

Honorary professors for students and staff of the Technological Institute of St. Petersburg

Prof. Dr. Chistian Kohlert

Studied process engineering at TH Merseburg in 1975

Aspirant at the Leningrad Technological Institute in 1978

Honorary Professor St.Petersburg Technological Institute 1998

Group Director Process Technology Klöckner Pentaplast until 2019

Owner Kohlert Consulting 2019 – today

Member of 2 academies of sciences

scientific collaboration with

- Prof.Dr.T.Chistyakova
- Prof.Dr.V.Britov
- Prof.Dr.A.Malygin
- Prof.Dr.M.Sychov
- Prof. Dr.A.Taburzak
- Prof.Dr.Sirotinkin
- Prof.Dr.V.Krasovski

Together with russian scientifics 3 books, about 20 patents,
50 articles, 5 PhD graduation, 100 masters and bachelors

Folien - Herstellung, Eigenschaften und Verarbeitung



Honorary professors for students and staff of the Technological Institute of St. Petersburg

(every last Thursday at 4 p.m. russ.time)

Foils - production, properties and processing

- Manufacturing process calendering, extrusion, blown film
- Properties for production, processing and use
- Further processing - laminating, thermoforming, printing
- From mono to multilayer film
- Film recycling and sustainability

Datum : 24.2.2022

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Market situation for packaging films

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Market situation

Customers requirements

Territory situation

Recipe components

- Base polymer: PVC, PET, PA, PP, PS
PVdC, EVOH, Aclar, COC
- Modifier
- Filler: pigments,...
- Stabiliser
- Lubricant: wax system,...
- Additives for special applications
- Multilayer for high quality



Competitive situation

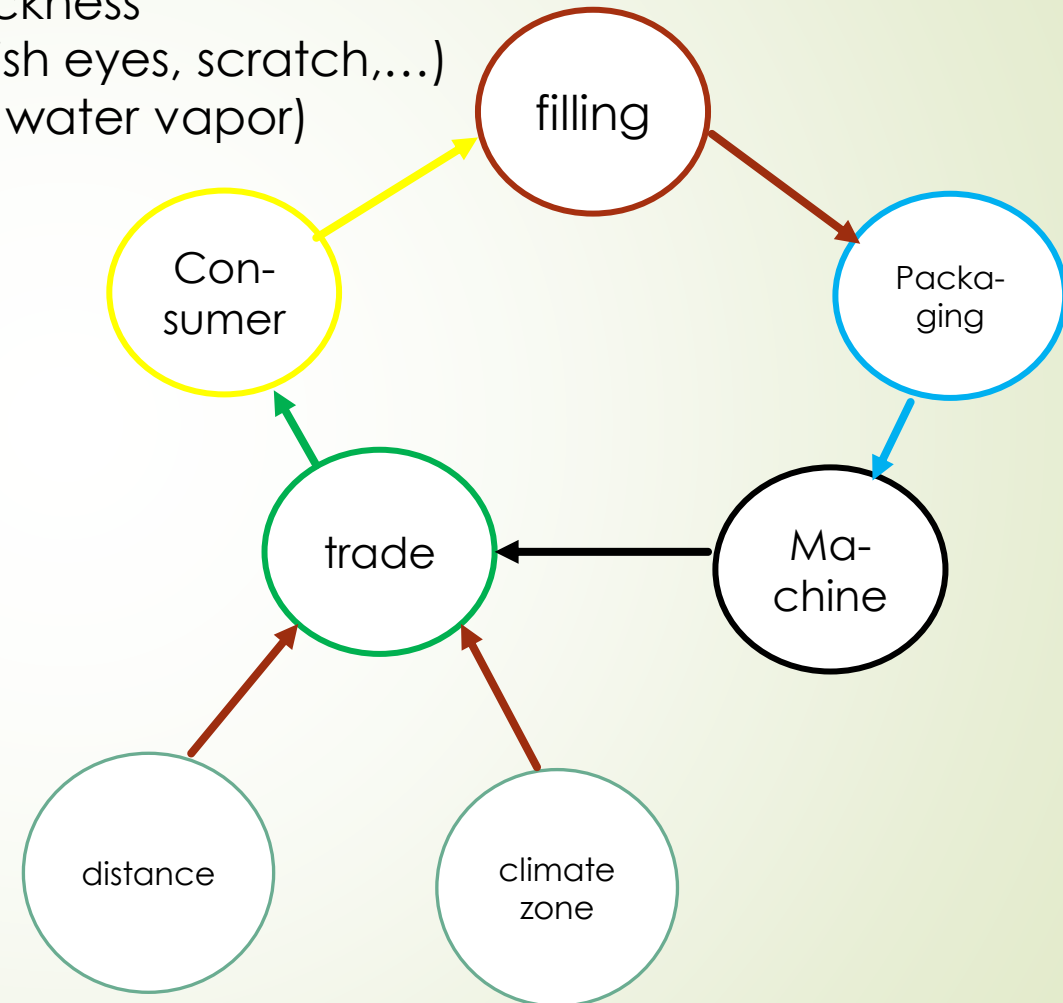
Costs

Legislation

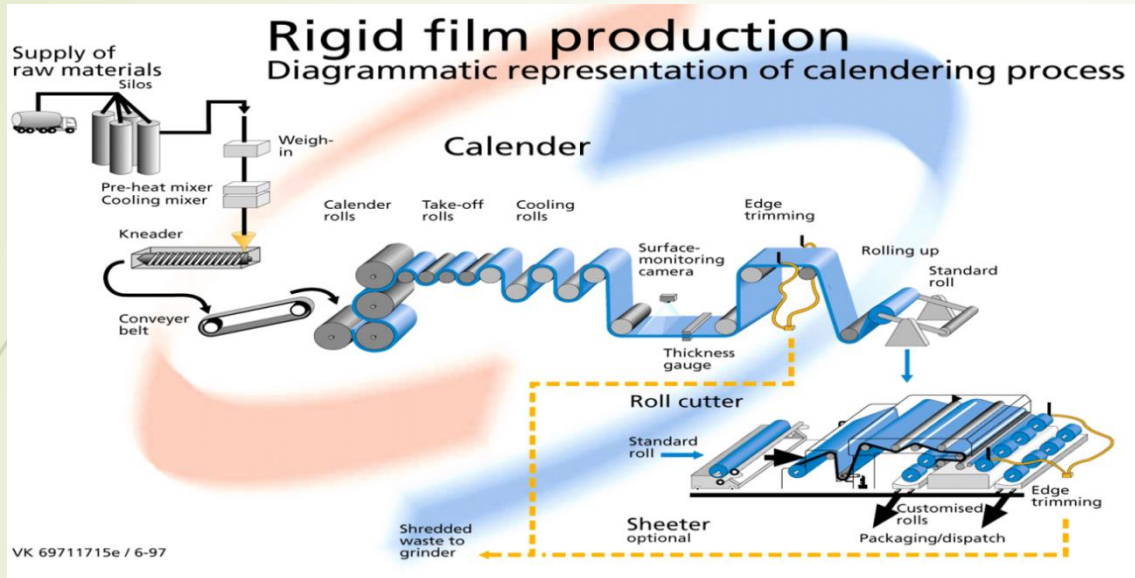
Properties of various packaging films

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- Thickness and slight variation in thickness
- no surface defects (black points, fish eyes, scratch,...)
- Barrier properties (oxygen, aroma, water vapor)
- Antimicrobiological characteristics
- Break through resistance
- Tear strength
- Seal strength
- Elasticity, Shrinkage
- Thermoforming
- Printability
- Transparenz
- Shelf life



Film by calendaring method



Properties/ quality of kp-films from rigid PVC

- Thickness tolerance MDO, TDO
- Shrink MDO, TDO
- Mistake-free (black points, specks, ...)
- Surface roughness, luster
- Barrier again water vapor and/or oxygen
- Thermoforming
- Printability
- Color consistency
- Mechanical and thermal properties

Folien - Herstellung, Eigenschaften und Verarbeitung

Kp-machinery

41 calender and calandrette in 9 sites with a capacity of rigid PVC of about 400 Tto/year

Technology

- Silo storage and Big-Bag
- Dosing
- Mixing (heat and cool)
- Gelation (Buss-kneader, extrusion)
- Important roll temperature, roll velocity
roll diameter, surface, roughness
roll parallelism
- Inline measurement
thickness, surface defects, color, gloss

Specification

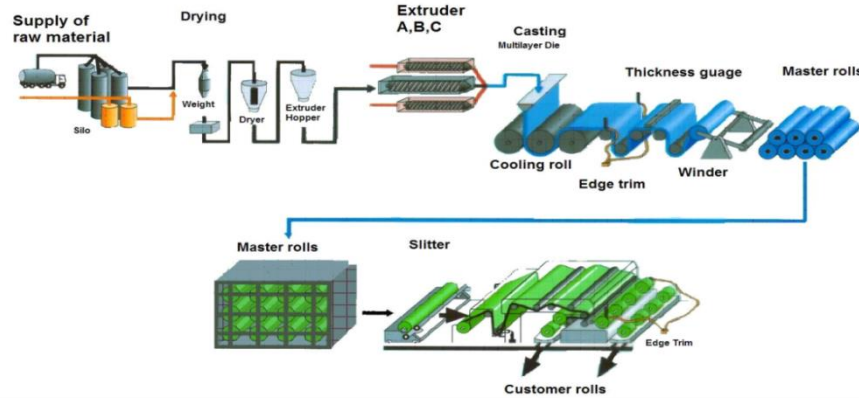
- Thickness from 25 to 1200 μm
- Width from 100 to 2500 mm
- Surface: gloss or different embossed
- Shrinkage from 0 to 60 % MDO
- Color : all Lab

24.2.2022

Film by Castextrusion method

Extrusion process

Diagrammatic representation of Extrusion process



Properties/ quality of kp-films from extrusion

- Multilayer:
 - Coextrusion, up to 7 layers; multiple polymer combinations
 - Lamination, thermal and aqueous; multiple polymer combinations
 - Side-by-side (XY) structures
- In line MDO or TDO for shrink applications
- Foaming
- PCR-content
- FDA, Reach compliance
- Colors, tints, color consistency, bi-color, light blocking, UV inhibitors
- Surface roughness, luster
- Corona treatment

Folien - Herstellung, Eigenschaften und Verarbeitung

Kp-machinery

- Global presence, with 35 extrusion lines in 12 sites (Americas, Europe, Asia).
- Global Capacity of over 250ktons/year

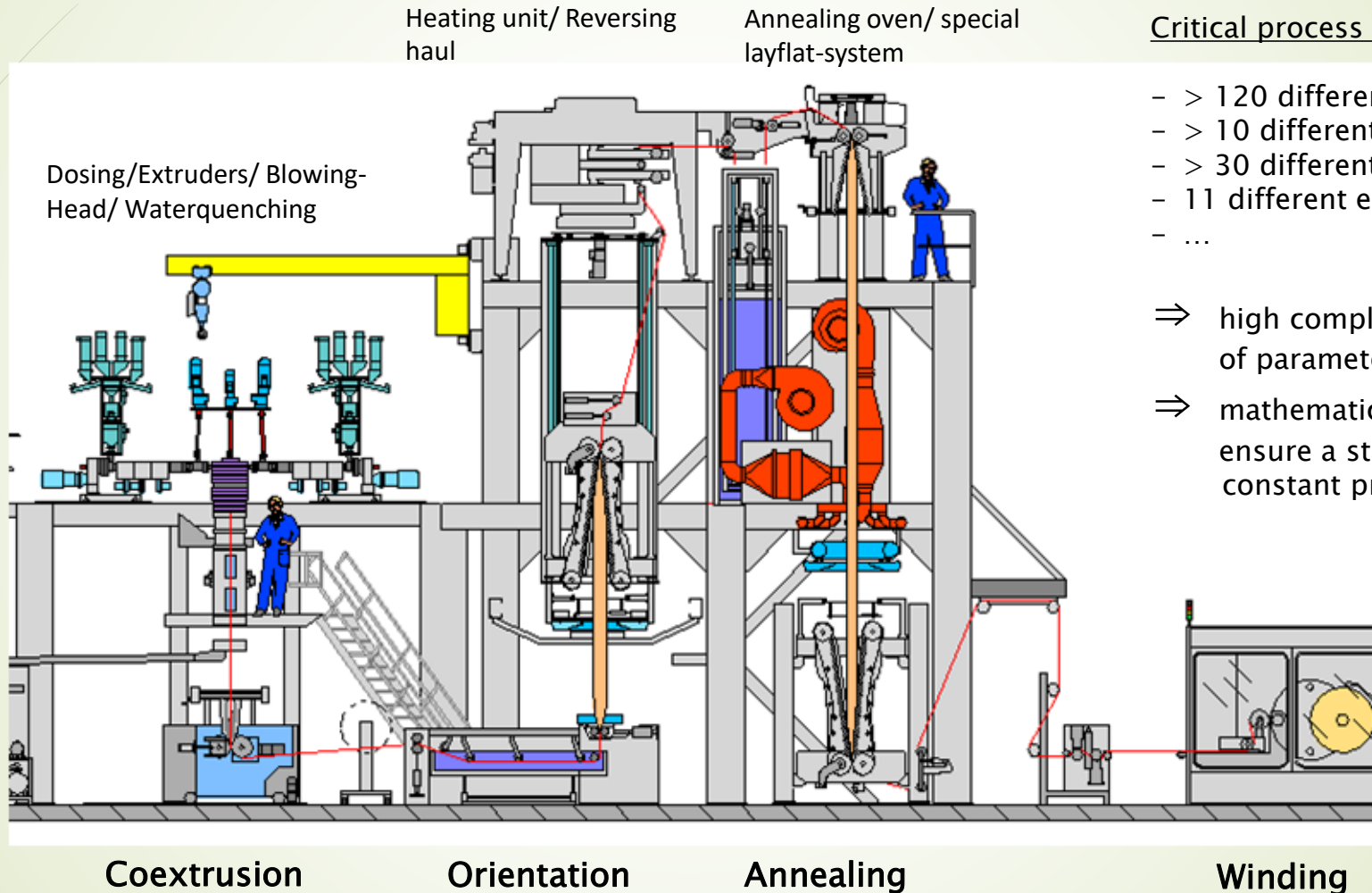
Technology

- Incoming raw materials, drying, blending
- Extrusion, decontamination, melt filtration, foam incorporation
- Layer combination, profile control
- Blown film, cast film, rollstack
- Lamination, Coating, Winding
- In-Line Measurement
 - Vision System (OCS)
 - iV
 - Color, gloss, haze
 - Gauge

Specification

- Thickness from 20 to 1650 μm
- Width up to 2200mm (6.2m for TDO)
- Recycle content up to 100%
- Shrinkage from 0 to 80%, MDO or TDO
- Color tolerance

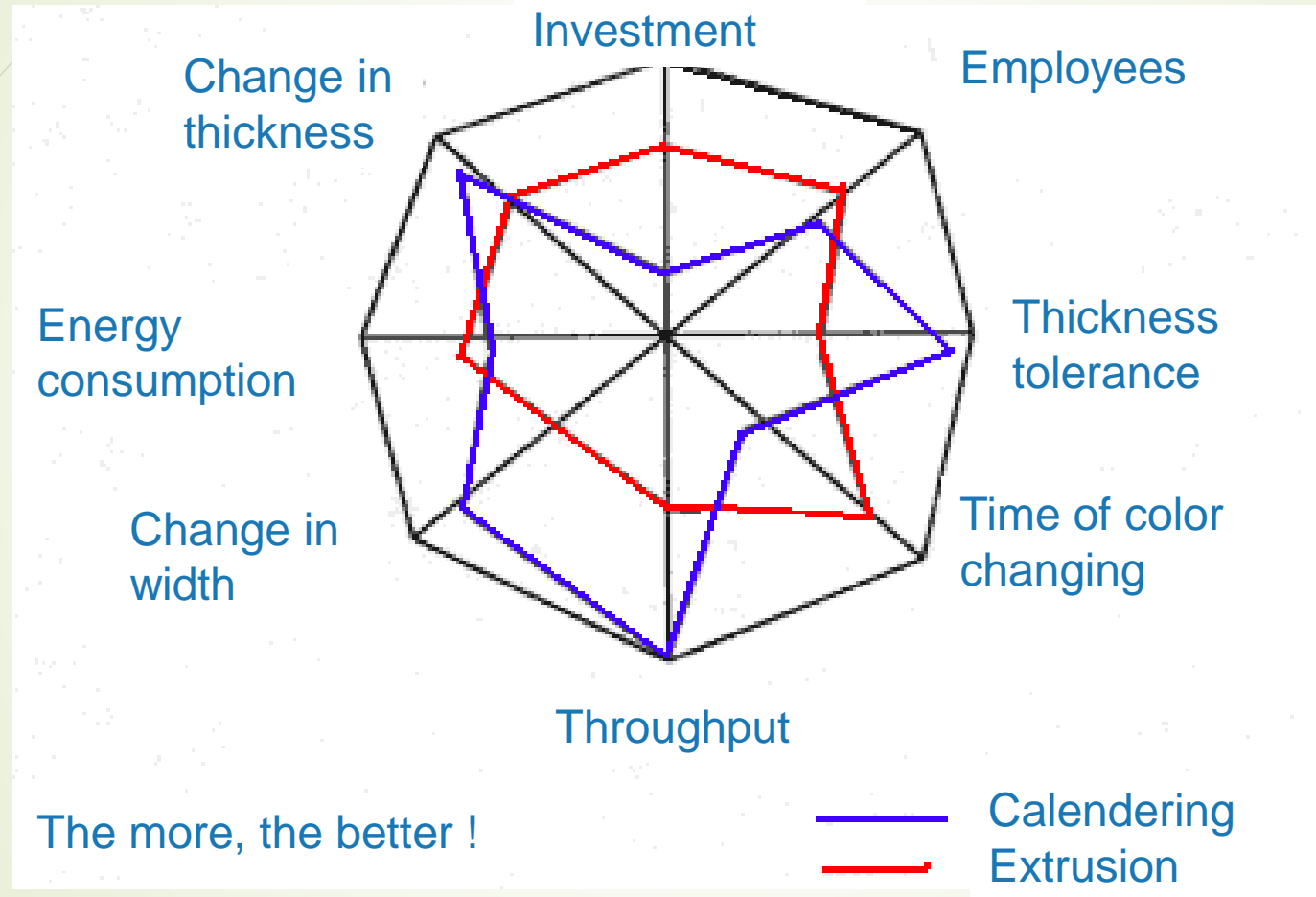
Film by blow extrusion method



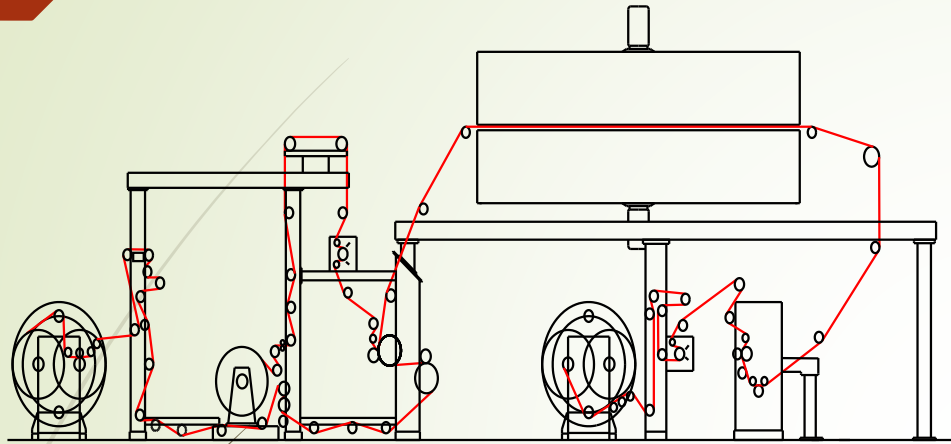
Critical process parameters:

- > 120 different temperatures
 - > 10 different velocities
 - > 30 different pressure values
 - 11 different extruder output
 - ...
- ⇒ high complexity of the interplay of parameters
- ⇒ mathematical methods to ensure a stable process leading to constant product quality

Comparison Calendering / Extrusion



Lamination (pharma lines)



Properties/ quality of laminated kp-barrier films

- Thickness tolerance MDO, TDO
- Shrink MDO, TDO
- Optical aspect (black points, specks, ...)
- Barrier against water vapor and/or oxygen
- Thermoforming
- Printability (base film side)
- Color consistency
- Mechanical and thermal properties

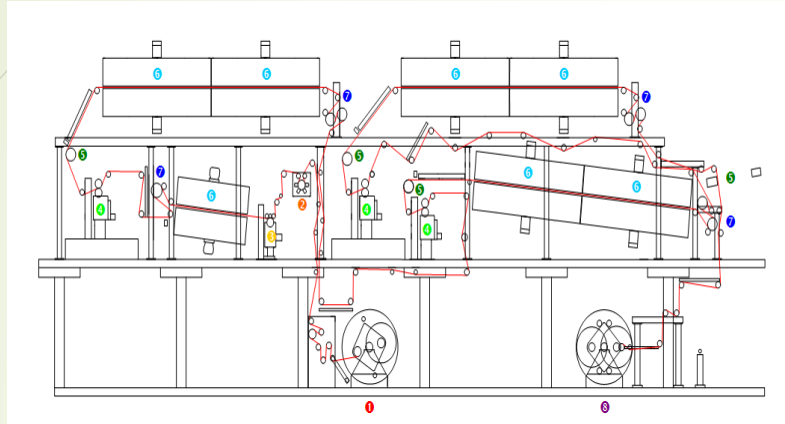
Technology

- IBC storage for adhesives and mono mother reels
- Mixing (adhesives)
- Important adhesive type and grammage, film temperature, temperature/pressure in the lamination nip, reels aligned roll diameter, clean surface, roll parallelism
- Inline measurement surface defects

Specification

- Thickness of used mono films from 16 to 500 μm
- Width from 100 to 1600 mm
- Color : all Lab

Coating PVdC



Properties/ quality of kp-PVdC barrier films

- Thickness tolerance MDO, TDO
- Shrink MDO, TDO
- Optical aspect (black points, specks, ...)
- Mid to High Barrier again water vapor and/or oxygen
- Thermoforming
- Printability (non coated side)
- Color consistency
- Mechanical and thermal properties

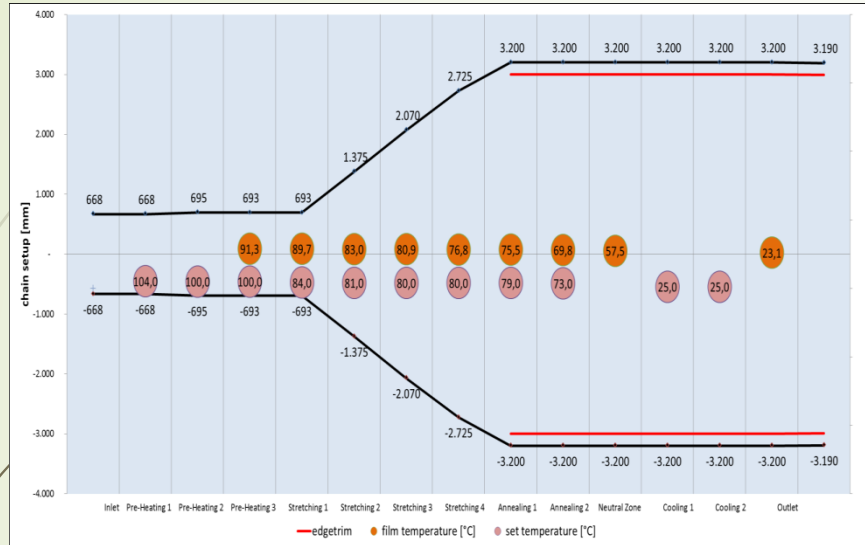
Technology

- Silo storage and IBC
- Dosing
- Important drying temperature, tension roll diameter, surface, PVdC grammage roll parallelism, primer grammage
- Inline measurement thickness/grammage PVdC, surface defects

Specification

- Thickness base film from 100 to 500 µm;
- PVdC up to 210 g/m²
- Width from 80 to 2000 mm
- Color : all Lab

Stretching MDO, TDO



Properties/ quality of stretched films

- High shrinkages realizable up to 80%
- Functional layers due to Co-extrusion
- Great printability due to Corona pre-treatment
- Excellent lay flat properties due to thickness control systems
- High optical quality due to melt filtration

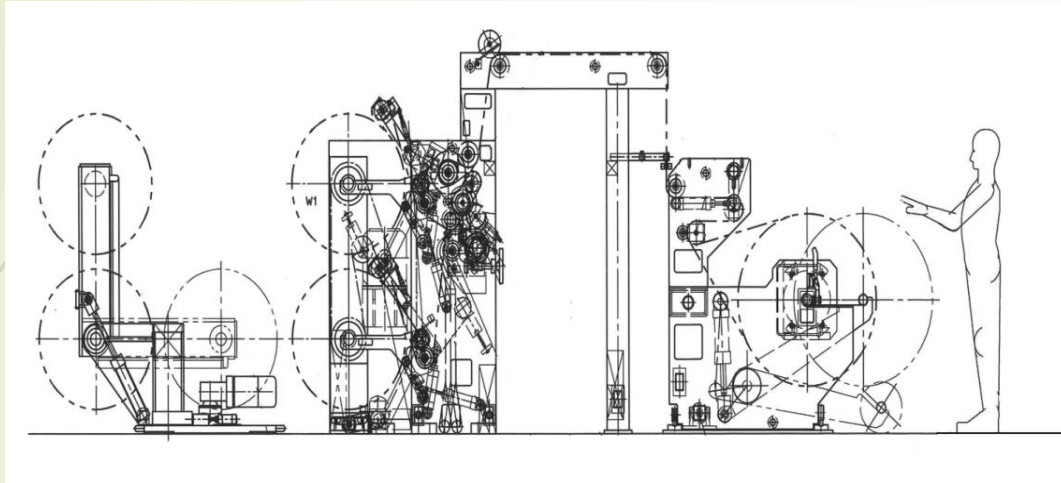
Technology

- High standard regarding thickness control systems to ensure best lay flat properties
- Highly accurate heating systems powered by natural gas or steam
- Capability of adding high amounts of rework to support an environmental friendly production

Specification

- Majority of thicknesses from 35 to 75 µm
- Stretched widths from 2.0 m to 6.2 m
- Mainly clear high transparent films, colors possible

Slitting



Properties/ quality of films

- Same properties and quality than extrusion, lamination, coating & calandering films
- latitude accuracy
- clean edge trimming
- Avoidance of cutting dust

Technology

Unwind: Dancing roller for tension control, Automatic web-guiding system

Slitting: Slitting system with oscillating Razorblades and/or Shear-cut rotary blades, Manual, semi-automatic or full automatic positioning of slitting blades

Rewind: Differential friction shafts or air expanding shafts.

Automation: PLC control with human interface operation

Specification

- Thickness base film from 20 to 1400 μm ;
- Width from 70 to 2100 mm
- Materials: PET, PVC, PP & PS (mono & multilayer)
- Color : all Lab

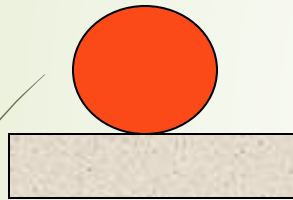
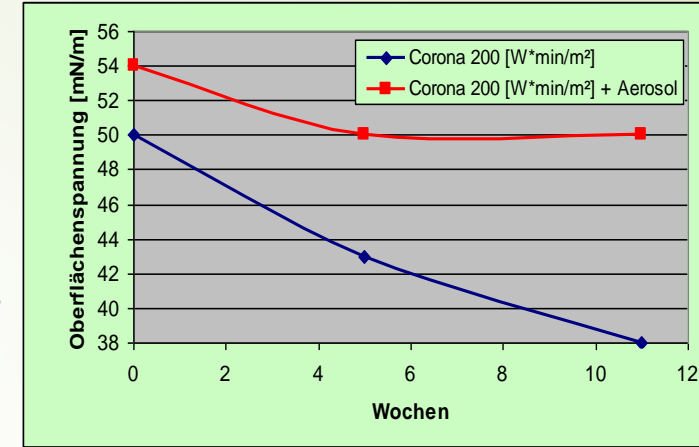
Printing



Corona treatment

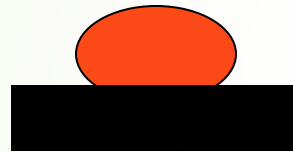


Corona aerosol treatment



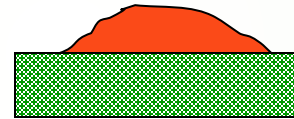
$\Theta = 180 \text{ grd}$

Not wettable



$\Theta = >90 \text{ grd}$

Poorly wettable



$\Theta = <90 \text{ grd}$



$\Theta = 0 \text{ grd}$

fully wettable

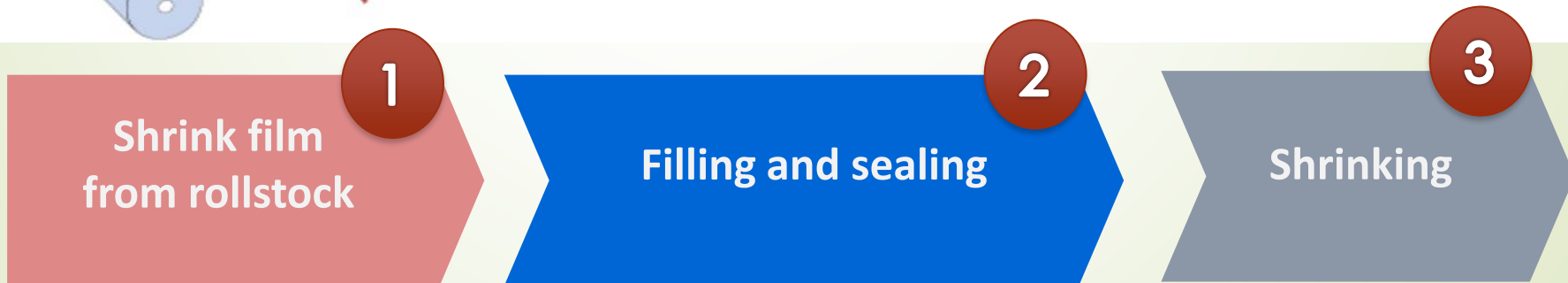
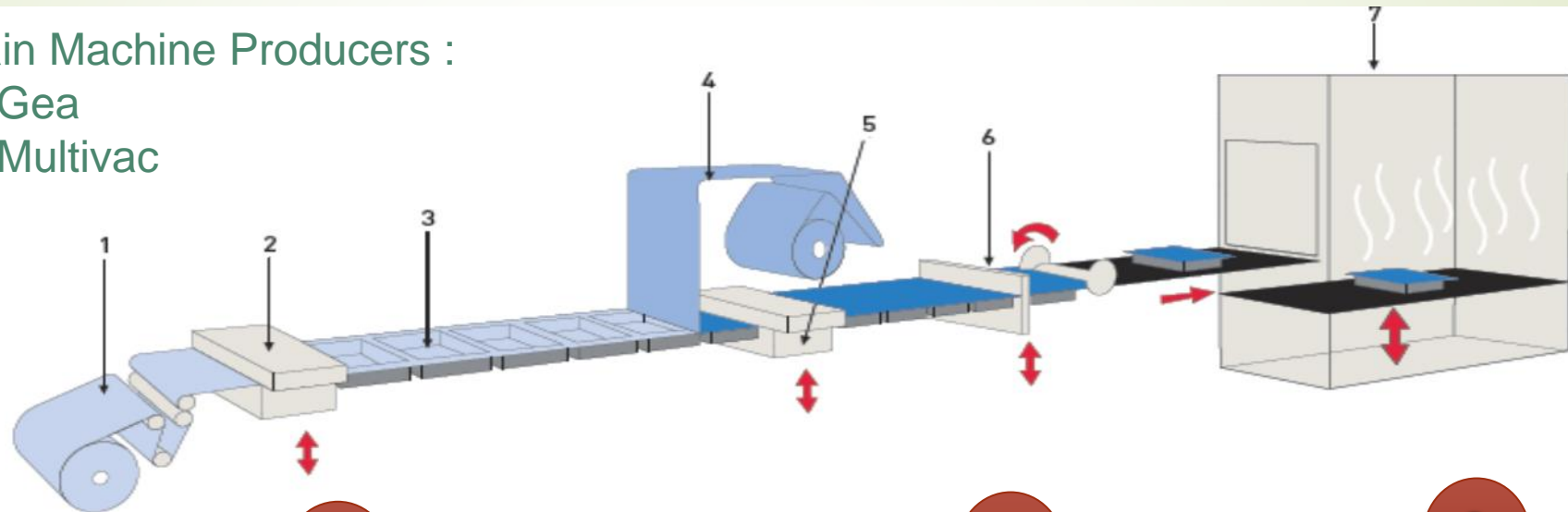
Packaging Methods

Fully automatic packaging: Bag is formed while packaging

□ Thermoforming film (from rolls)

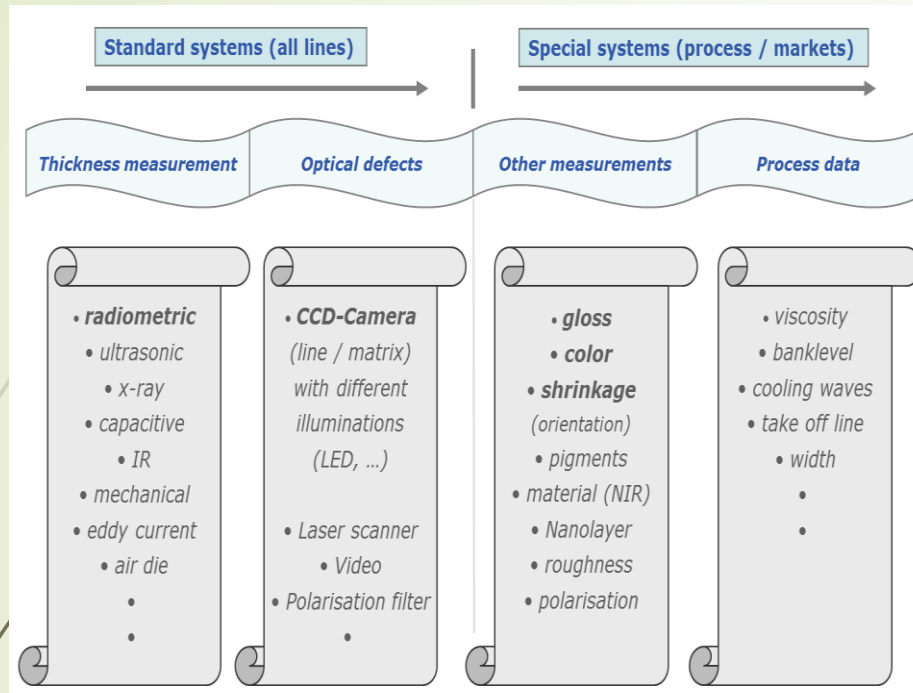
Main Machine Producers :

- Gea
- Multivac



Inline measurement systems

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Inline quality of films (all polymers)

global standards to measure critical quality values inline:

- Optical defects (black points, gels, air bubbles, holes, structures, burnings, ...)
- Thickness values from mono and multilayer films
- Color and gloss on different surfaces
- UR values on extrusion lines and on TDO frames

Kp-machinery

- Nearly all lines work with optical camera systems to detect critical optical defects inline (main supplier: OCS)
- All lines are working with inline thickness measurement systems (main suppliers are BST, EGS)
- For inline color and gloss measurement systems kp use different sensors (main suppliers are X-rite, Sensor instruments)
- All relevant data are saved in a historical data base
- SPC will be the new global standard on all lines (Main supplier: IQS)

Technology

Detection and classification of all relevant and critical defects:

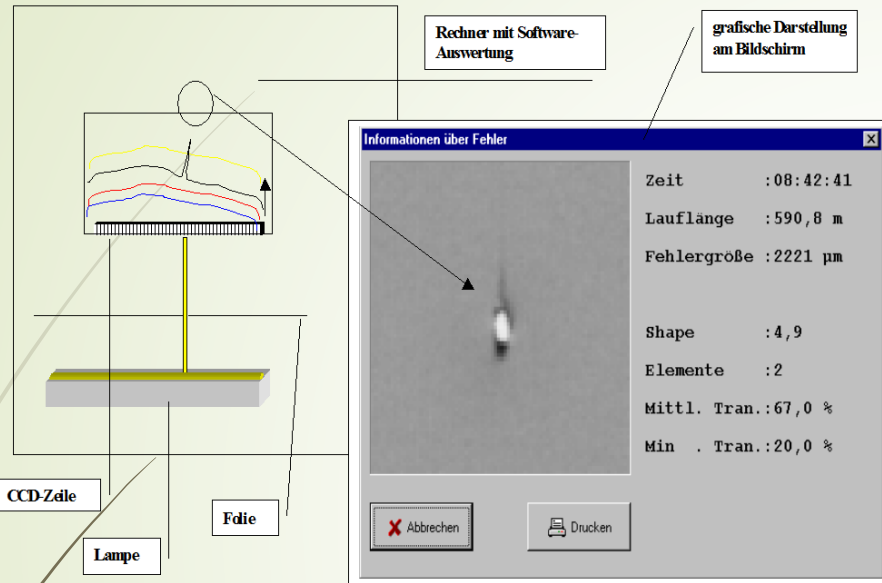
- With CCD and CMOS camera systems (line or matrix)
- Measurement in transmission or reflection mode
- Different sensors with sender and receiver (light, radiation, ...)
- For data with SQL data bases and OPC connections

Specification

All measurement results should give the same values like the QA/QS laboratory values. The adjustment and transfer will be done between T&E, OPS and QA

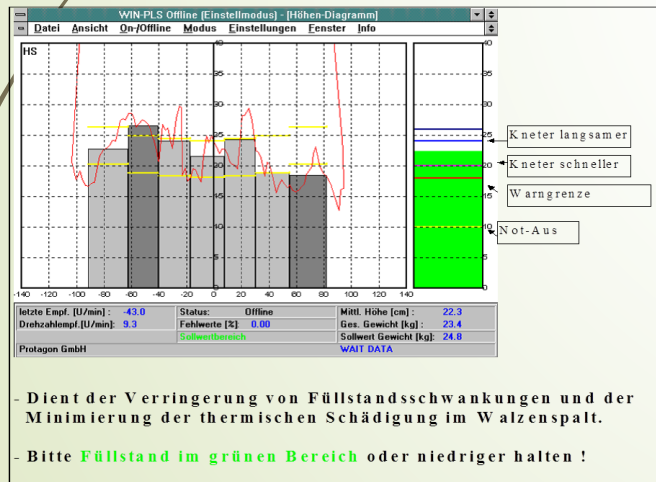
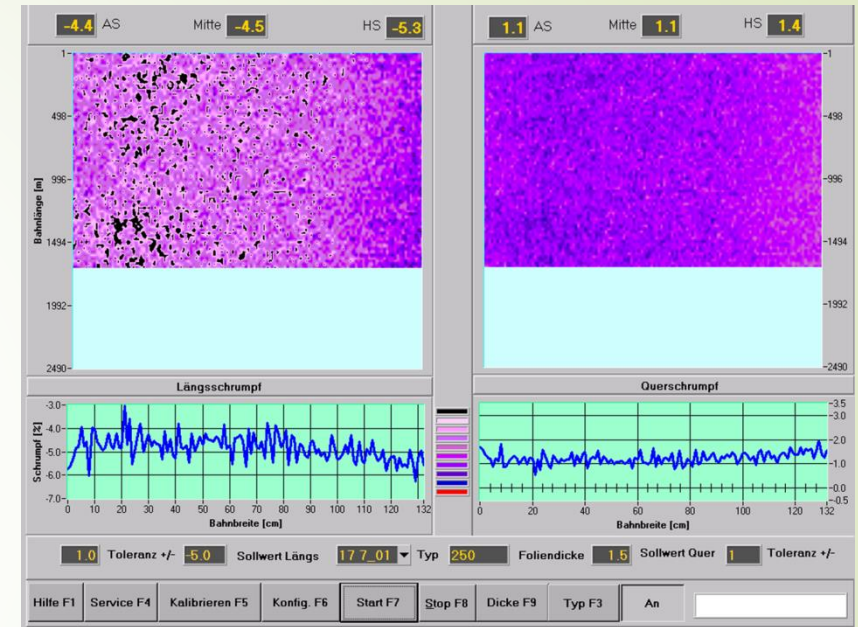
Measurement systems

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Camera system for surface mistakes

Shrink of films lengthwise and crosswise



fill level in the nip

thickness profile radiometrical



- Dient der Verringerung von Füllstandsschwankungen und der Minimierung der thermischen Schädigung im Walzenspalt.
- Bitte Füllstand im grünen Bereich oder niedriger halten !

Process technology by calendering

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Material value

- Density ρ
- Viscosity $\eta = f(T, \dot{\gamma})$
- Flow index n
- Specific heat capacity c_p
- Head conduction λ
- Heat transfer k
- Grain size distribution Δd
- Melting temperature T_s

Machine value

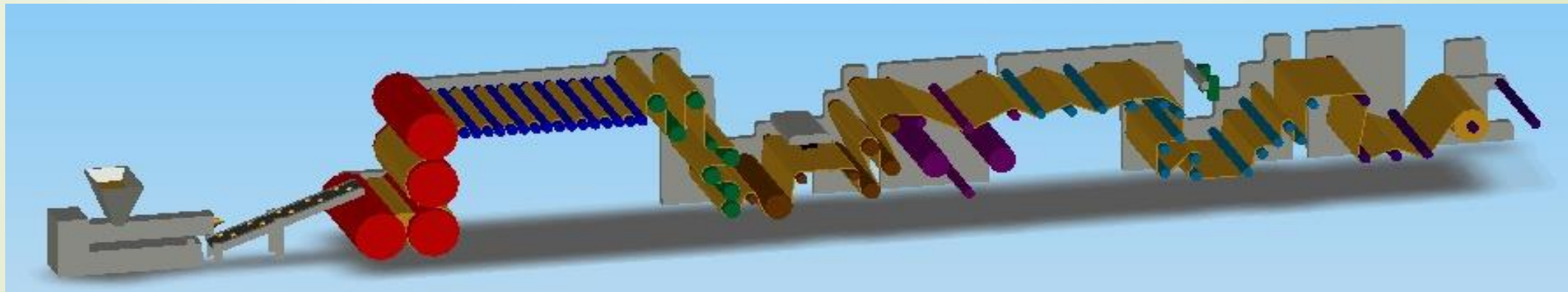
- Construction of calender or extrusion
- Construction of nozzle
- Roll diameter D
- Distance h
- Roughness R_z

Process value

- Velocity v
- Different velocity Δv
- Temperature T
- Temperature field $T(x,y)$
- Output Q
- Pressure p

Quality value

- Thickness
- Glos
- Color Lab
- Mistake
- Shrinkage
- strength



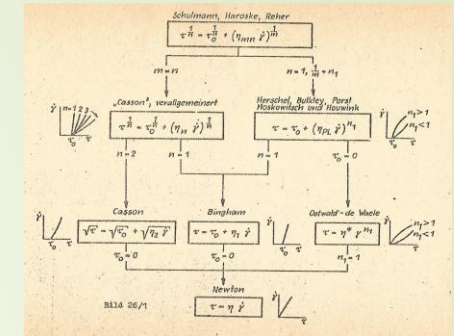
By calendering : about 100 values with 800 relationship

example: higher temperature \rightarrow lower viscosity \rightarrow lower pressure \rightarrow higher output

with lower thickness

Development objectives of Klöckner Pentaplast for calendering film

- High quality (low thickness distribution, no surface defects such as black spots, specks and holes, small color tolerances, optimal shrinkage)
- High productivity (quick changeovers, high velocity, high degree of automation)
- New characteristics for customers and service

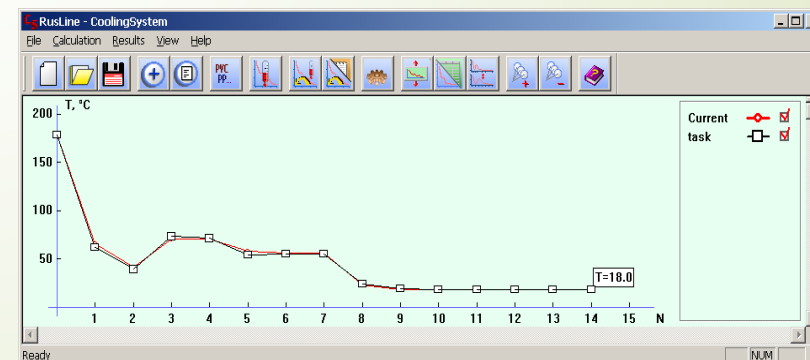
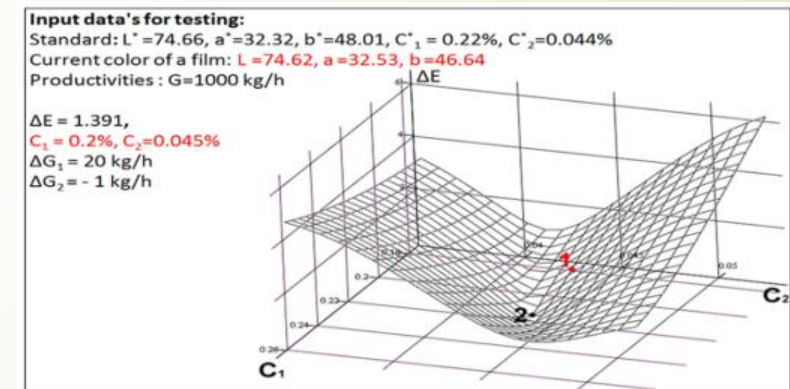


Quality of the final product will depend on (cooperation with Prof.Chistyakova)

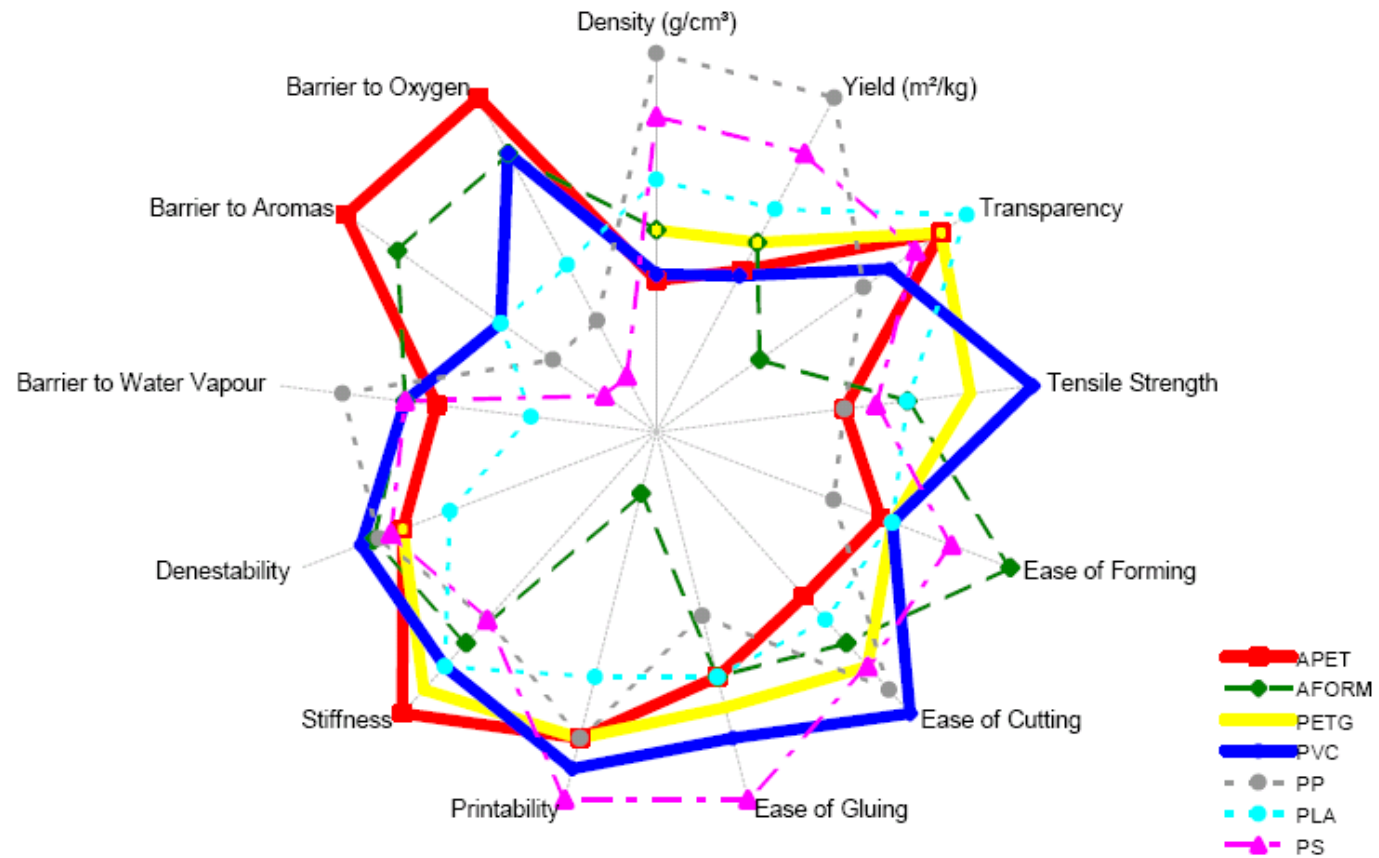
1. optimal gelling in the extruder
2. Optimal dosing of liquid colors in the extruder
3. optimal thickness distribution by roll-bending and Acrossing
4. optimal cooling of the film for high transparency
5. Optimal shrinkage of polymeric films
6. Small number of films errors

Special characteristics of polymeric films

7. Anticounterfeiting
8. Thermoforming process
9. Ecological properties of different polymeric films
10. Plant development



Material and processing properties for Monofilms



Note:

The more external the points, the better the polymer property.

Material and processing properties for Monofilms

PVC

good thermo-forming

good embossing

self-extinguishing

good barrier-properties

recycling possible

PET

high stiffness

high transparency

high price

good barrier-properties

recycling / positive image

PP

low density / low price

high flexible

high heat resistance

pleasant feel

recycling / positive image

PS

low density / low price

good thermo-forming

transparent

brittle

recycling possible

Properties polymeric films - packaging

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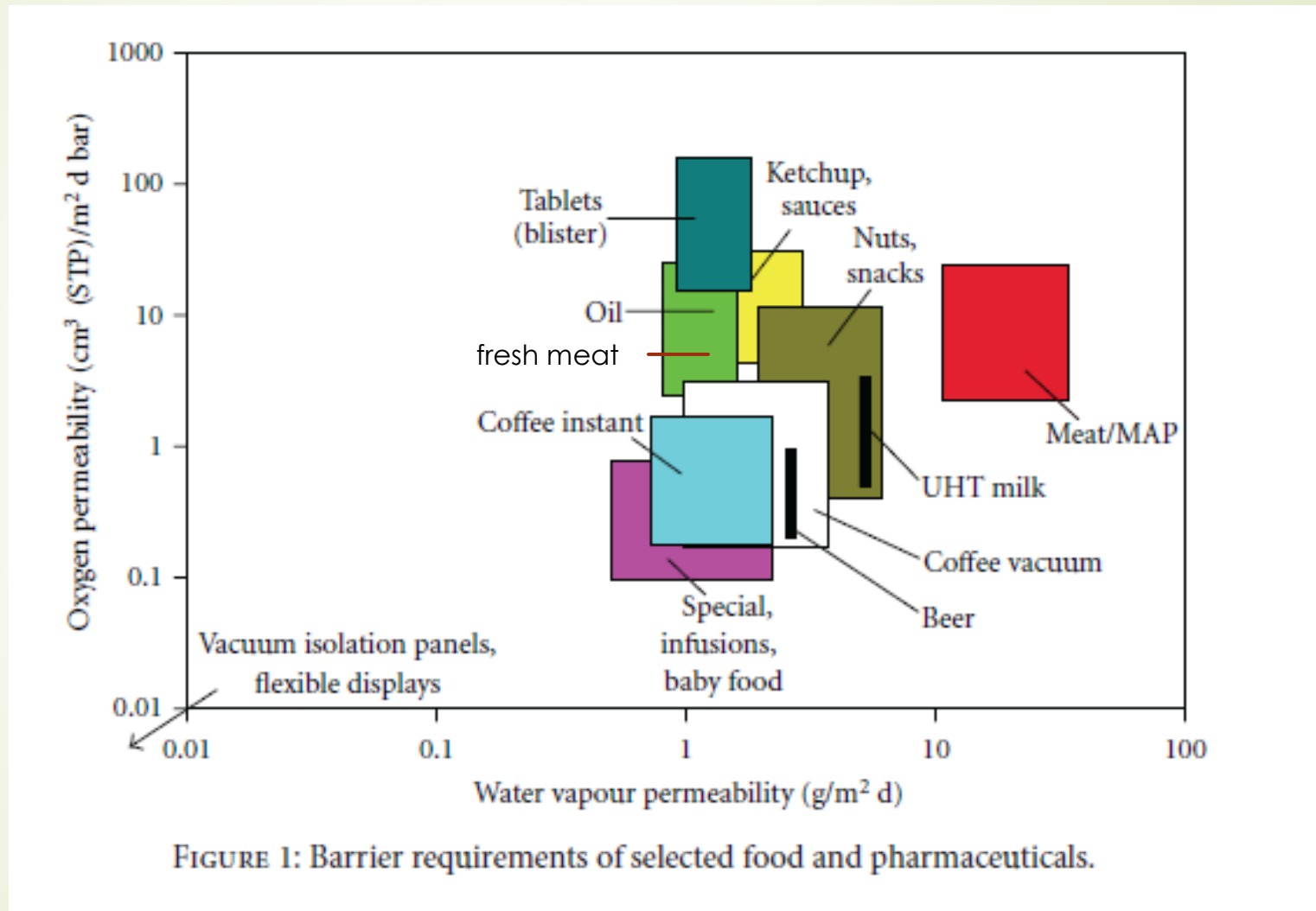
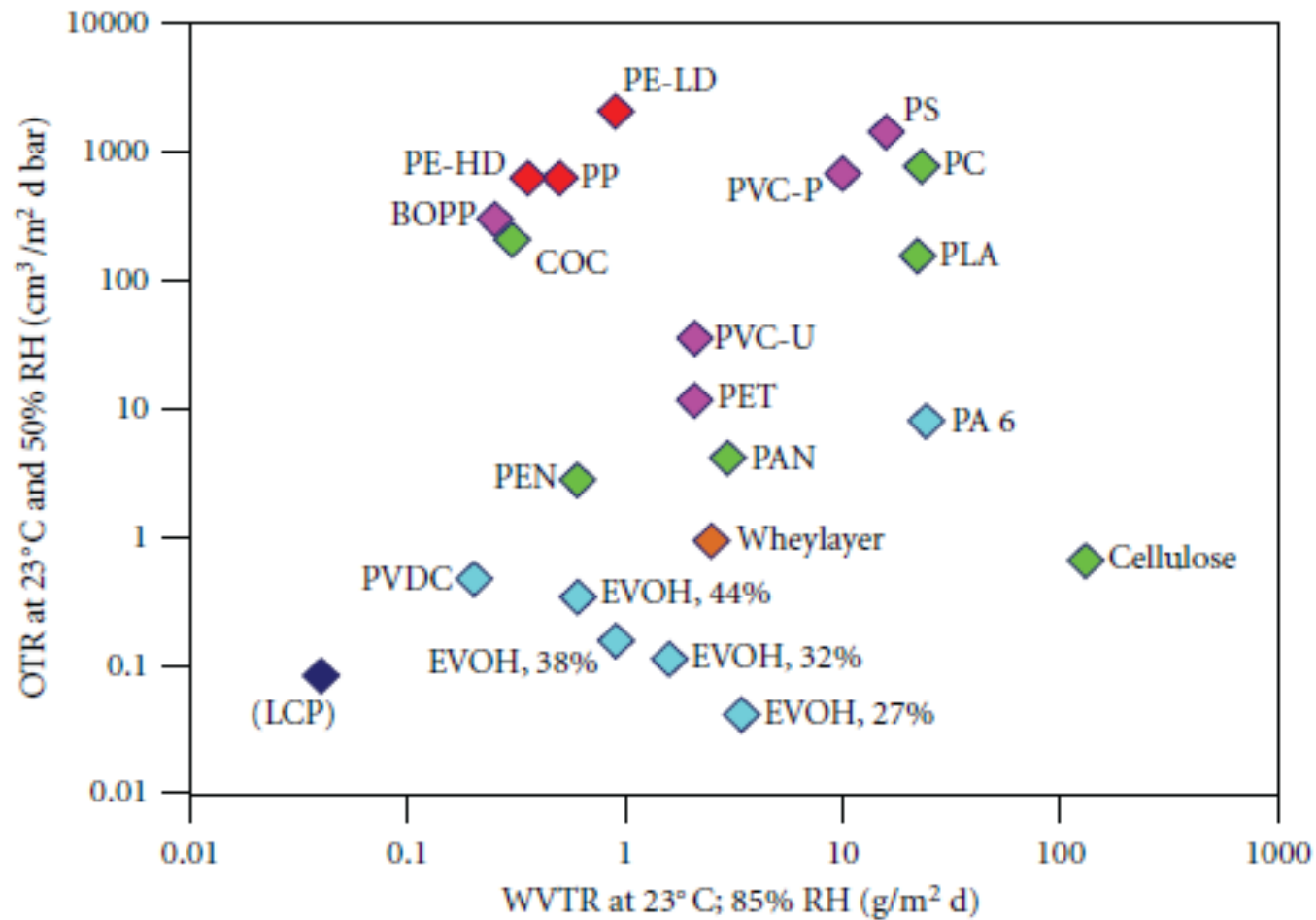


FIGURE 1: Barrier requirements of selected food and pharmaceuticals.

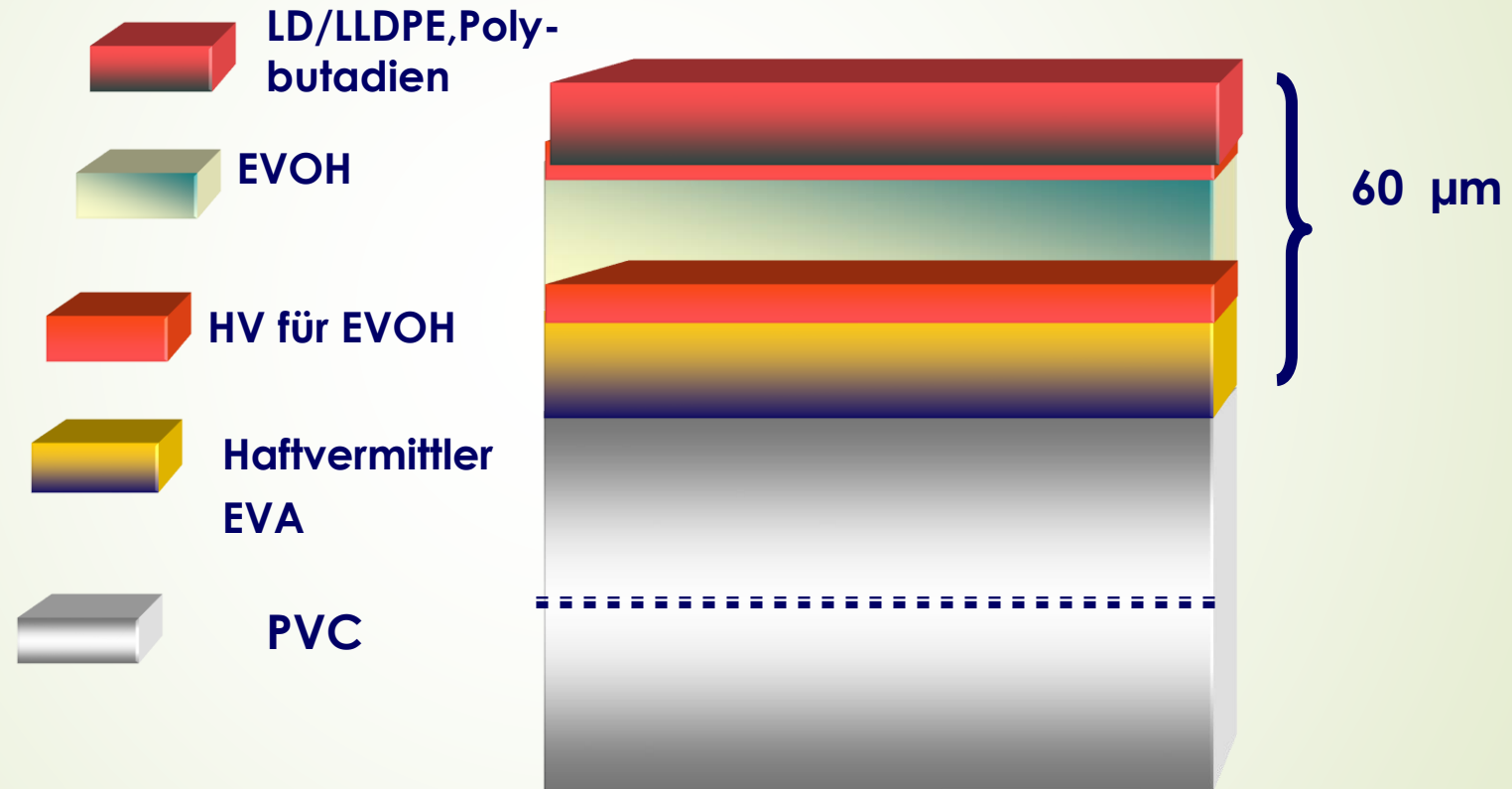
Properties polymeric films - packaging



5: Barrier properties of whey-based layer versus other plastics commonly used in the packaging industry.

Multilayer films for meat packaging

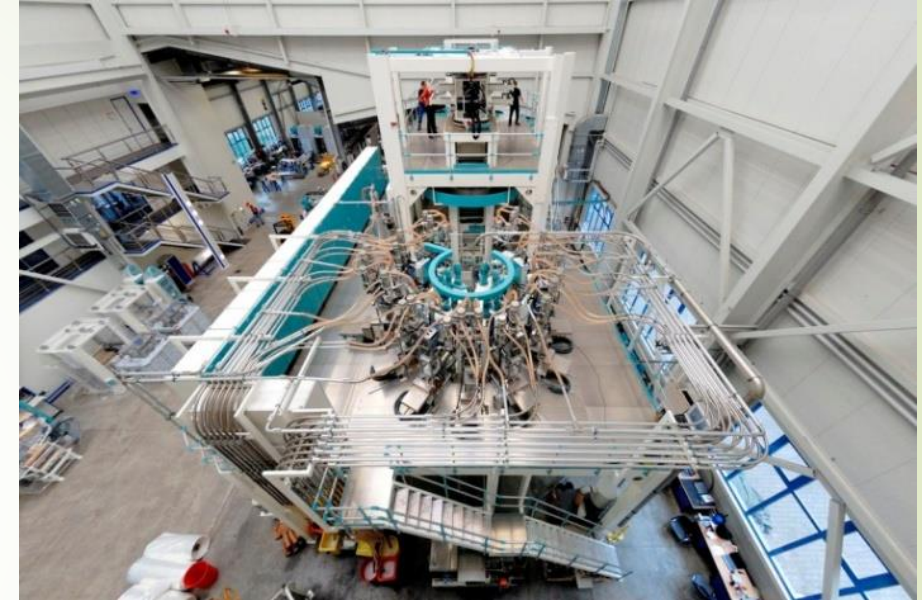
with rigid films from Klöckner Pentaplast



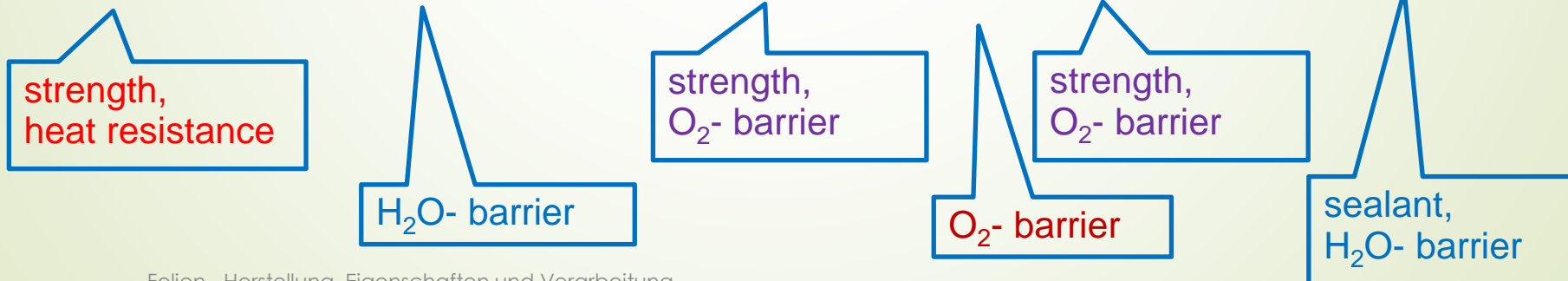
Maria Soell – Shrink Film specification

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- Barrier films with PET or PA outer layer in a range of 20 to 120 μm (Monofilms in a range of 50 – 300 μm)
- Tube width 200 – 700 mm
- Adjustable shrinkage from 10-50 %
- Barrier films with EVOH as replacement of PVDC barrier films and also PETmet, Alu, SiOx or AlOx laminates
- Films with peel- and antifog- properties

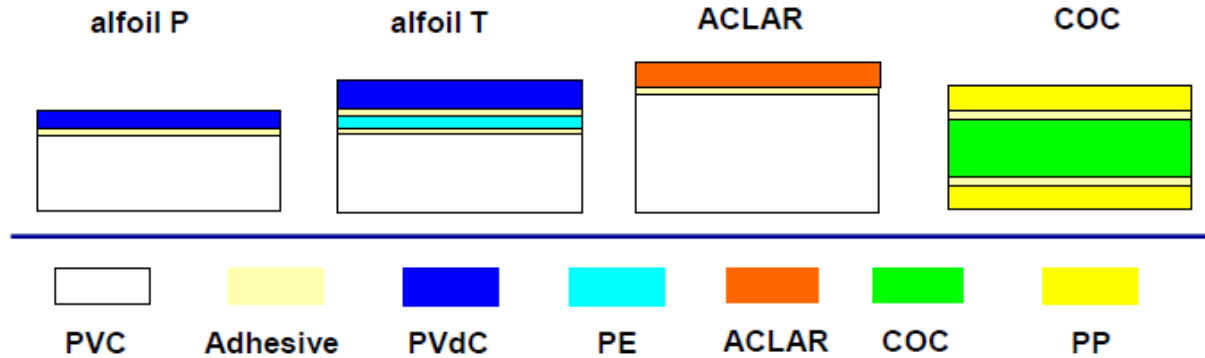


PET / T / PO / PO / T / PA / EVOH / PA / T / PO / PO



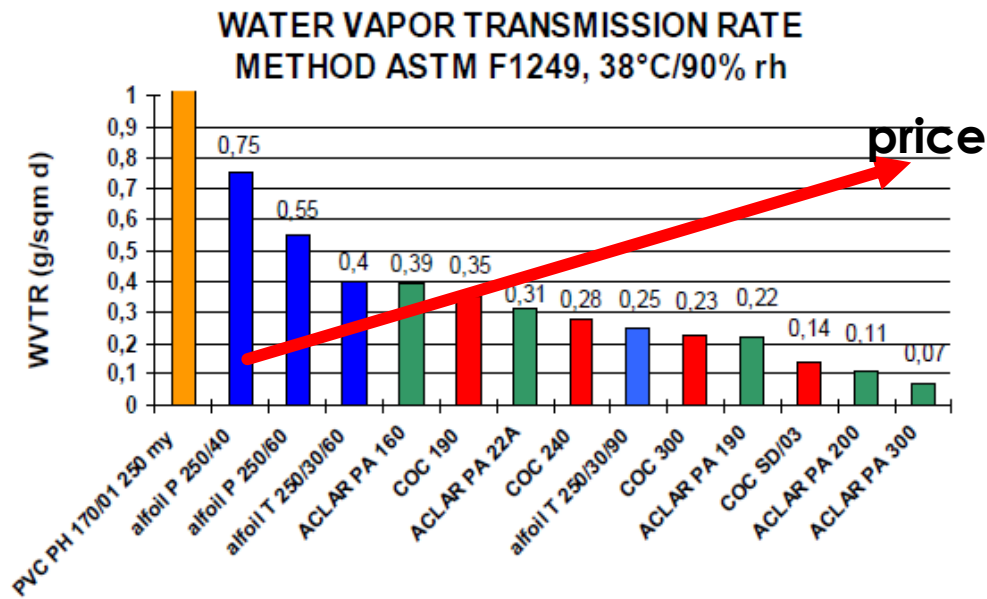
Vapor transmission rate for multilayerfilms for pharmaceutical films from Klöckner Pentplast

Folienverbunde mit spezifischen Eigenschaften



Coating and laminating for barrier properties

Alfoil = PVC/PVDC/PE-Verbund
 Aclar = Polychlorotrifluorethylen
 COC = Cyclo Olefine Copolymere
 Source: Klöckner Pentplast



Properties polymeric films

Production Costs

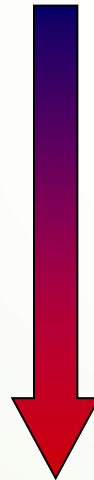
Polymer

PVC
PP
PS
APET
PETG

Technology

Calendering / Extrusion
Calendering / Extrusion
Extrusion
Extrusion
Coextrusion
Extrusion

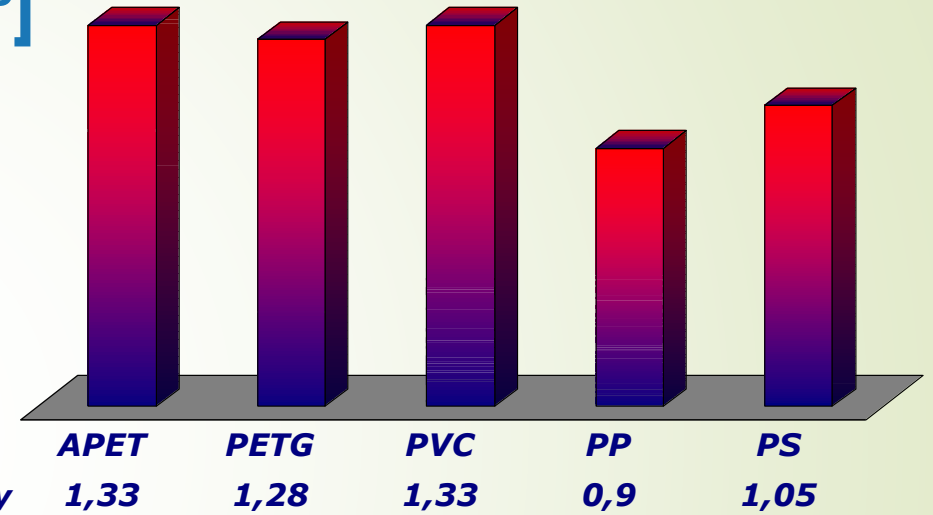
lower



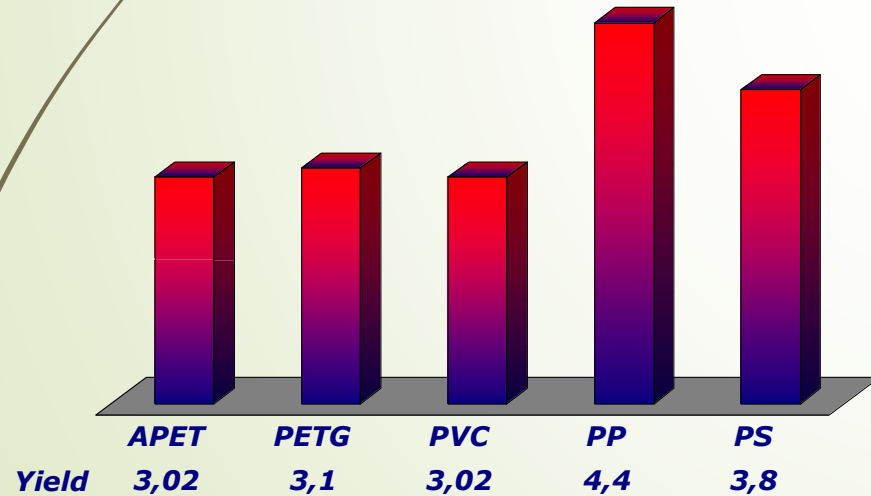
higher

Properties polymeric films

Density [g/cm³]



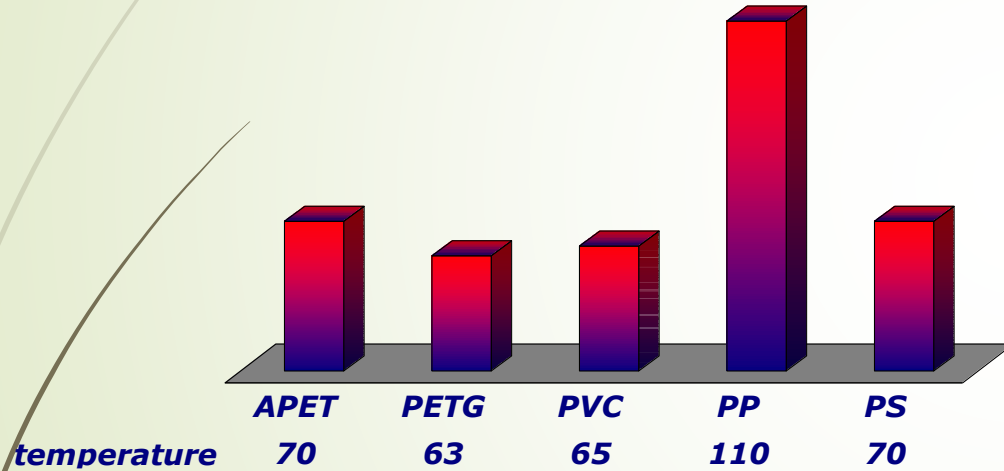
better !



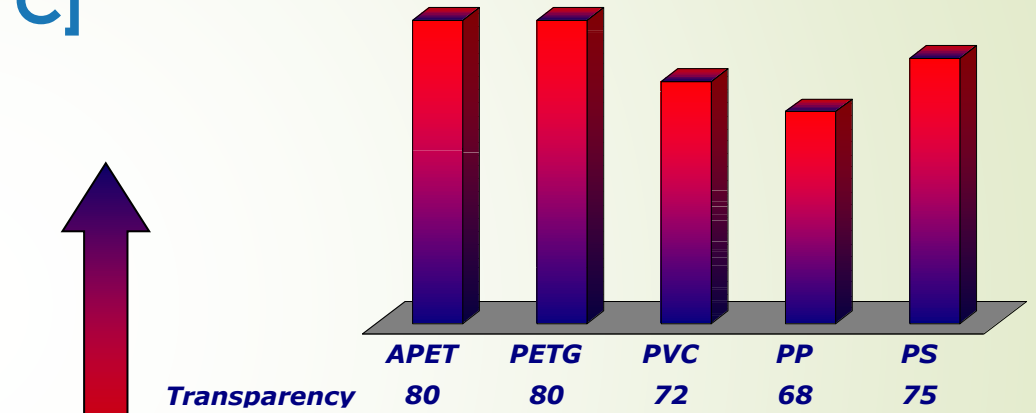
Aria yield [250 μm; m²/kg]

Properties polymeric films

Maximum operating temperature [°C]

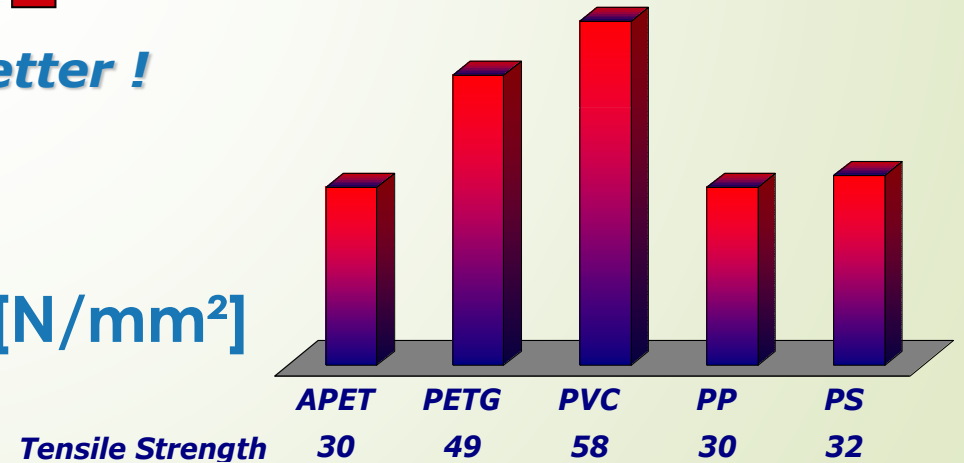


Transparency [250 μm; %]



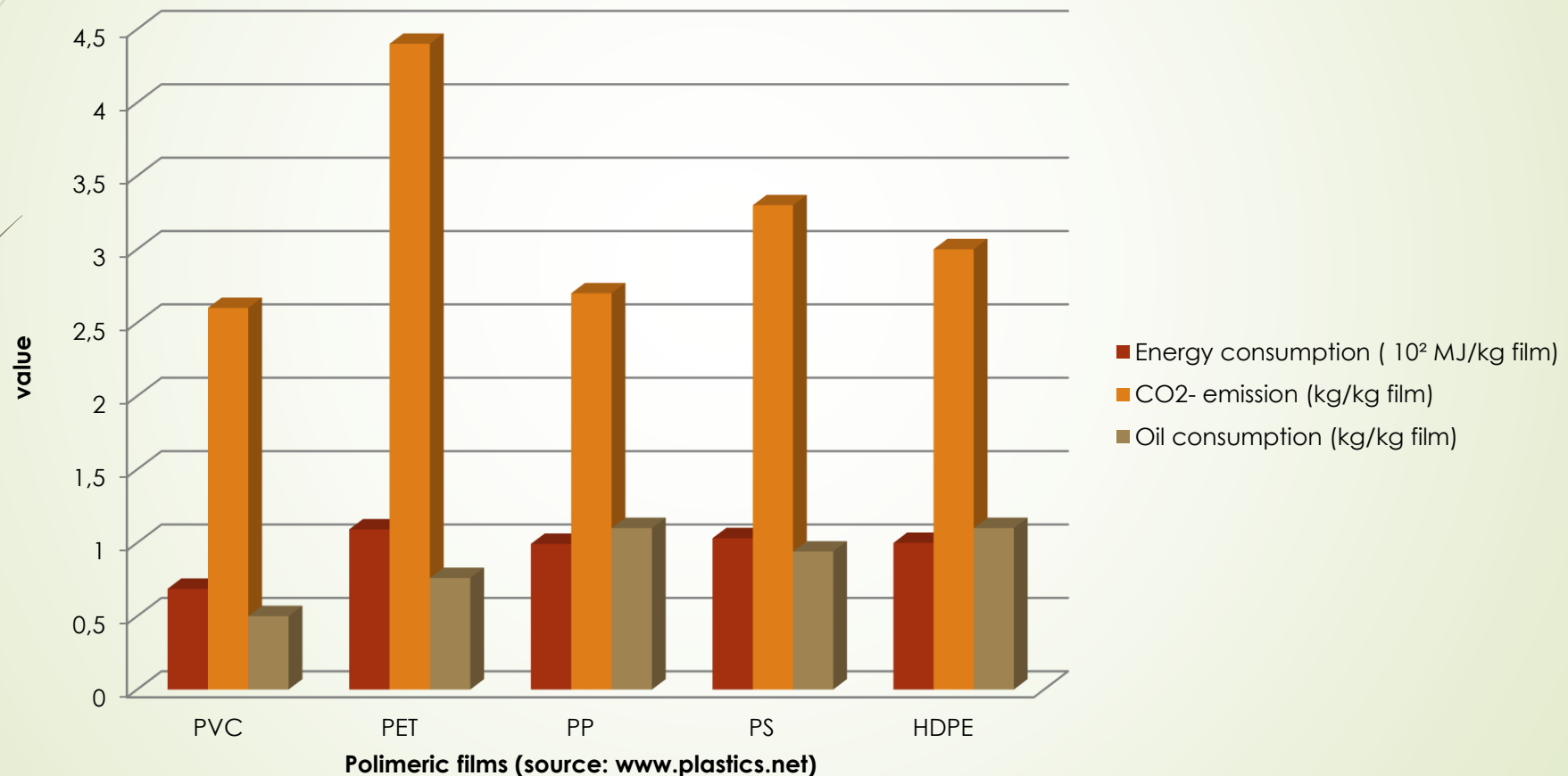
better !

Tensile strength [N/mm²]



Comparison of ecological indicators for basic polymer films

Ecological comparison of polymeric films

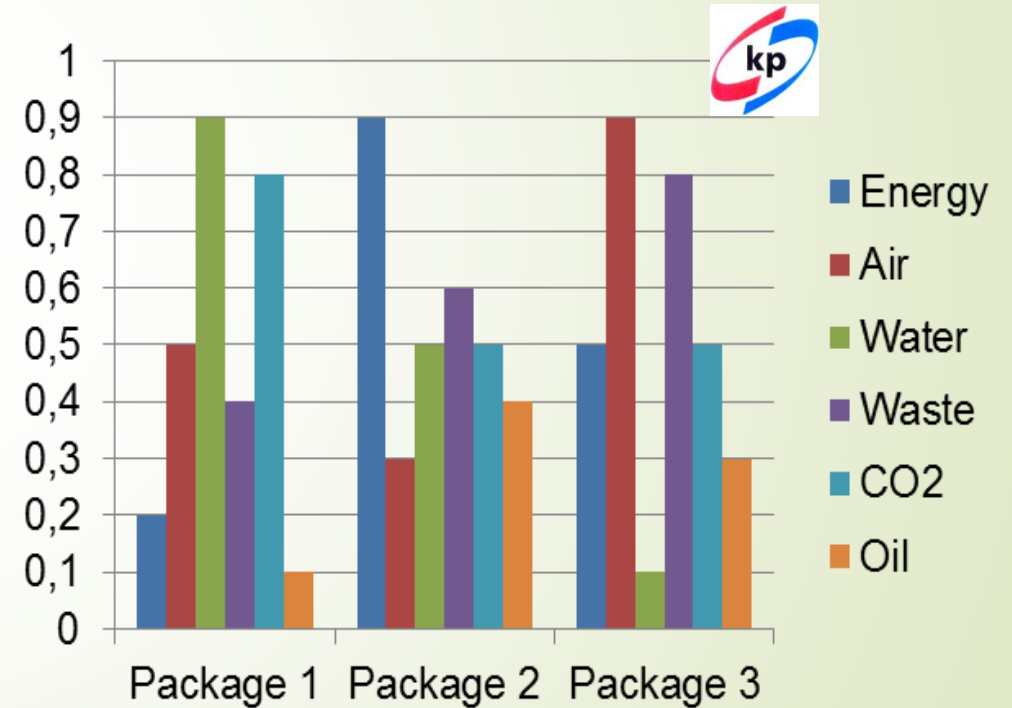


Comparison of ecological indicators for basic polymer films

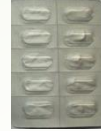
Oekobil 4 is a kp internal software which was developed by TU St.Petersburg to show the ecological comparison of different packaging material

Goal of Oekobil 4 is comparing the ecological characteristics of:

- PS Energy consumption (MJ/kg)
- PET Air quantity (m³/kg)
- PVC Water quantity (dm³/kg)
- PP Solid waste (cm³/kg)
- HDPE CO₂ emissions (mg/kg)
- LDPE Oil consumption (g/kg)
- PVdC Water consumption (l/kg)
- PLA
- CaCO₃



Comparison of ecological indicators for basic polymer films



Packaging	Aluminum	PVC, aluminum	PP, aluminum	PVC, aluminum	PVC, paper, aluminum
Capacity (pieces)	10	10	10	10	10
Bottom film (gramms)	Aluminum 1,3262	PVC 1,2075	PP 1,1984	PVC 0,8301	PVC 0,841
Top film (gramms)	Aluminum 0,8922	Aluminum 0,603	Aluminum 0,5989	Aluminum 0,5125	Paper, aluminum 0,23

Start window

Ecobalances of different packages
Calculation of ecological characteristics comparable packaging:
PVC, PP, PS, HIPS, LDPE, HDPE, PET, glas, aluminum, cardboard, paper, metal (tin), etc.

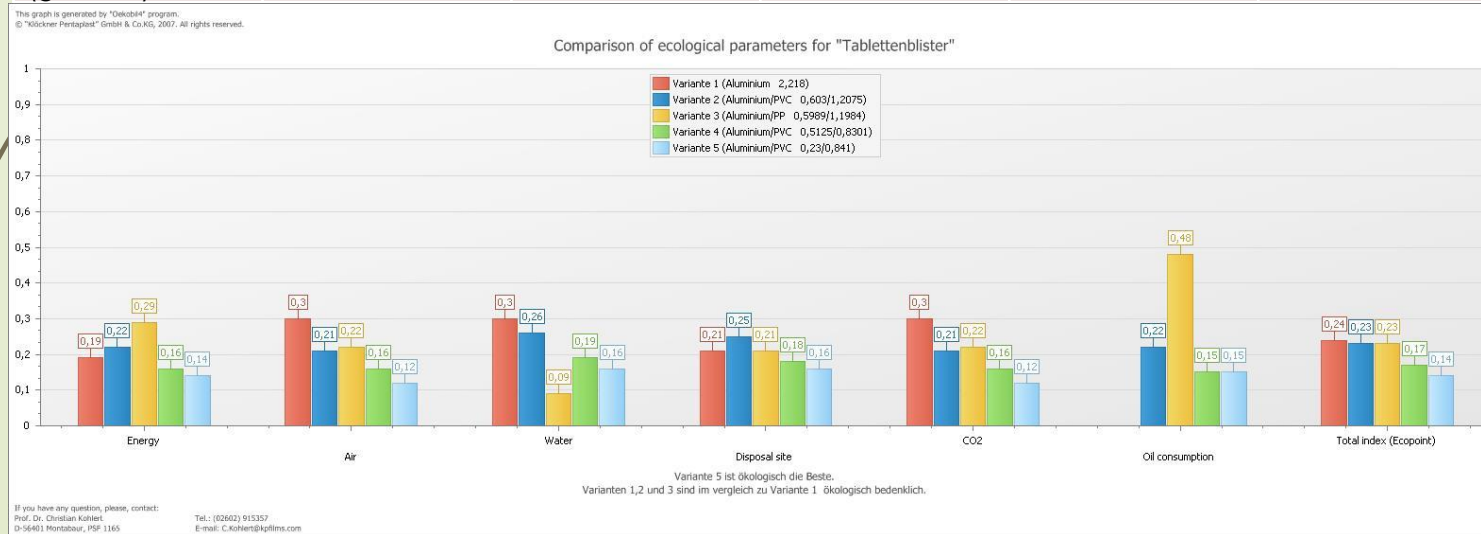
Attention!
Comparison in the "OekobiZ" program is applicable only for packages with the same contents, same volume, and same package-objective.

At the packages comparison the following deviations of the Total index (Ecopoint) are not considerable:
- 2 packages: 20%;
- 3 packages: 10%;
- 4 packages: 5%.

This rule is based on the approximate calculation method of the "OekobiZ" program.

For all the questions regarding the method of eco-balancing, please contact:
Prof. Dr. Christian Kohlet
D-56401 Montabaur, PSF 1165
Tel.: (02602) 915357
Email: C.Kohlet@kpfilms.com

Exit from "OekobiZ"

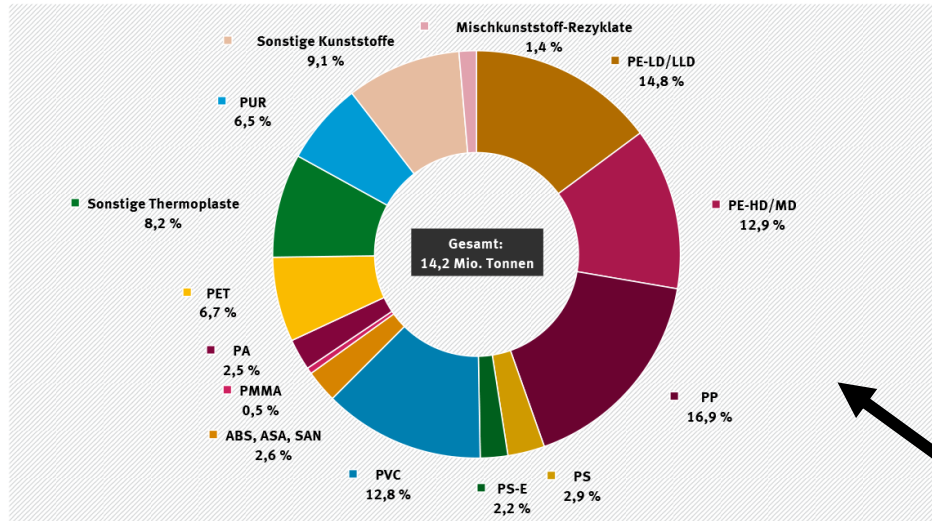


Advantage:

- Review environmental impact of different packaging options
- Decision support for customer

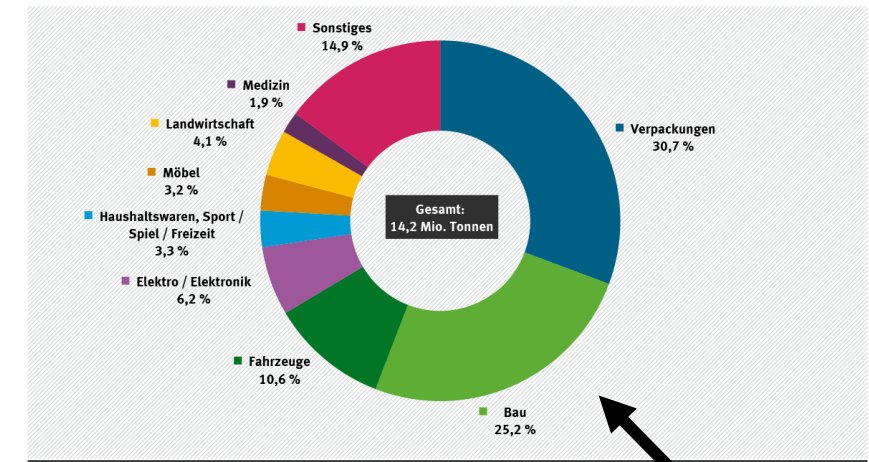
Recycling of polymers

Anteil der Kunststoffsorten an der Verarbeitungsmenge Kunststoffe 2019 (Neuware und Rezyklat)



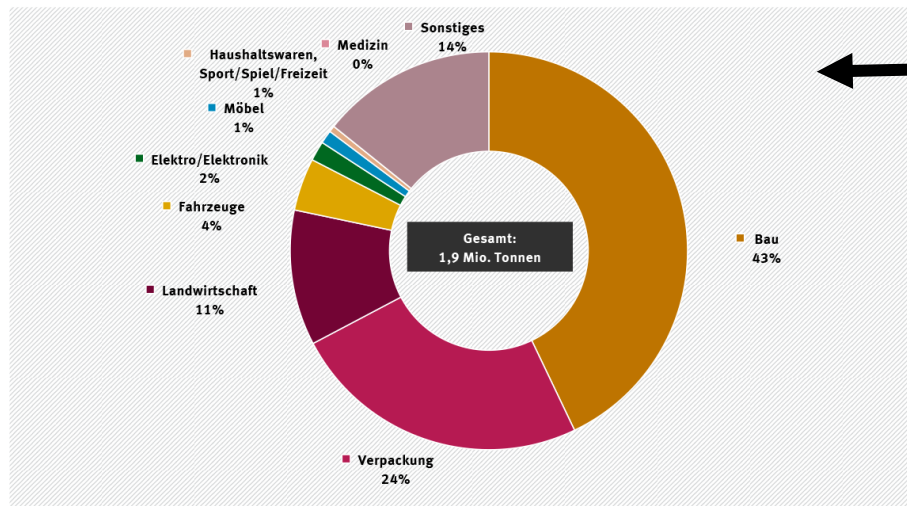
Quelle: Umweltbundesamt 2020, eigene Zusammenstellung mit Daten der CONVERSIO Market & Strategy GmbH - Stoffstrombild Kunststoffe in Deutschland 2019 (Stand 08/2020)

Anteil relevanter Branchen an der Verarbeitungsmenge Kunststoffe 2019 (Neuware und Rezyklat)



Quelle: Umweltbundesamt 2020, eigene Zusammenstellung mit Daten der CONVERSIO Market & Strategy GmbH - Stoffstrombild Kunststoffe in Deutschland 2019 (Stand 08/2020)

Einsatz von Kunststoffrezyklaten in Deutschland in 2019



Bezogen auf in Deutschland zum Einsatz kommende Rezyklate; Rezyklate stammen aus Post-Consumer-Abfällen sowie Produktions- und Verarbeitungsresten

Quelle: Umweltbundesamt 2020, eigene Zusammenstellung mit Daten der Convesio Market & Strategy GmbH - Stoffstrombild Kunststoffe in Deutschland 2019 (Stand 08/2020)

types of plastic recycling use

plastic branches

user



recycling

future developments

Нанотехнологии для пластиковых пленок

ситуация

Проблема:

- Нестандартные свойства поверхности для пластиковых пленок

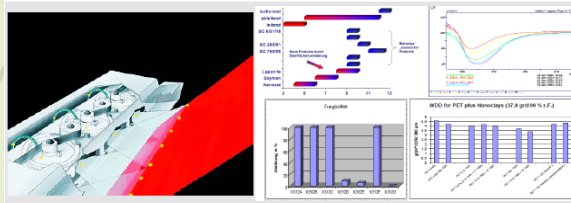
потенциал:

- Антимикробные поверхности
- Проводящие поверхности
- Лучше / хуже для печати
- Устойчивые к царапинам поверхности

партнер:

- Klöckner Pentaplast

результаты



Описание:

- Использование золь-гель технологии
- Распыление с ИК-сушкой

Моделирование процесса термоформования пленок

ситуация

Проблема:

- Прогнозирование ожидаемого распределения толщины стенок при термоформовании полимерных пленок.

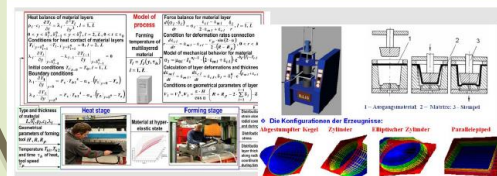
потенциал:

- Оптимизация параметров термоформования
- Оптимизация материалов и машин

партнер:

- ТУ Санкт-Петербург

результаты



Описание:

- Обнаружение проточных процессов с учетом реологических и термических параметров обработки
- Графическое представление результатов термоформования

защиты от подделок

ситуация

Проблема:

- Использование продукты и упаковки для защиты от подделки
- Быстрое и надежное обнаружение подделок без особых усилий

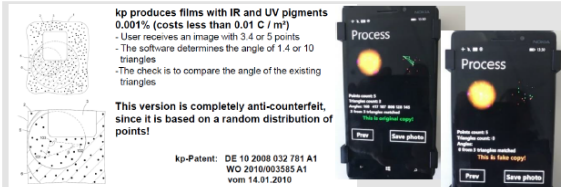
потенциал:

- Обнаружение подделок с помощью смартфона без подключения к Интернету, поскольку возможно хранение многих миллионов продуктов из-за небольшого объема данных.

партнер:

- ТУ Санкт-Петербург
- Sensor Instruments

результаты



kp produces films with IR and UV pigments 0.001% (costs less than 0.01 € / m²)
 - User receives an image with 3.4 or 5 points
 - The software determines the angle of 1.4 or 10 triangles
 - The check is to compare the angle of the existing triangles
 This version is completely anti-counterfeit, since it is based on a random distribution of points!
 kp-Patent: DE 10 2008 032 781 A1
 WO 2010/003555 A1
 vom 14.01.2010

Описание:

- Использование люминесцентных пигментов (около 10 промилле)
- Озвучивание и оценка треугольника
- Хранение альфа и бета (около 5 кБ)
- Распознавание через смартфон без интернет-контакта

Data Mining для больших данных

ситуация

Проблема:

- Использование больших объемов данных для оценки влияния отдельных пакетов данных на качество продукции
- Связь технологии, качества и сырья

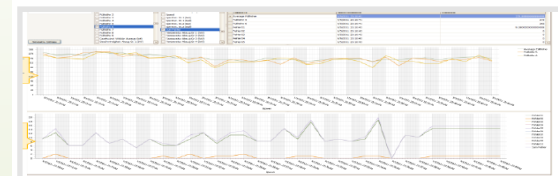
потенциал:

- Открытие причинно-следственной связи
- Прогнозирование вопросов качества
- анализ тенденций
- Более стабильный производственный процесс

партнер:

- ТУ Санкт-Петербург

результаты



Описание:

- Приобретение многих значений отдельных параметров
- Использование всех значений между Мин и Макс
- Целевое значение по умолчанию
- Оценка влияния отдельных параметров на целевое значение
- Схема управления (саморегулирующиеся машины)

future theme for

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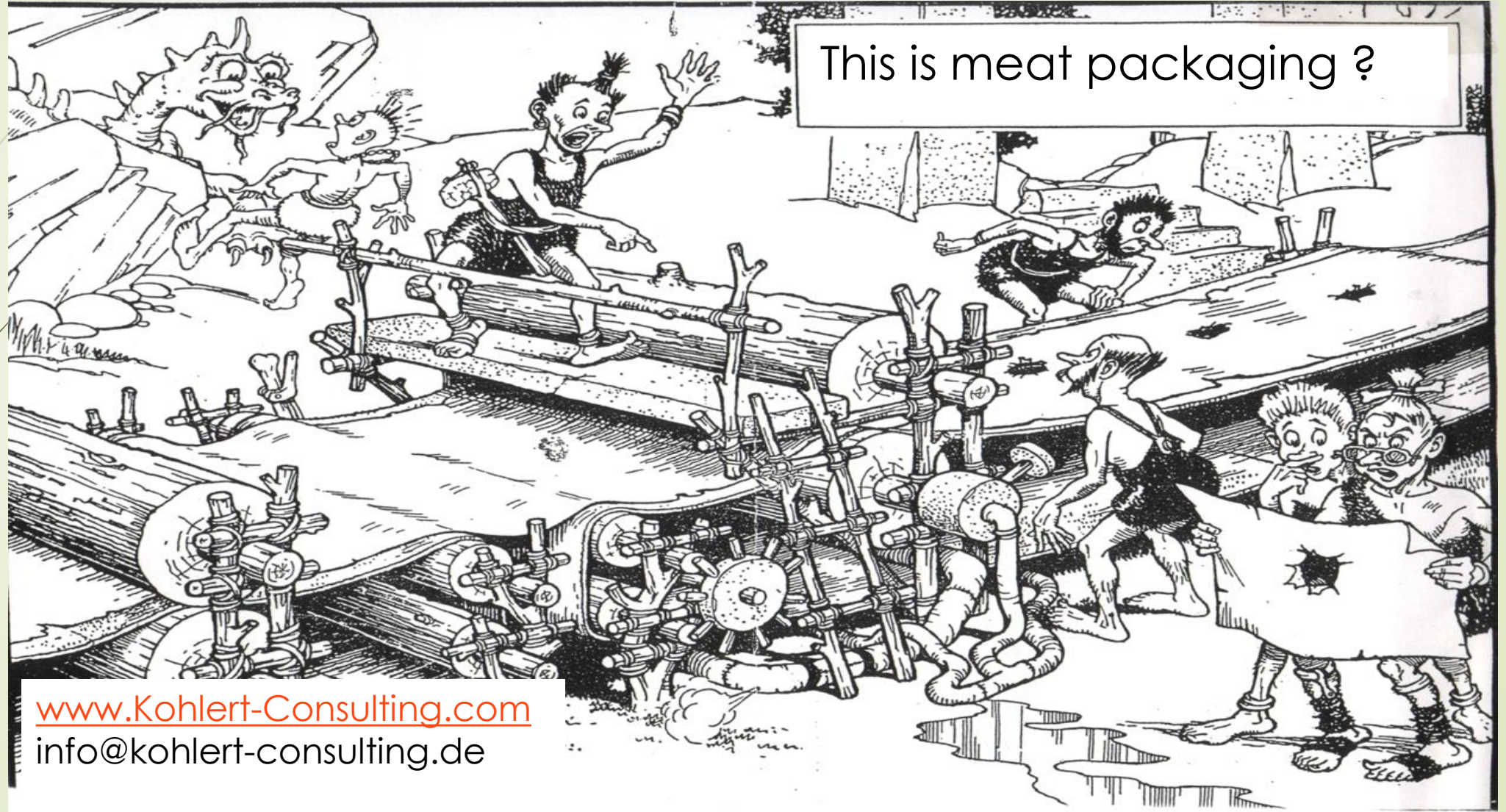
Honorary professors for students and staff of the Technological Institute of St. Petersburg

(every last Thursday at 4 p.m. russ.time)

- Nanotechnology to generate new film properties (Prof.Dr.Kohlert)
- Impact of CO2 savings on energy consumption in the context of climate change (Dr.Dr.h.c.H.Gärtner)
- Directed and uncontrolled processes (micro decisions) with a global context comparison 1990 with 2020 (Prof.S.Steinmeier)
- Industry 4.0 and the current situation in the manufacturing industry (Prof.Dr.F.Kleinert)
- PET bottles recycling (Prof.Dr.F.Kleinert)
- Lean Six Sigma – continuous improvement and project management (Prof.Dr.F.Kleinert)
- The Supply Chain Digitization (Dr.M.Kohlert)

Multilayer films for meat packaging

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