



Extruding Biopolymers on Conventional Extrusion Equipment

Summary

This paper will briefly present some aspects of the extrusion of the following polymers using the Blown, Cast or Thermoforming Sheet processes

- PLA (Polylactic Acid)
- Biopar (with Ecoflex)
- PBS (Polybutylene Succinate)

PLA

- Currently the major use we see for this resin is in Thermoforming Sheet applications
- This material has to be extruded with a moisture content of less than 250 ppm and typically requires pre-drying of 4 hours at 60 deg C using a desiccant type drier
- A conventional 3 stage screw design (feed/compression/metering) is used as barrier screws give problems with the melt “hanging up” in the barrier flight section

PLA Thermoforming Sheet

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Typical 3-roll Cooling
and Polishing stack
for thermoforming
sheet



PLA Thermoforming Sheet

It is important to minimise web sag between the die exit and the primary roll gap.

This can be done by utilising a special “duck bill” die design and using a smaller diameter top roller on the cooling and polishing roll stack

Correct die gap setting is also important

High roll closing forces are required so hydraulic operation rather than pneumatic is necessary

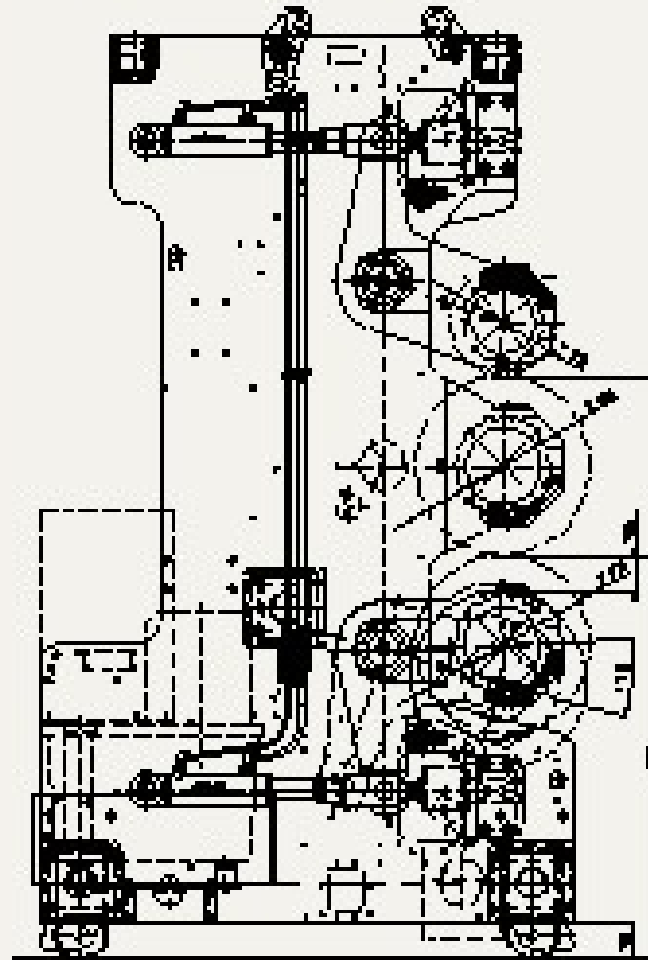
Individual roll drives by servo motors enable cooling rates, shrinkage and brittleness to be better controlled

PLA Thermoforming Sheet

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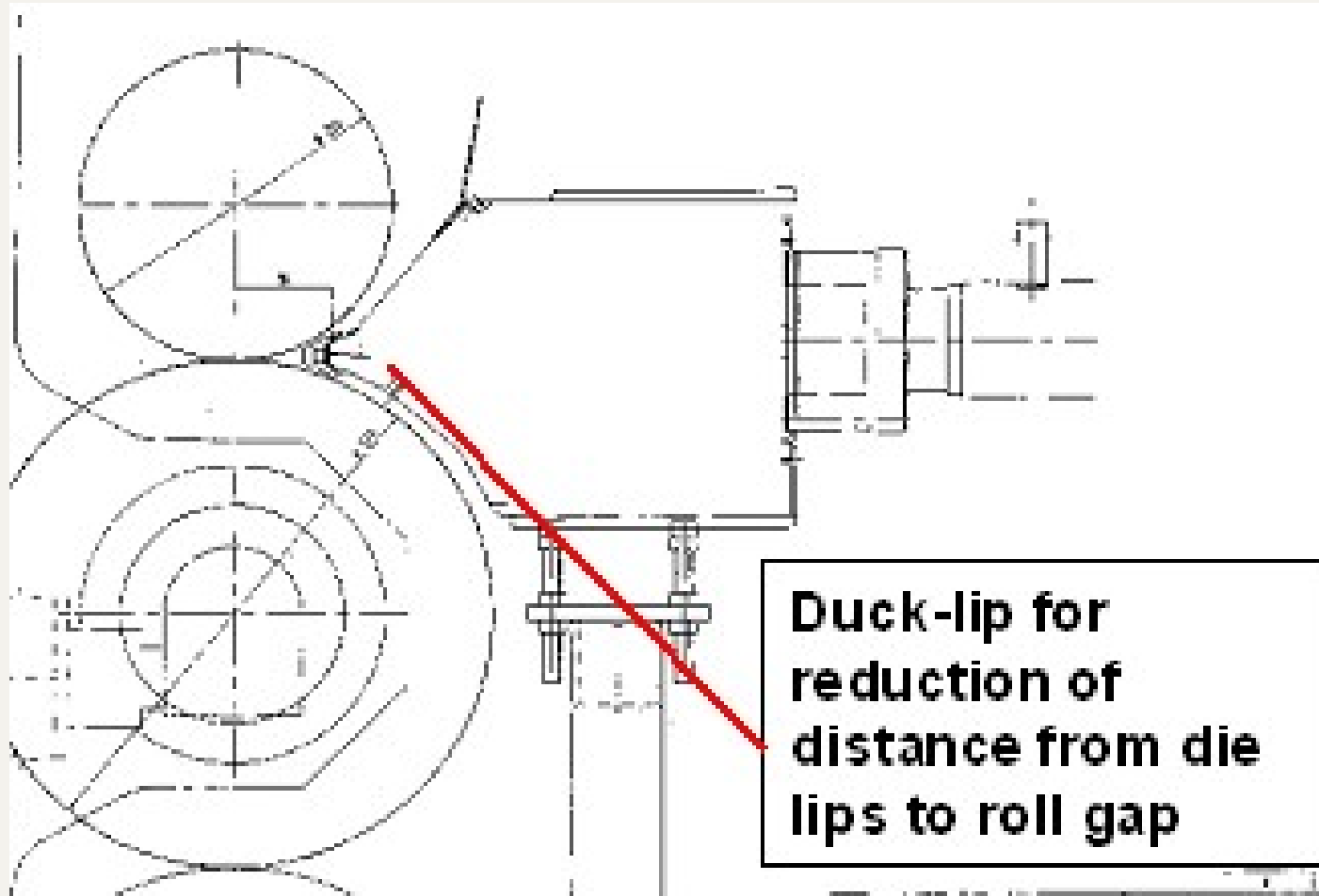
**3 Polishing Rolls - typically:
1 x Ø310mm - 2 x Ø510mm**

Drive: 3 x AC - Servomotor



PLA Thermoforming Sheet

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PLA Thermorming Sheet

- The cooled sheet produced has good mechanical properties but it is brittle.
- The film path needs to contain a minimum number of rollers that should ideally be around 6" minimum diameter to minimise web breaks
- Thicker sheet (>1 mm) requires the use of rotary shears rather than conventional blade slitters for the same reason
- Winding cores should also be 6" rather than 3" diameter

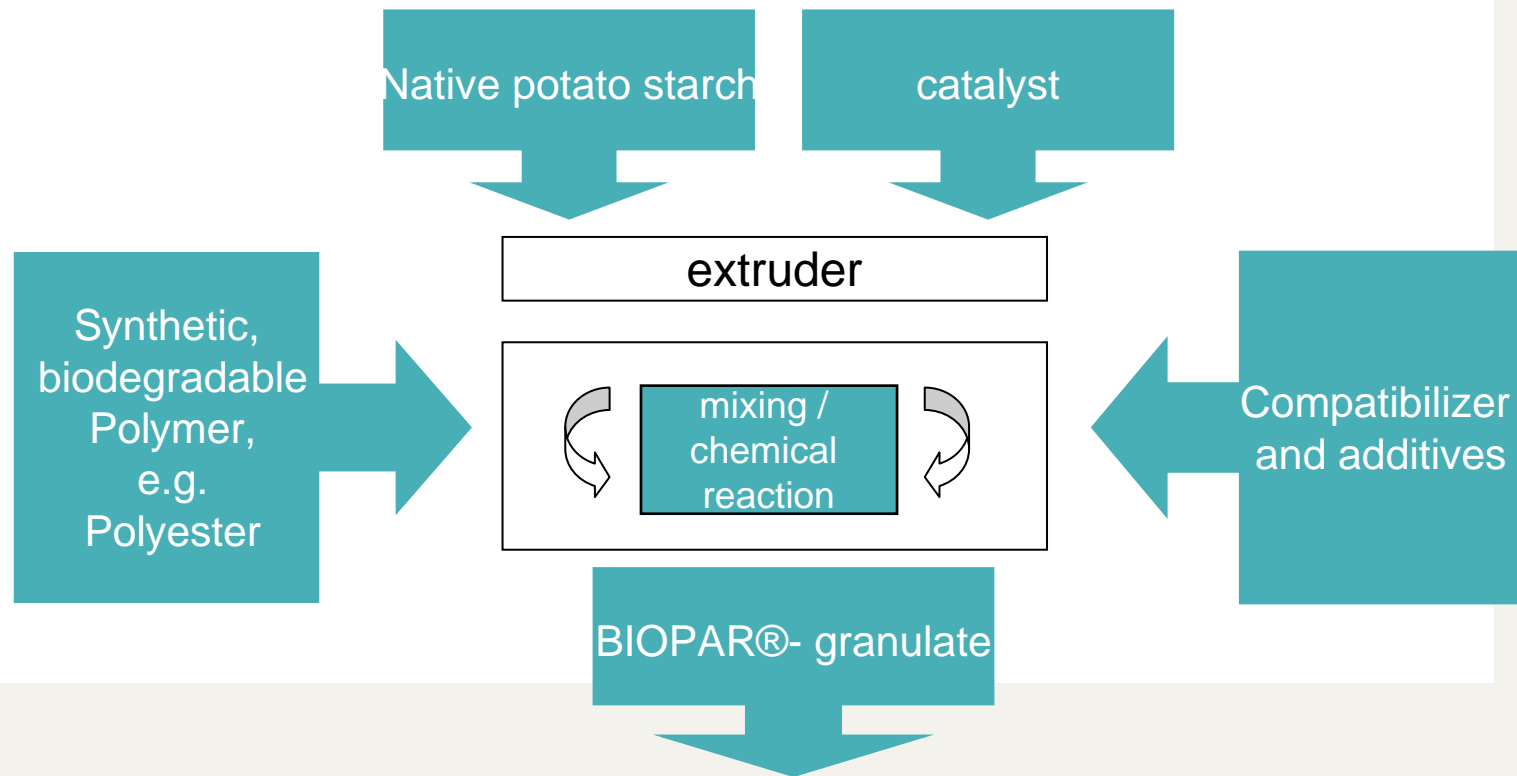
PLA Thermorming Sheet

There are several difficulties involved in reprocessing skeletal waste.

In some cases crystallisation is required before adequate pre-drying can be attempted. This is determined by the relative level of amorphous material and the percentage of addition of the regrind.

BIOPAR

- *Compounding: production process by a reactive extrusion*

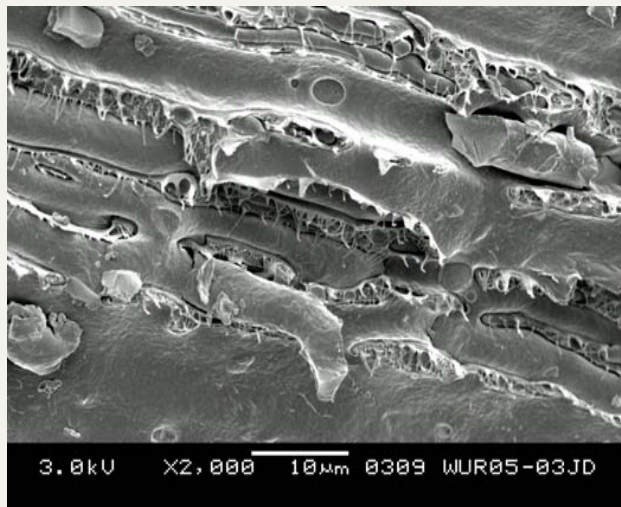


- direct gravimetric dosing of components
- reactive extrusion using twin screw extruder
- processing temperatures: between 120 and 180°C

BIOPAR

Internal structure of BIOPAR® materials: influence of formulation

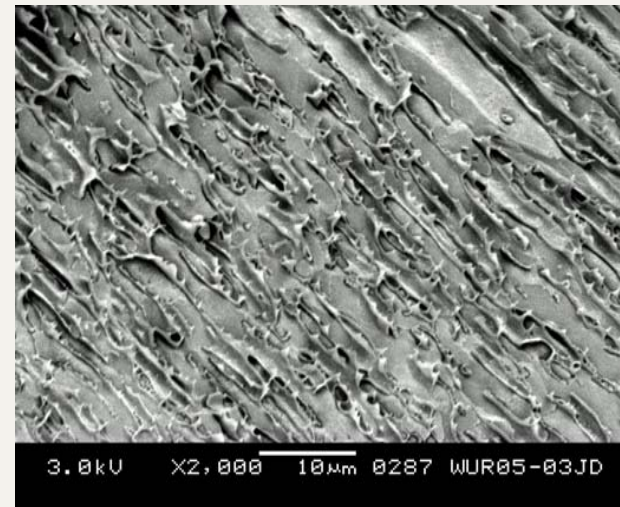
- Comparison of structure and morphology inside BIOPAR®- pellets in dependence on content of compatibilizer and plasticizer



BIOPAR® - Compound: potato starch
in combination with Ecoflex

No compatibilizer

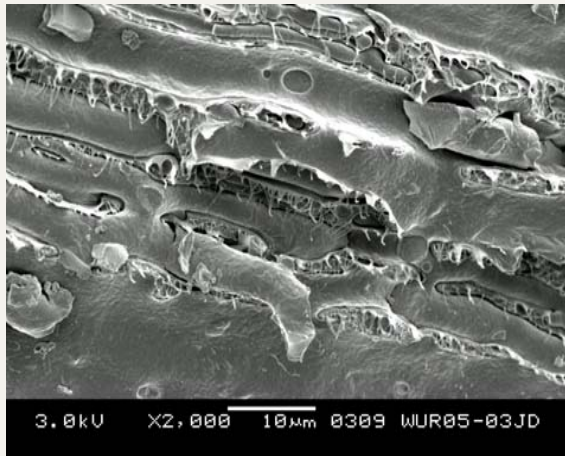
Low content of plasticizer (< 8wt%)



BIOPAR® - Compound: potato
starch in combination with Ecoflex

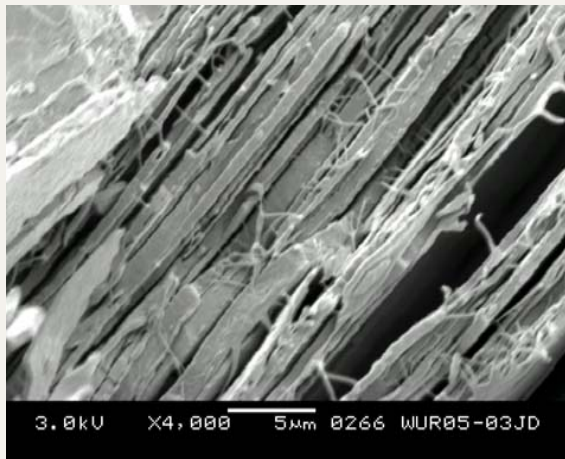
With compatibilizer

High content of plasticizer (> 15wt%)



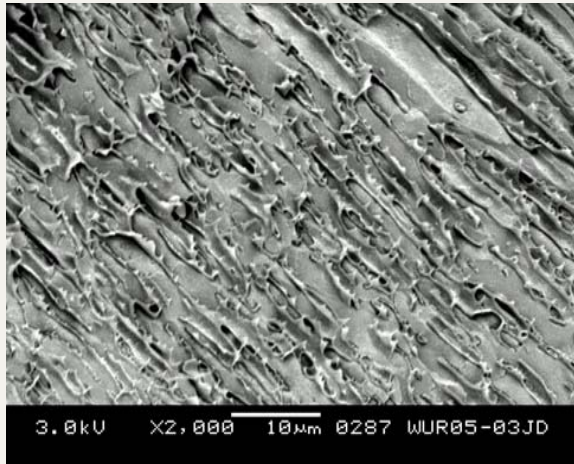
Compound:

- potato starch in combination with Ecoflex
- No compatibilizer
- Low content of plasticizer (< 8wt%)



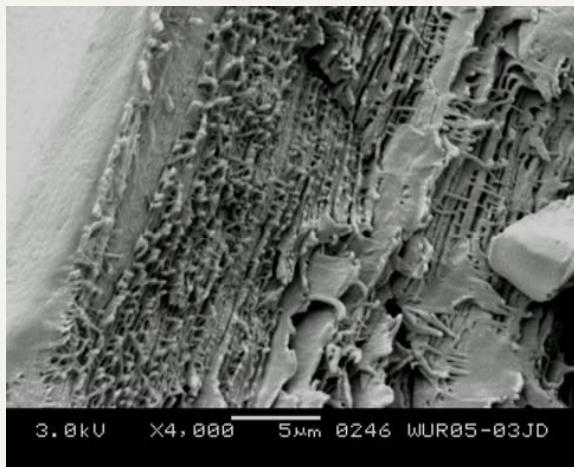
Film formed from the Compound

- a lot of cracks inside the material
- no adhesion between starch and Ecoflex-phase
- Tear resistance: 2.100 – 2.700cN/mm



Compound:

- potato starch in combination with Ecoflex
- with compatibilizer
- high content of plasticizer (> 15wt%)



- Film formed from the Compound
- a lot of layers of starch and Ecoflex
- good adhesion between starch and Ecoflex-phase
- Tear resistance: 26.000 – 28.000cN/mm

BIOPAR Blown Film

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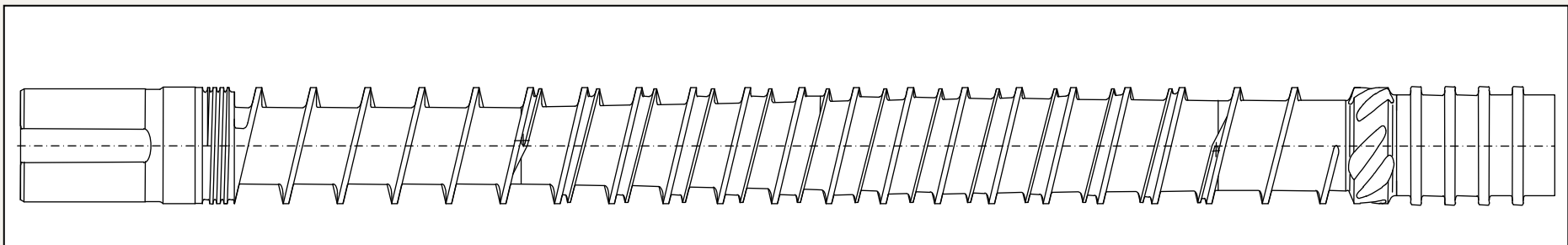
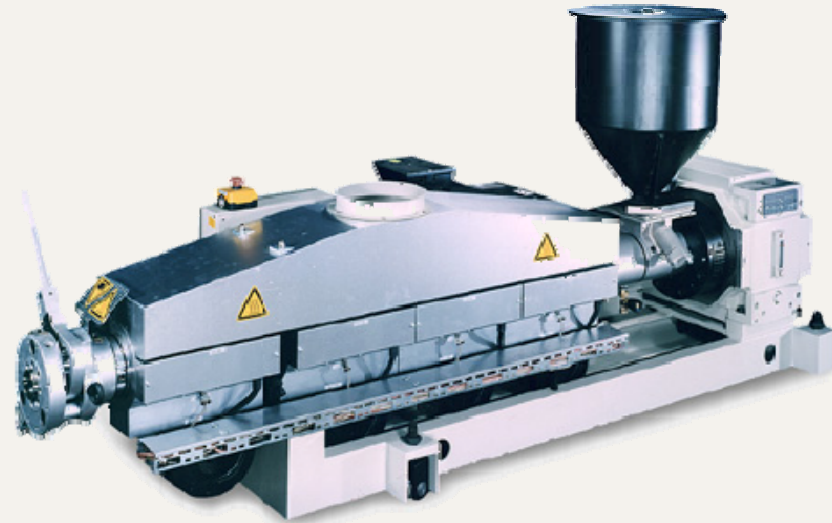
3-layer Blown Film Line with IBC



BIOPAR Blown Film

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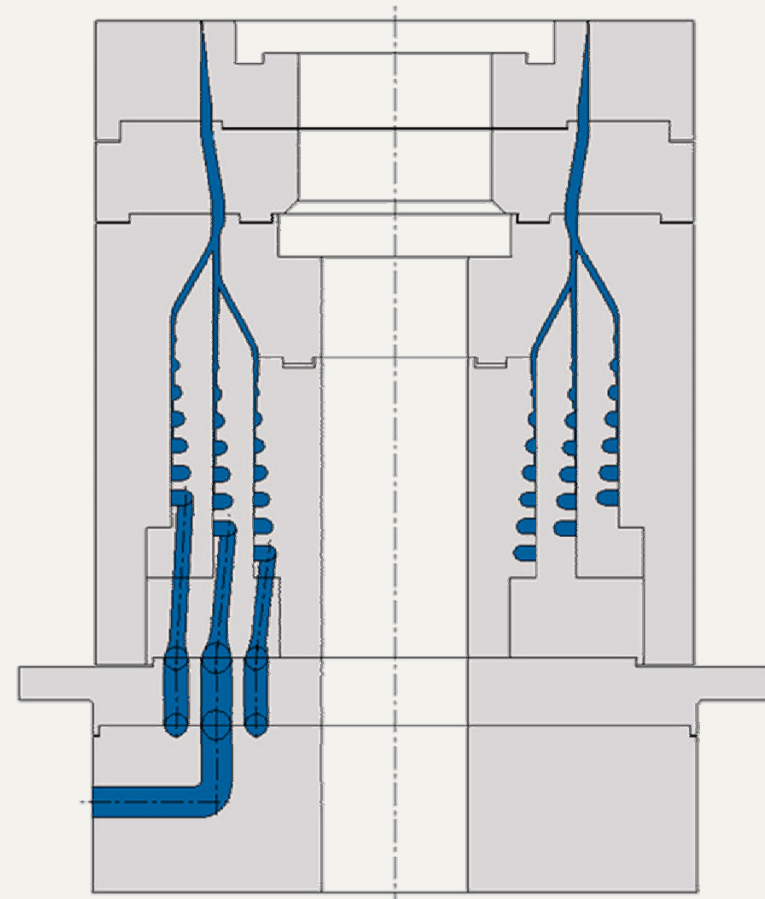
Extruder with AC-drive
And high output barrier
screw



BIOPAR Blown Film

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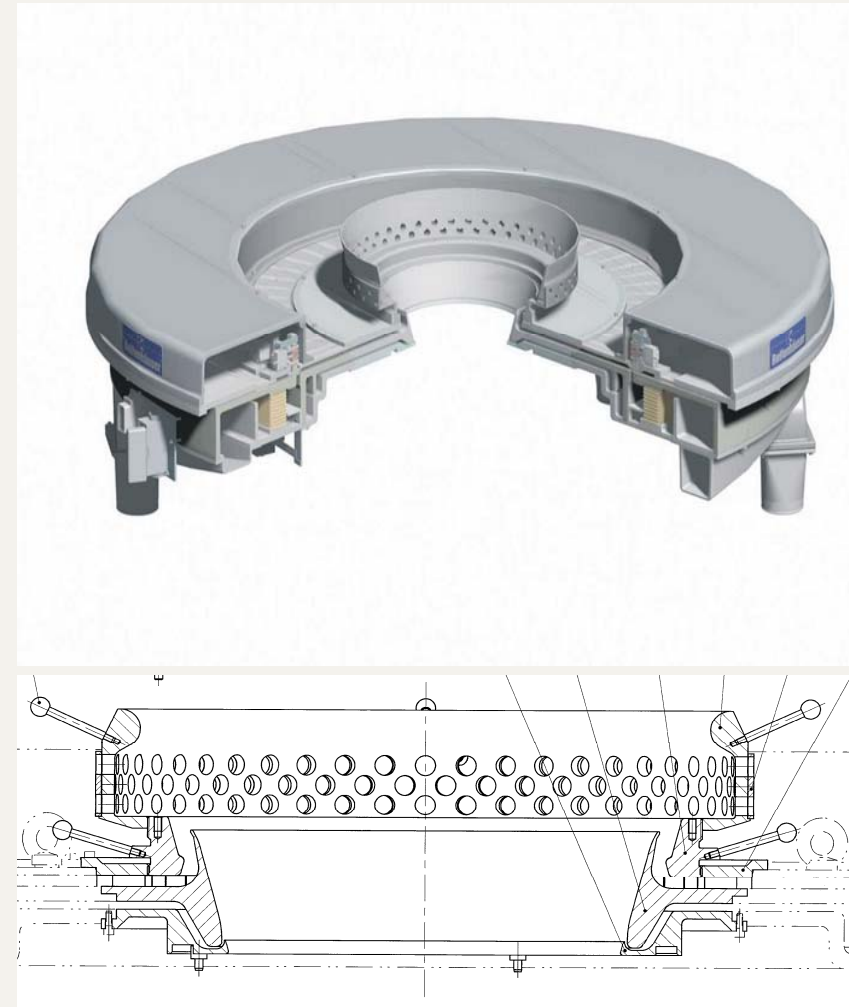
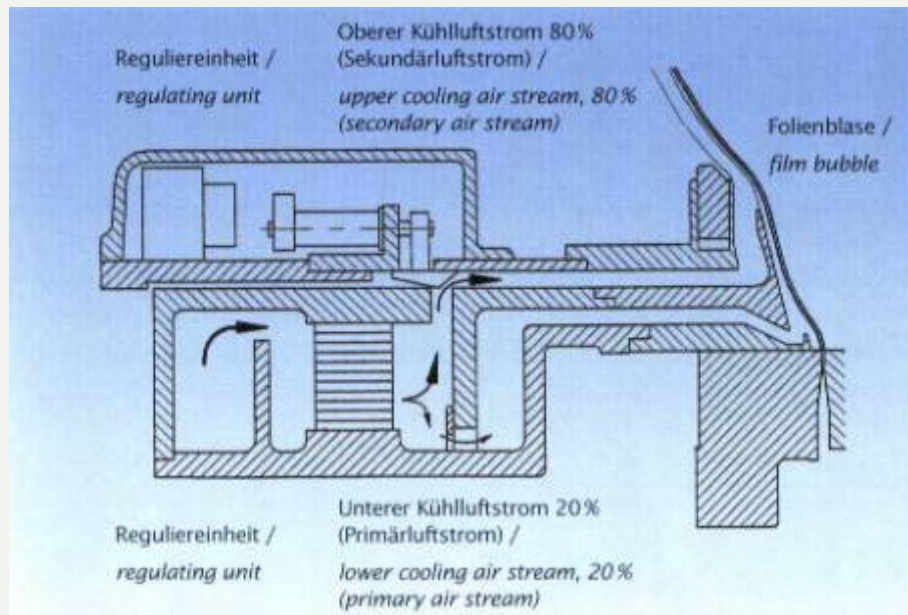
3-layer Blown Film Die Head
basic lay-out 1:1:1 up to 1:3:1



BIOPAR Blown Film

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High performance air cooling ring



BIOPAR – Blown Film

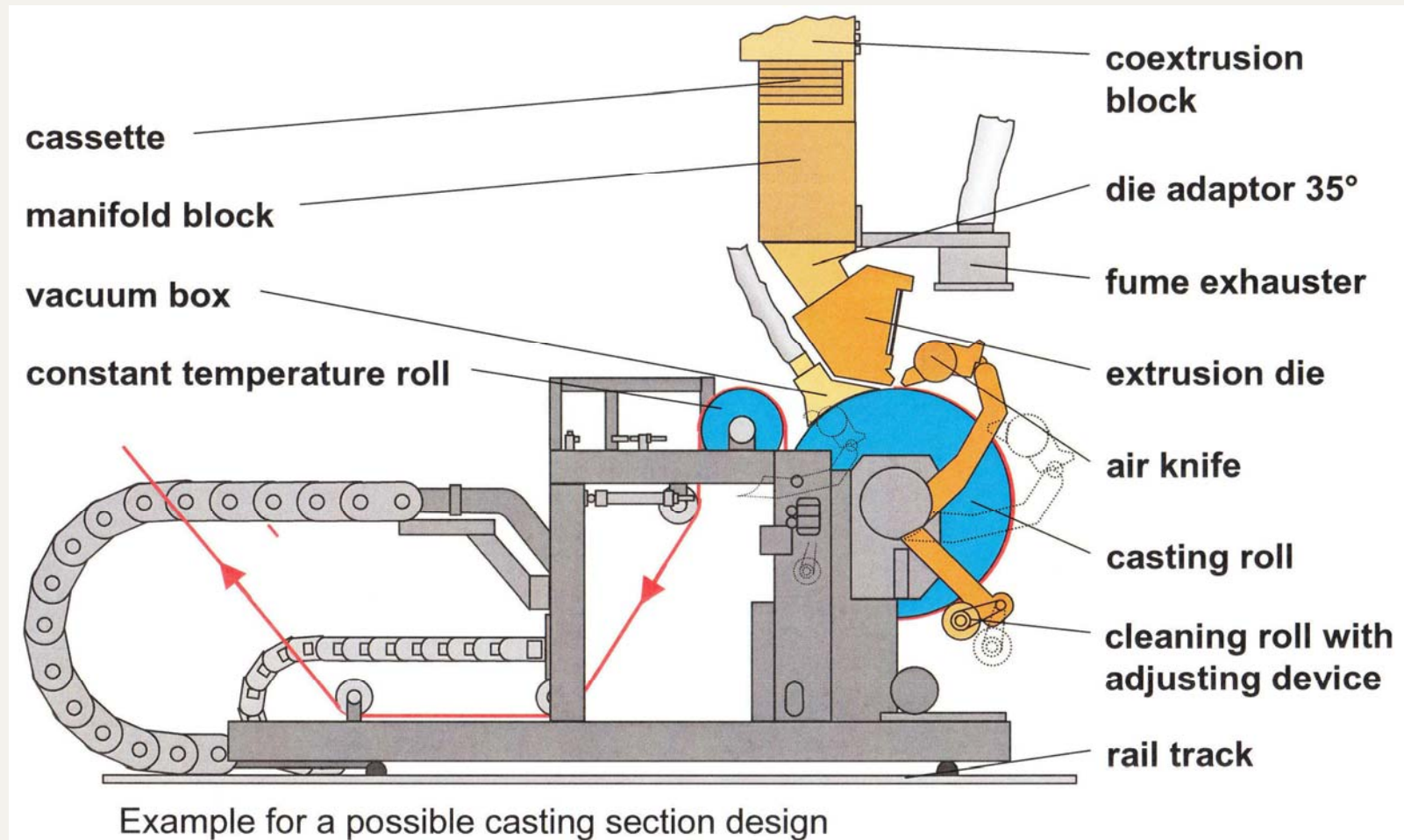
- The resin can be run on conventional equipment with little modification
- Extrusion temperatures are much lower than normal for PE/PP
- Barrier screws give the best results – 3-zone screws are not as effective
- Conventional dies and air cooling rings work well
- Very high throughputs can be reached: 390 kg/ with 300mm die insert, die factor around 1,40

BIOPAR – Cast Film

- Barrier screws give best results in cast film extrusion
- Conventional dies and feed blocks give good results
- Pressure must rise constantly along screw length – pressure drops are fatal!
- The „damp“ nature of the film means special attention must be paid to edge pinning. Electrostatic techniques work well
- Controlled cooling down to processing temperature required to ensure no deposits or “frozen“ polymer

BIOPAR Cast Film

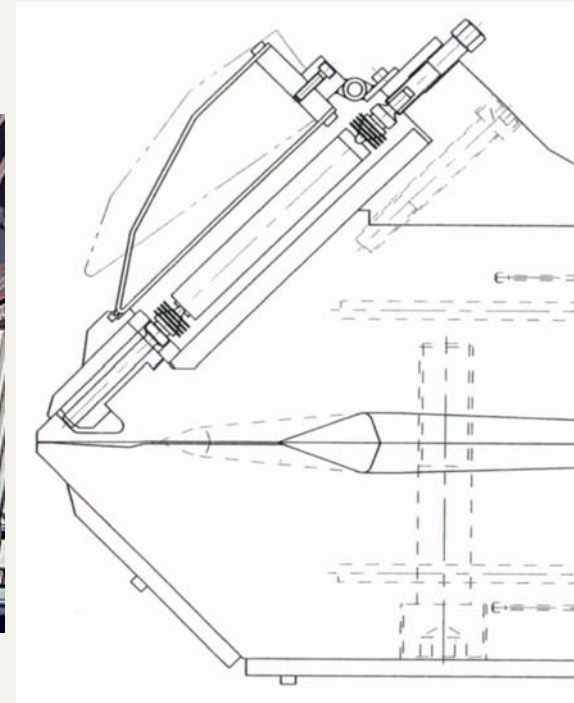
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BIOPAR Cast Film

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Adjustment of
the die gap
with fast
reaction time



BIOPAR Cast Film

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High accuracy
($\pm 1\text{ }^{\circ}\text{C}$) of the
casting roll's
surface



Risks in processing the resin

- Risks include
- Problems in stabilising the extrusion process
- Danger of gel formation if there are any “hang up points“
- Die lip build-up in cast extrusion
- Capacitive thickness measurement not possible in blown film lines
- Unresolved challenge of finding tie layer resins for coextrusion to LDPE or L-LDPE due to melt temperature differences

- This biopolymer is easier to process than most other biopolymers and the film produced does not resemble typical biofilms.
- The material is supplied in moisture proof bags and provided it is not exposed to atmospheric moisture for prolonged period, no pre-drying is required
- Set point temperatures of around 180 deg C are similar to those for many conventional polyolefines

- The material runs well on barrier screws with high specific outputs
- The material exhibits good draw down from the die lips
- The film can be effectively edge-pinned using electrostatics
- There is a tendency towards die lip build up

PBS Cast Film

- The film produced has excellent stiffness and mechanical properties in the machine direction
- There is marked “splittiness” in the transverse direction
- This can be improved by careful control of annealing (post-cooling) roll temperatures
- There is no tendency to “yellowing”

Thank you for your attention