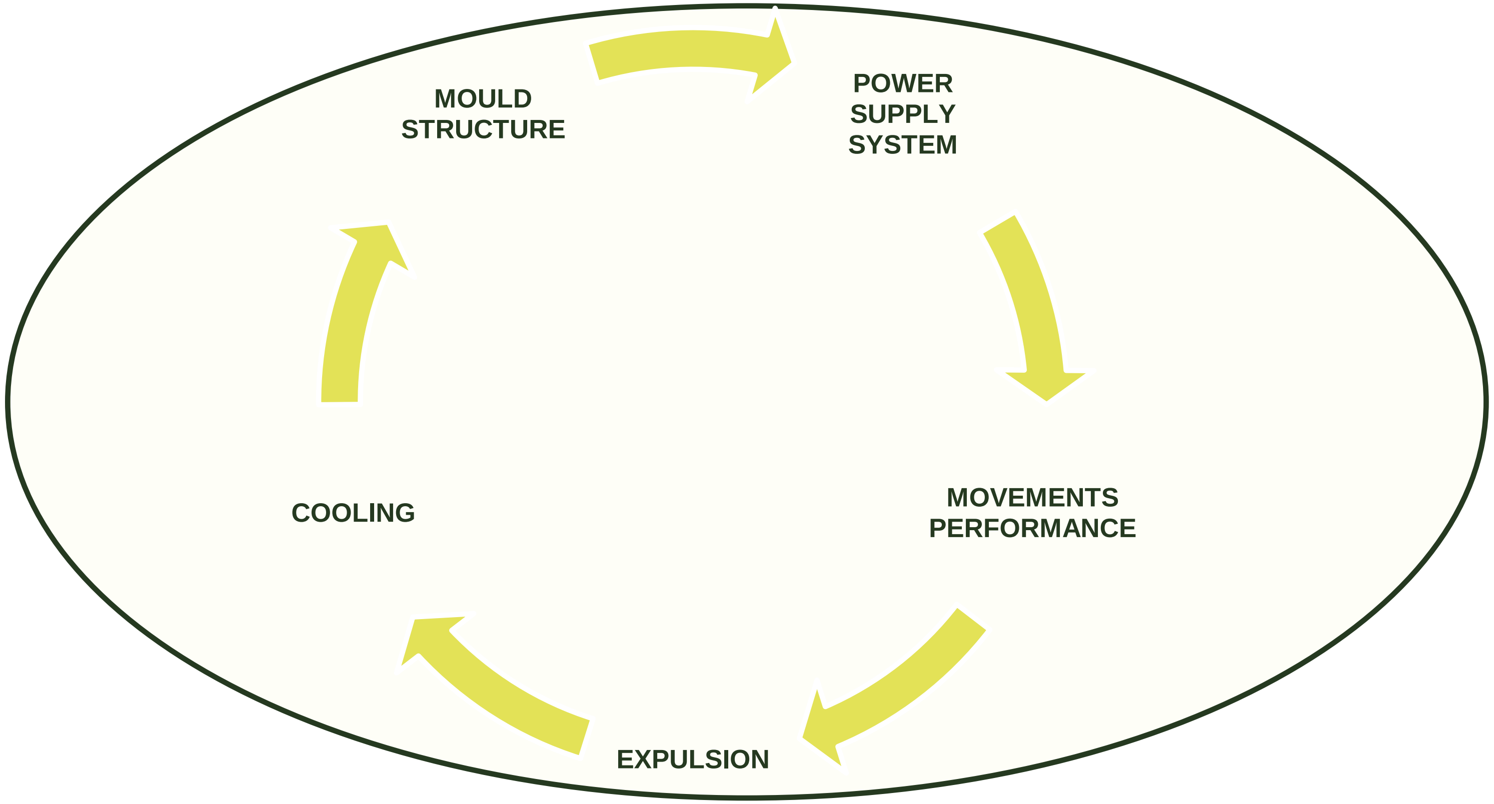
Material flow



Injection cycle (mould)

MOULD: A part in which the figure that is to be obtained in solid form is hollowed out with the molten material that is poured into it. An instrument used to shape something. In reality, it is a set of metal elements that give shape to the molten material that is introduced into it. It is a complex and different system depending on the part to be manufactured. However, in any case, it will have some common elements that we describe below.



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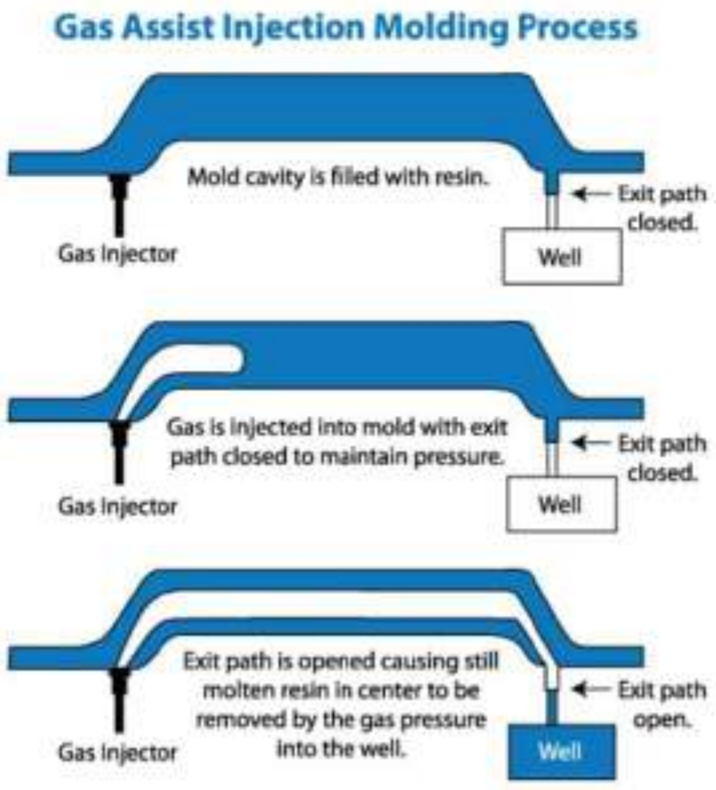
Gas assisted injection



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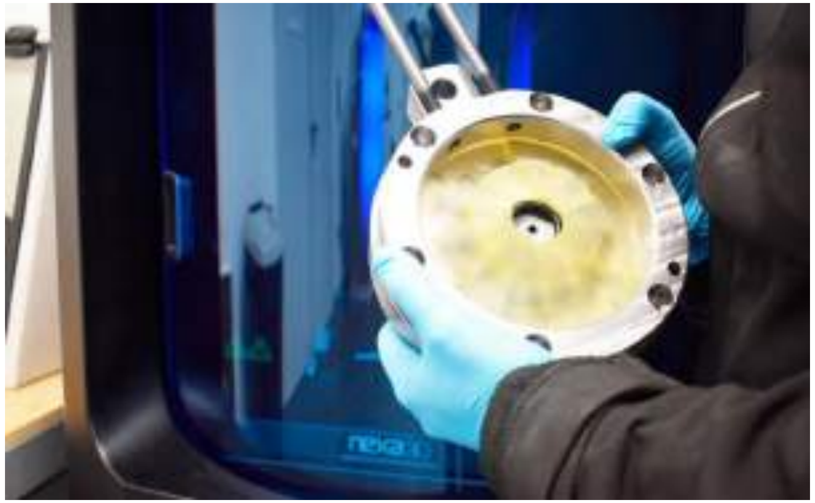
Overinjection



Our injection moulded products

Agriculture sector

Improvement →

- Anti-spark function
- Blade heating reduction
- Ease of assembly and change
- Sustainable cutting process



Coffee sector

15 millions capsules → Domestic 25%, HORECA 75%

Improvement → Adaptability in terms of material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Upscaling of Injection Moulding Process

Alejandro Marqués Paola

Aitiip Technological Centre

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Leading transformation processes and materials

Building together the future

Advanced Materials

Advanced Manufacturing

Advanced Recycling Technologies

Sustainable Solutions & Products

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Upscaling of Injection Moulding Process

Aitiip Technological Centre

Upscaling of Injection Moulding Process: Advanced Multi-Component Technologies

Challenges in the integration of Bio-Based Materials

- **From lab to industry -** The need for special processes.
- **Objective:** Increase functional density and reduce assembly steps**.**
- **Focus:** Over-moulding Technology applied to sustainable technical polymers.

Advanced Injection Technologies

Justification for Special Processes in Upscaling

- **Upscaling Drivers:**
  - **Function Integration**: Combining properties (e.g., rigid-flexible) in a single cycle.
  - **Cost Reduction:** Elimination of downstream assembly processes and reduction of cycle times.
  - **Quality Improvement:** Control of differential shrinkage and warpage in complex geometries.
- **The Logical Step:** Evolving from Standard Injection to Multi-Component Injection.

Over-moulding Process Variants

Multi-Component Strategies: Over-moulding

- **Definition: Production of components with two or more different plastics (color, mechanical properties) in one cycle.**
- **Technology Variants for Upscaling:**
  - Transfer (Robot): Moving the preform to a second cavity/mould.
  - Rotation Technology (Turntable/Index Plate): Rotating the mould or plate for the second shot.
  - Core-Back: Expansion of the cavity via internal mould movements without opening it.

The Critical Challenge: Adhesion and Compatibility

Interface and Material Compatibility

- **The Challenge:** The bond between components is not just mechanical; it is chemical and thermal.
- **Factors Influencing Adhesion:**
  - Temperature and pressure at the contact surface (interface).
  - Basic chemical compatibility between the substrate and the over-moulded material.
  - **Shrinkage Differences:** Main cause of residual stresses and delamination.
- **Risk:** Delamination failures if shear or cooling are not controlled.

Case Study – Over-injection of Reinforced PA10-10

Process Characterization for Bio-Based PA10-10

- **Validation Methodology:**
  - Analysis of the processing window (Melt Temperature vs. Mold Temperature).
  - Evaluation of Bonding Strength via tensile testing on over-moulded specimens.
  - **Importance of Simulation:** Predicting thermal behavior and molecular reptation at the interface

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User case – Reinforced biobased PA10-10 over-injection

Aitiip Technological Centre

Case Study – PLA Organosheet BioPA10-10 Over-injection

Objectives:

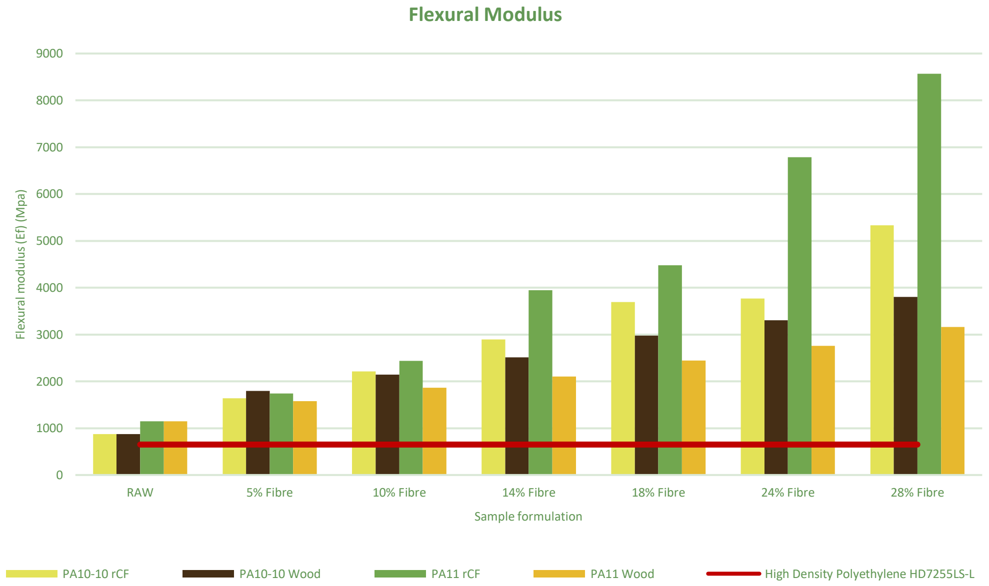
- Eco-Design & Material Substitution
  - Container Lid
- Enhanced End-of-Life (EoL) Performance.
- Circular Economy Integration.
- Valorization of Industrial Side-streams

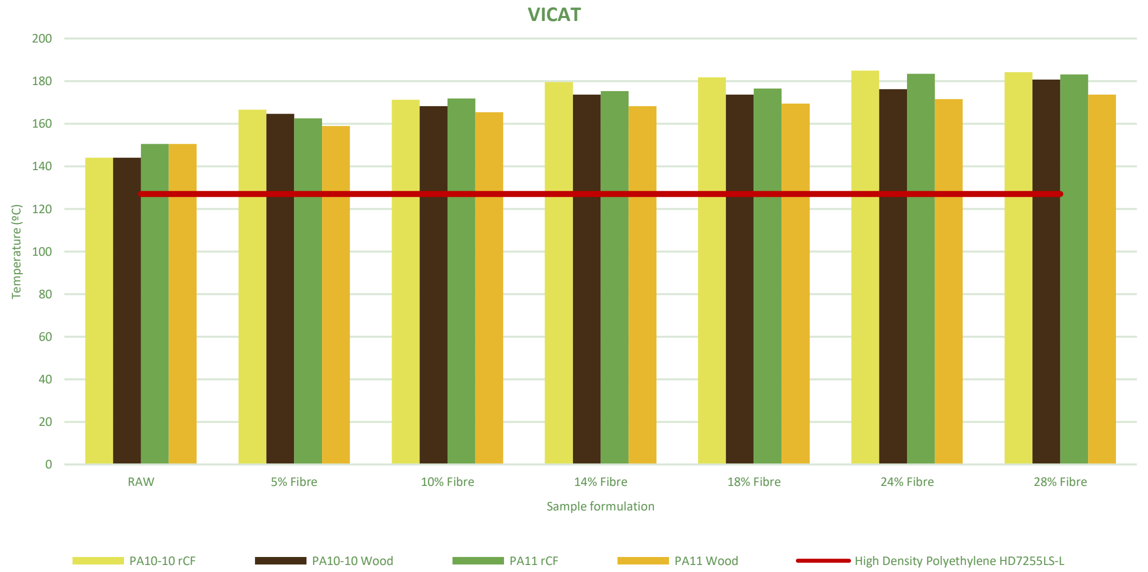
Case Study – PLA Organosheet BioPA10-10 Over-injection

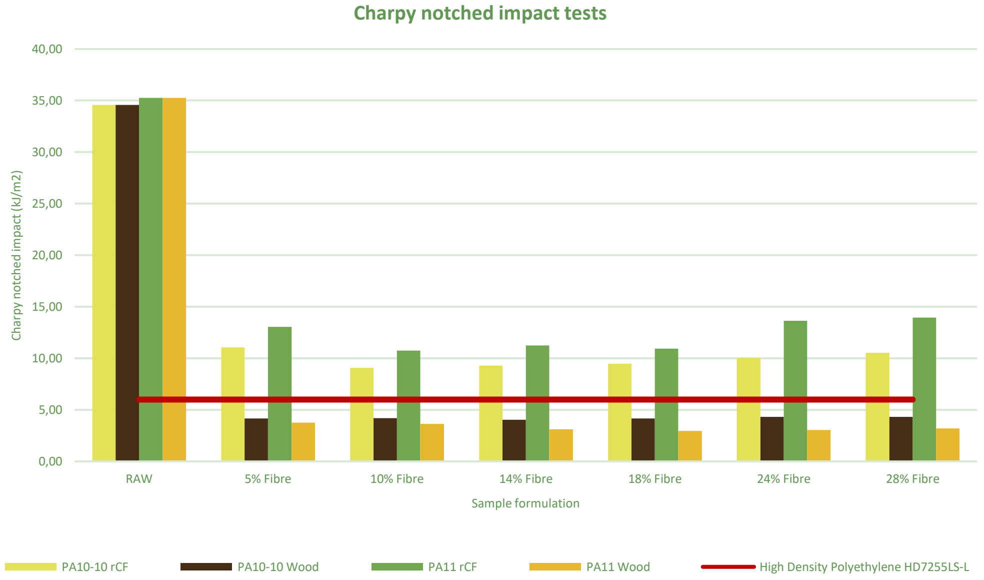
Objectives:

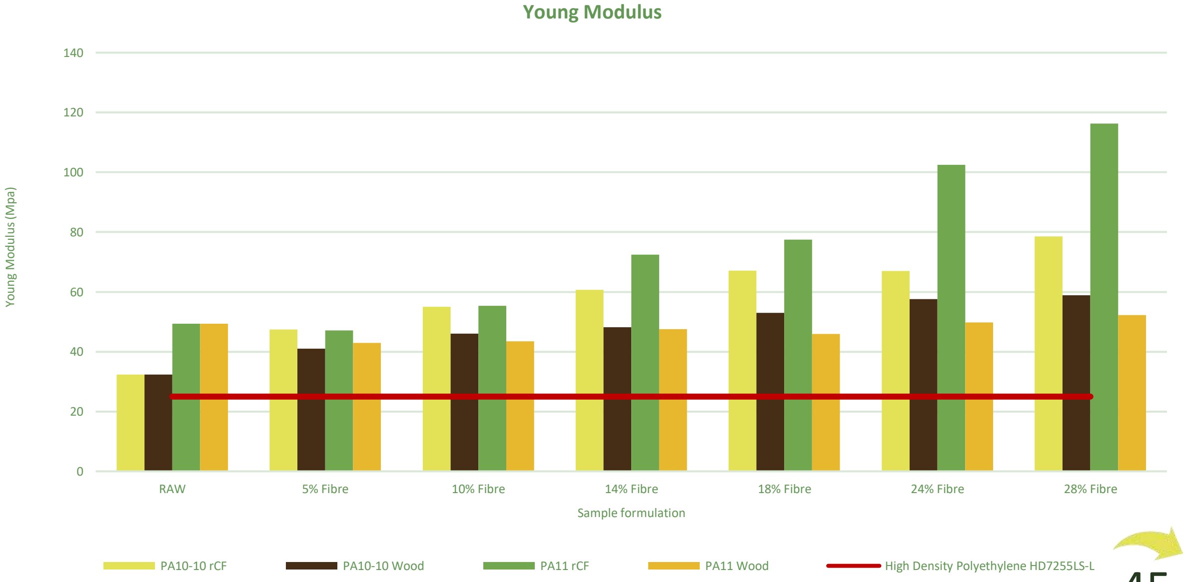
- Eco-Design & Material Substitution
  - Container Lid
- Enhanced End-of-Life (EoL) Performance.
- Circular Economy Integration.
- Valorization of Industrial Side-streams

Tested formulations





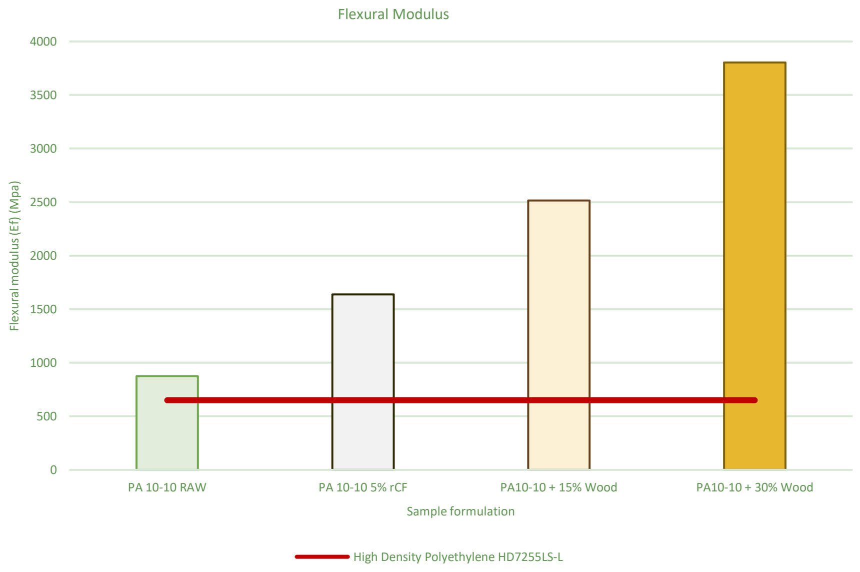


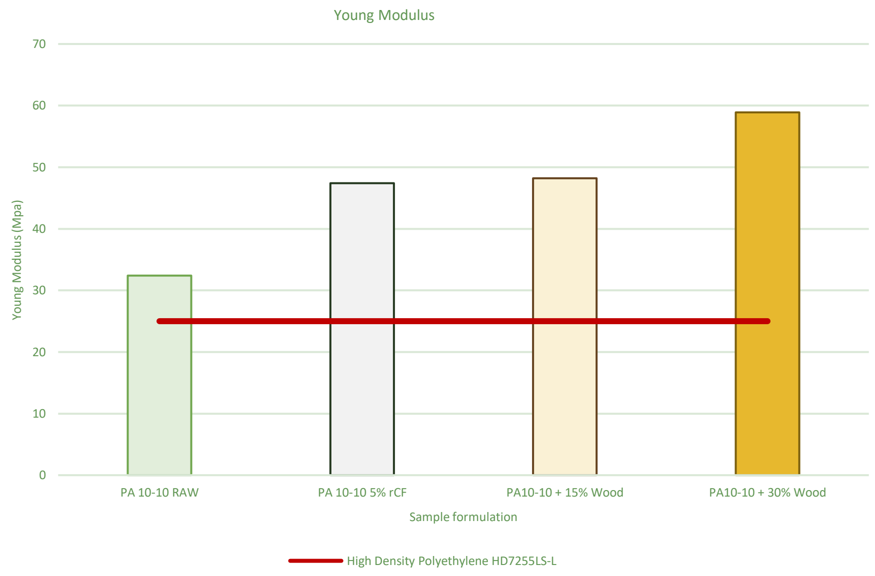


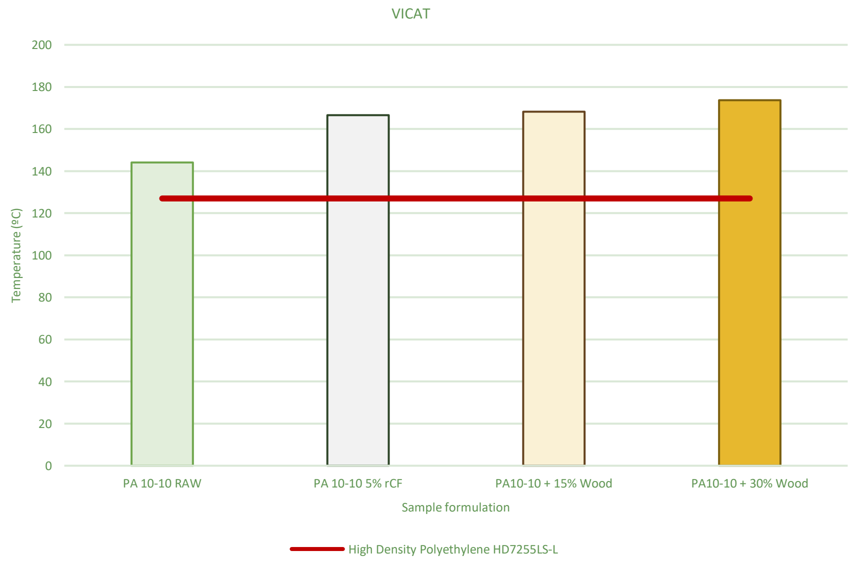
Selected formulations to be scaled up

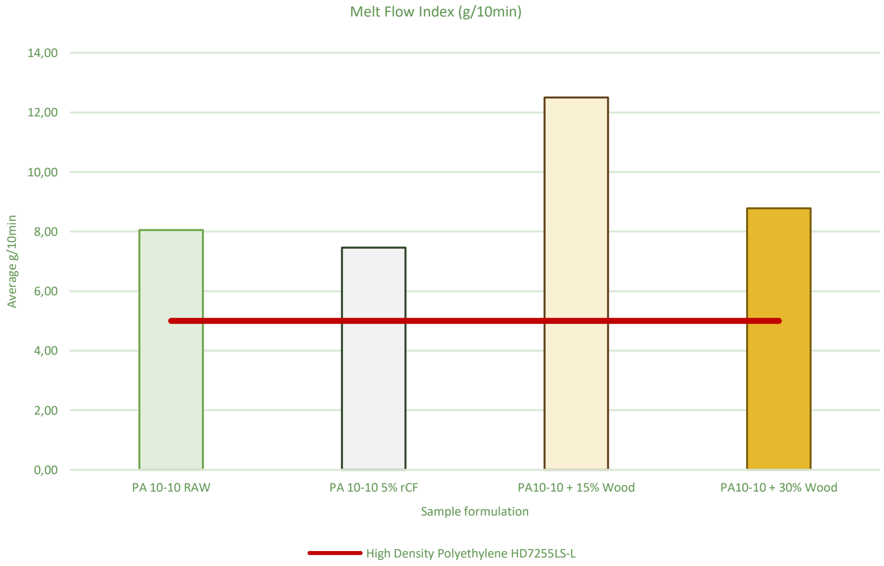
- **PA10-10 Raw:**
  - Meets the thresholds of the lid requirements
    - Lower mechanical properties
  - Low cost
  - Bio-based material
  - Bio-pellets easy to process
  - Low impact matrix
  - Absence of fibre
- **PA10-10 + 15% Wood reinforcement:**
  - Meets almost all thresholds of the lid requirements
    - Lower properties than PA10-10 + 30% Wood reinforcement
    - Does not reach threshold in the impact test
    - Applies the PLA organosheet
  - Bio-based matrix + Recycled reinforced
  - Reuse of waste - lowers overall price
  - Fibre reinforced bio-pellets easy to process
  - Low impact matrix + Low impact reinforcement
- **PA10-10 + 5% recycled Carbon Fibre:**
  - Exceeds all thresholds of the lid requirements
  - Bio-based matrix + Recycled reinforced
  - Objective to use recycled CF from VIBES-BBI project
  - High price
  - Fibre reinforced bio-pellets difficult to process
  - High impact reinforcement
- **PA10-10 + 30% Wood reinforcement:**
  - Meets almost all thresholds of the lid requirements
    - Does not reach threshold in the impact test
    - Applies the PLA organosheet
  - Bio-based matrix + Recycled reinforced
  - Reuse of waste - lowers overall price
  - Fibre reinforced bio-pellets easy to process
  - Low impact matrix + Low impact reinforcement

Selected formulations to be scaled up









Case Study - Reinforced PA10-10 over-injection

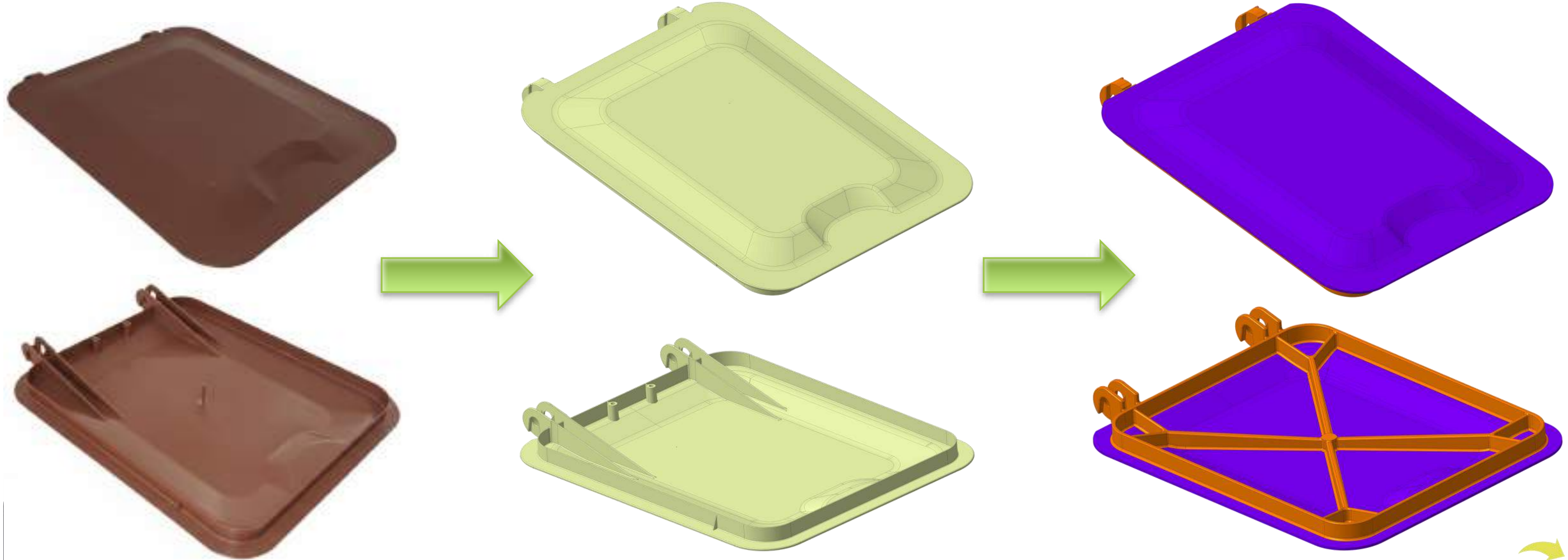
Over-injection process integration

Case Study - Reinforced PA10-10 over-injection

Process Characterization for Bio-Based PA10-10

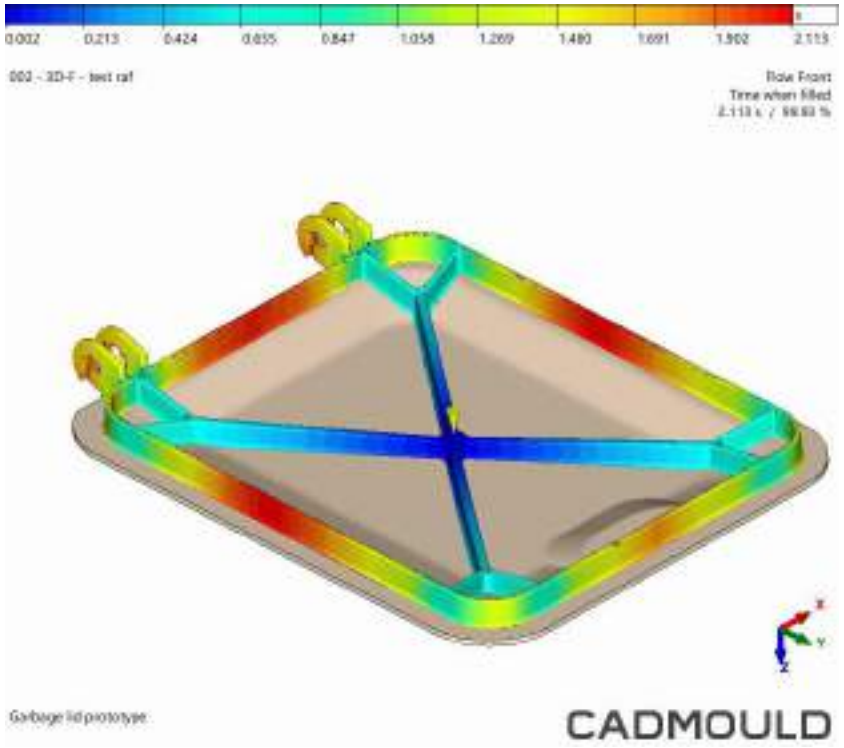
Case Study - Reinforced PA10-10 over-injection

Process Characterization for Bio-Based PA10-10



Case Study - Reinforced PA10-10 over-injection

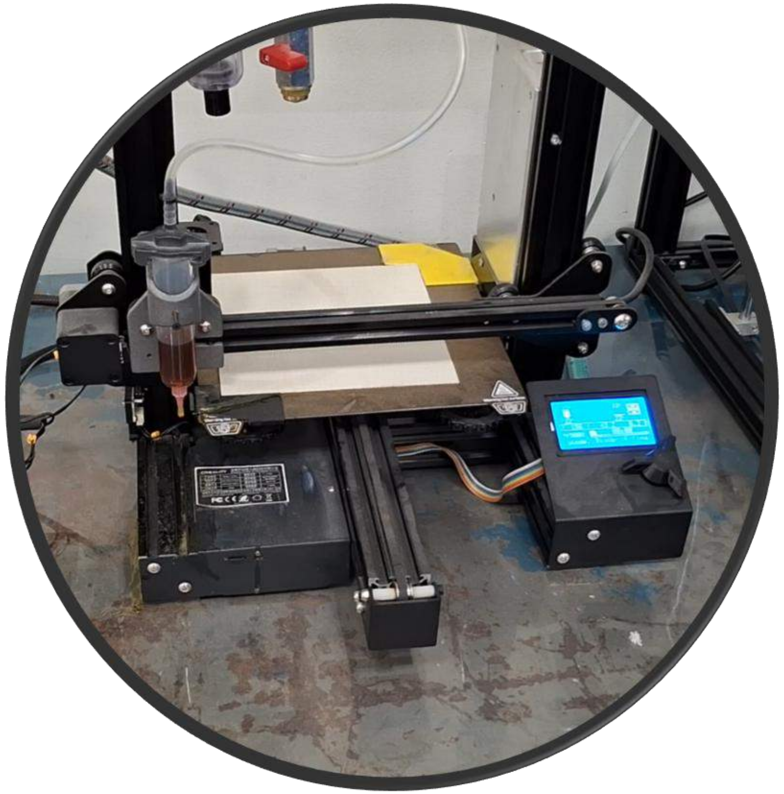
Process Characterization for reinforced PA10-10 over-injection



- The new design must be simulated.
  - Test the mould filling.
  - Optimize cycle time.
- Complete filling is verified
- The calculated filling cycle time is 2.1 seconds
  - The total cycle time must include:
    - Forming time (30 s)
    - Sealing time (60 s)

Organosheet - injected material adhesion

Reversible dynamic chemicals (CANs)



- Thermally activated bond-exchange processes
- Structurally resemble thermosets
  - Permanent covalent crosslinks.
- Thermoplastic behaviour when dynamic chemical reaction is active
- CANs aplication – 3D printer system

Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

- **First step –** Organosheet allocation inside the Injection machine

Case Study – PLA Organosheet Over-injection

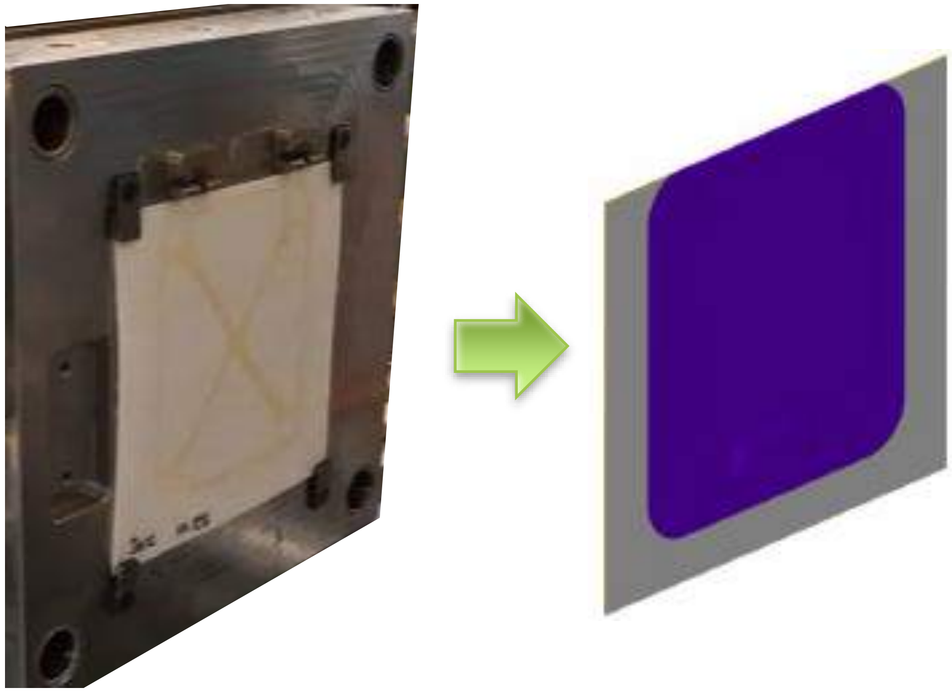
Over-injection demonstrator

- **First step –** Organosheet allocation inside the Injection machine

Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

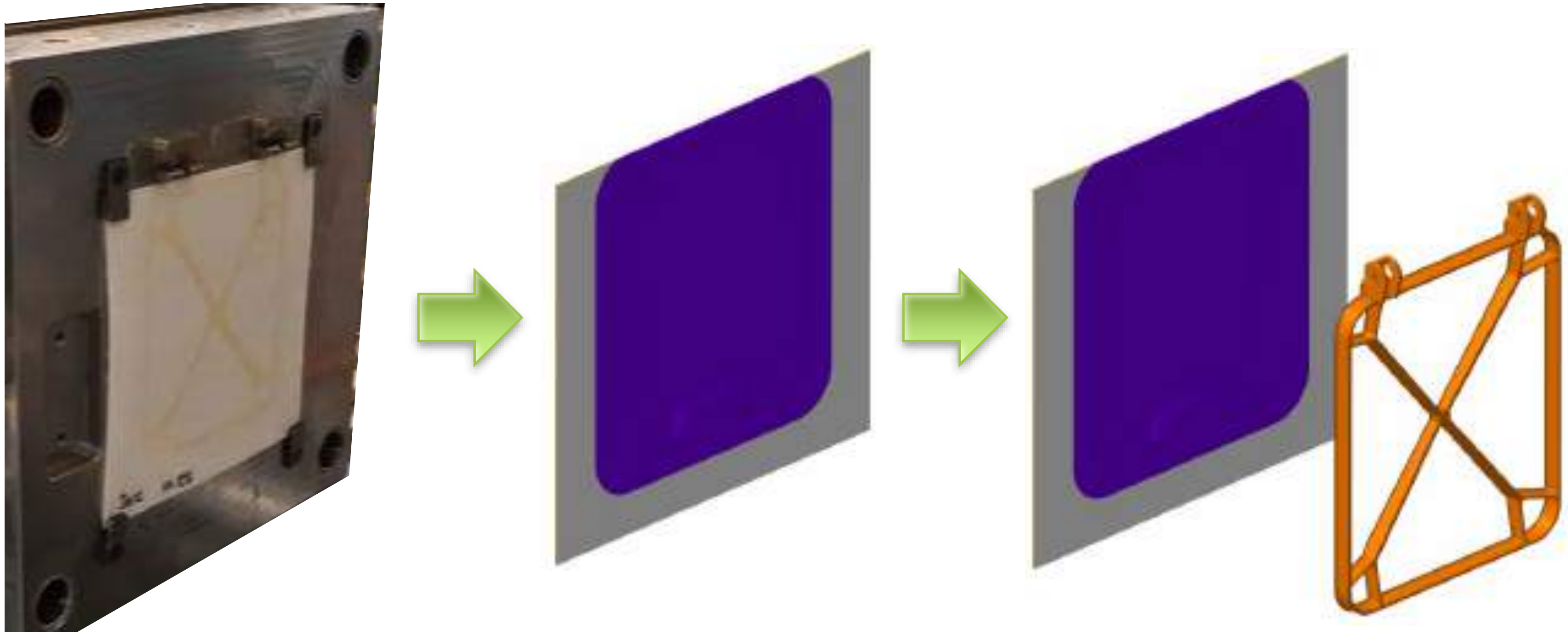
- **Second step –** Injection moulding machine closing – PLA organosheet conforming - injection moulding machine opening



Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

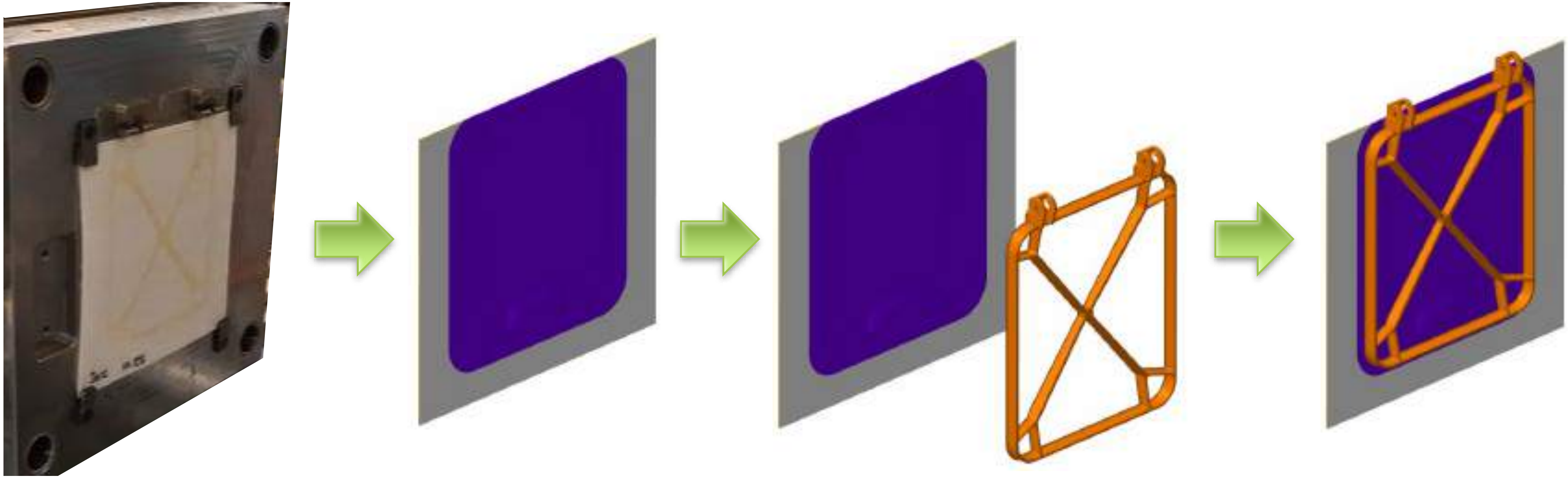
- **Third step –** Injection moulding machine closing – reinforced PA10-10 injection



Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

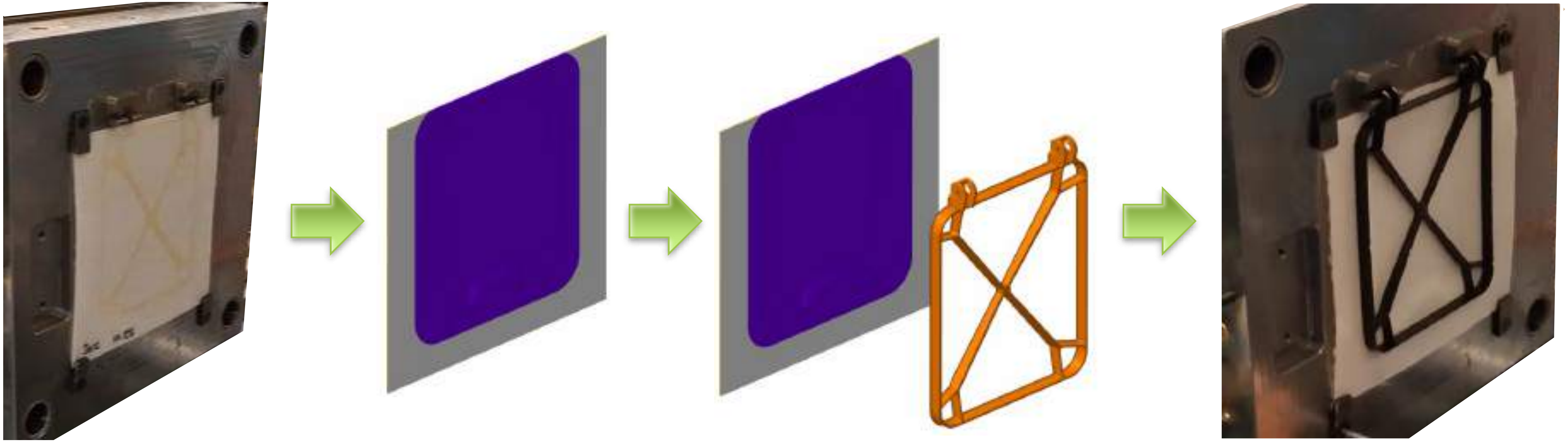
- **Fourth step –** Injection moulding machine opening – Over-moulded container lid extraction



Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

- **Fourth step –** Injection moulding machine opening – Over-moulded container lid extraction



Case Study – PLA Organosheet Over-injection

Over-injection demonstrator

- After an automated trimming process, the over-injected container lid is ready for installation

Container lid – Final result

- Need for Multi-Component Technologies for Scaling
- Trade-off between Performance and Processability in Biopolymers
- Hybrid Solution using Organo-sheets
- Critical Importance of Interface Validation

Injection Moulding of Bio-Based materials – FAQ Session

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