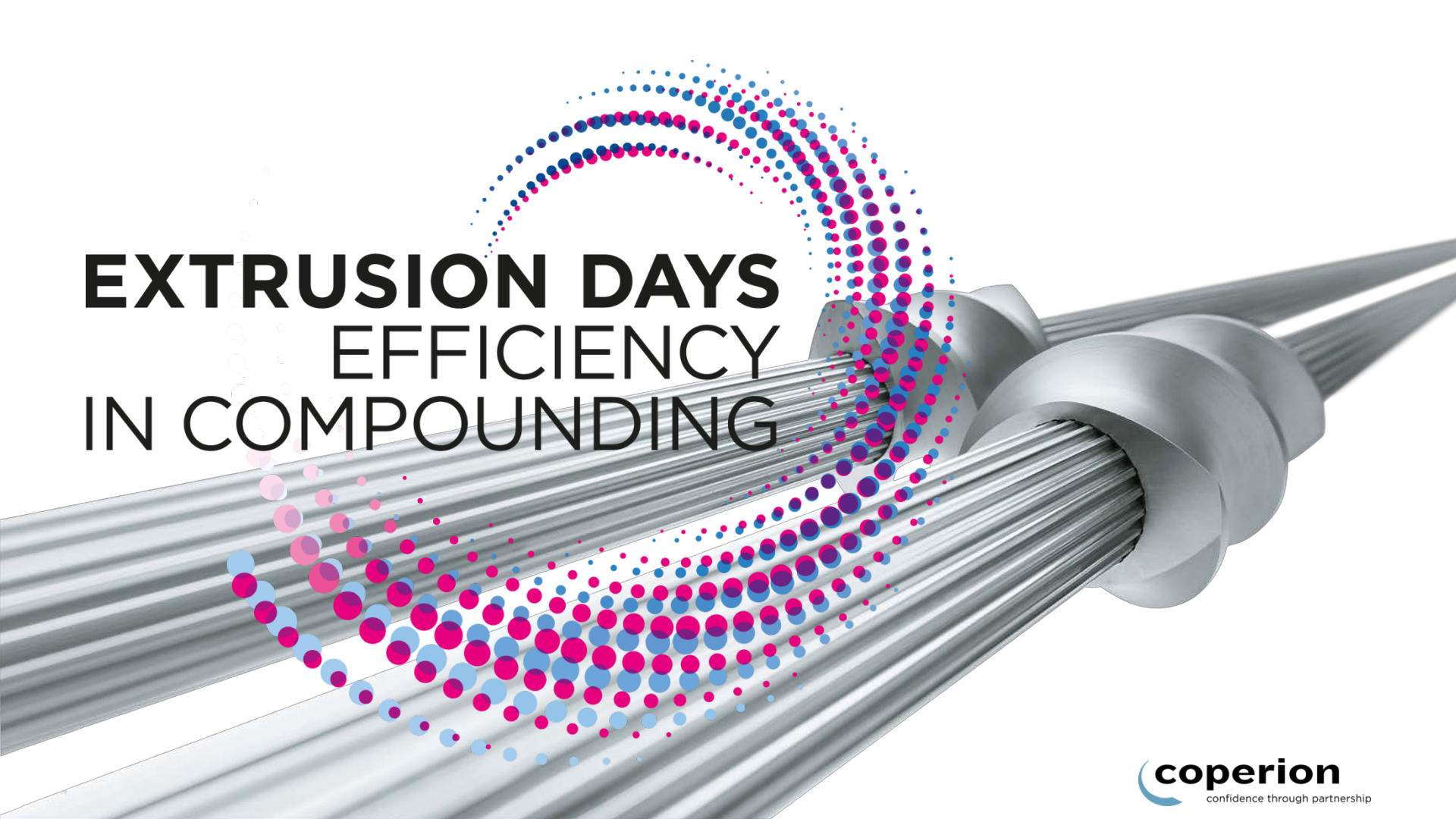
EXTRUSION DAYS
EFFICIENCY IN COMPOUNDING



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Efficient Design of Process Sections – From Theory to Practice

Svetlana Marinova, R&D Compounding & Extrusion
Frank Mack, Process Technology Compounding & Extrusion

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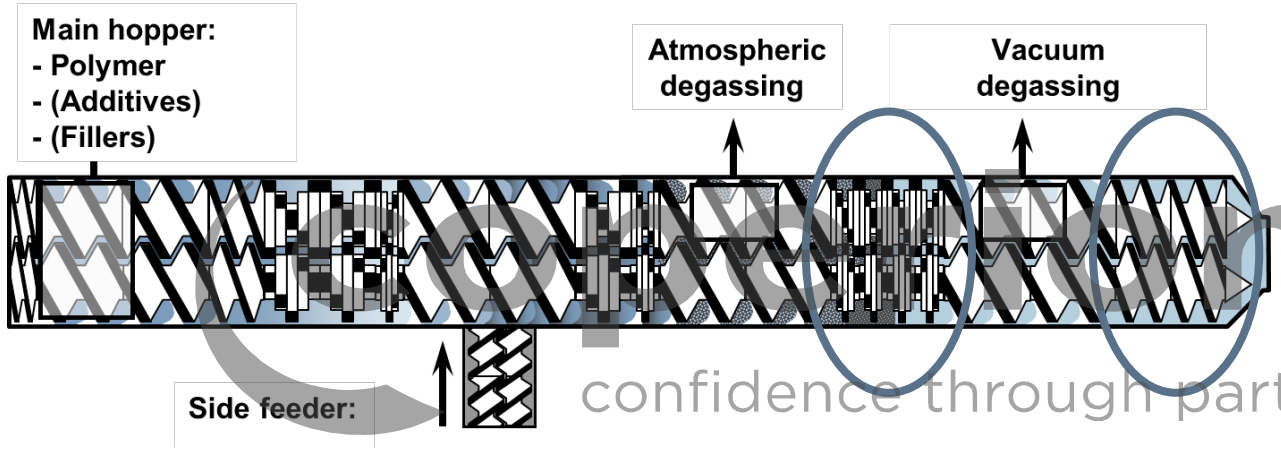
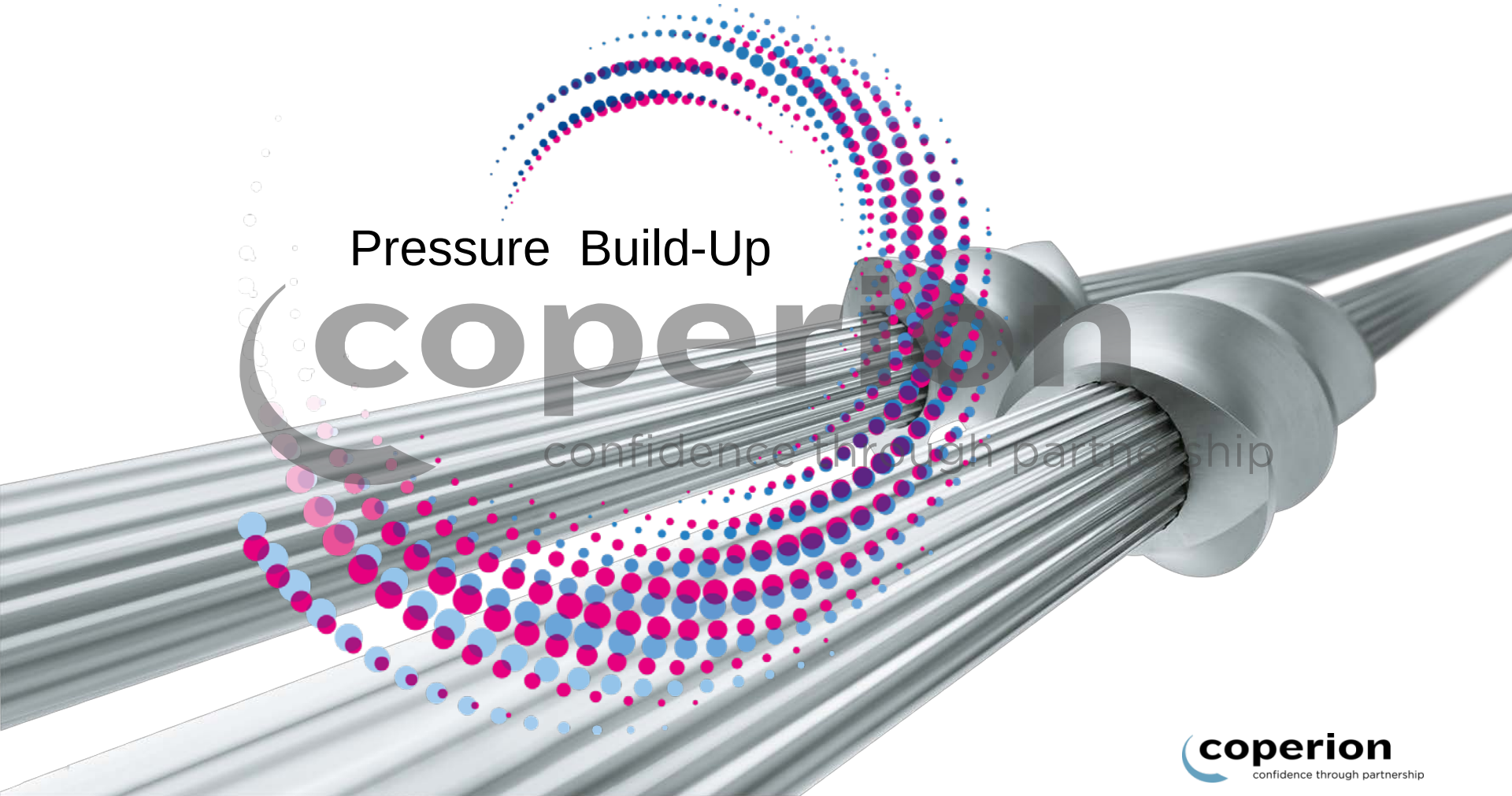
Set-up of the ZSK Extruder



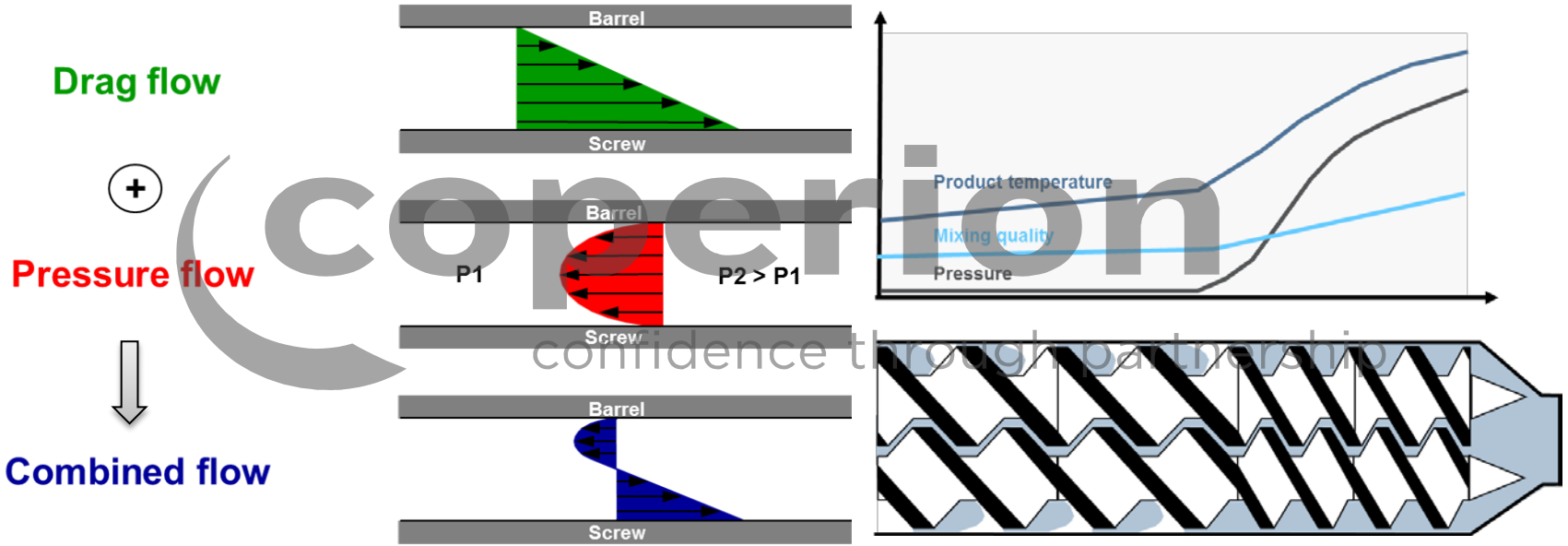
1. Pressure build-up
2. Mixing
3. Heat transfer

Main feeding and preheating	Melting	Feeding of fillers	Mixing	Degassing	Mixing	Degassing	Pressure build-up

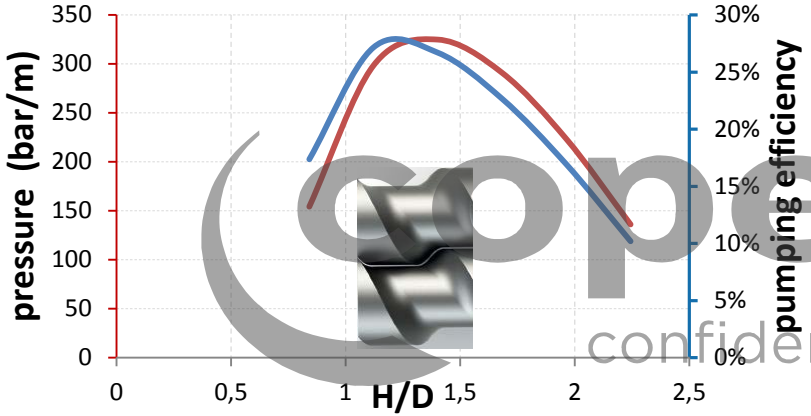
Pressure Build-Up



Pressure Section – Theory

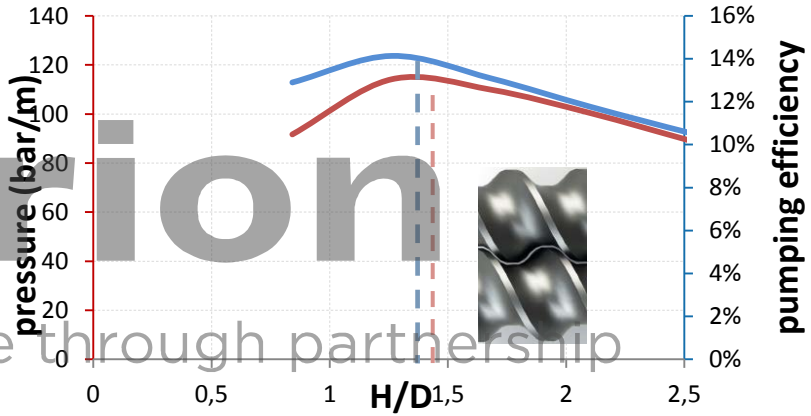


Pressure Section: Calculation



ZSK 70, single-flighted, 600 rpm, m=2 t/h

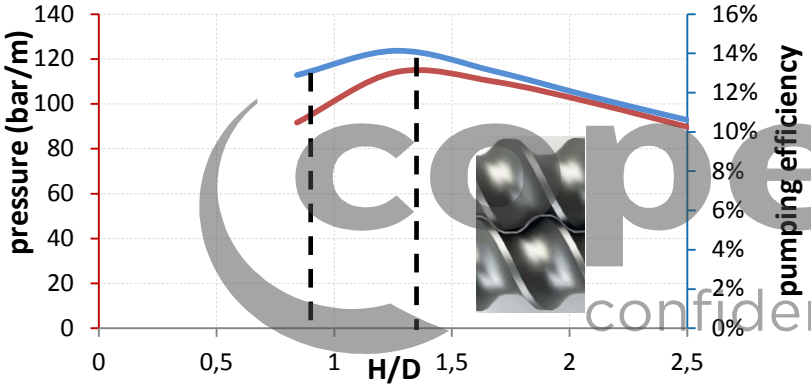
Product: PP, MI2=3[g/10min]

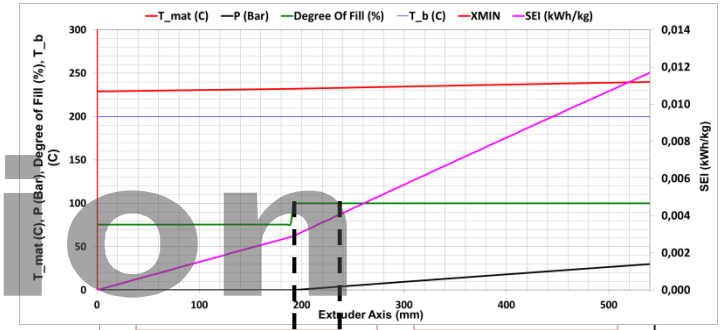


ZSK 70, double-flighted, 600 rpm, m=2 t/h

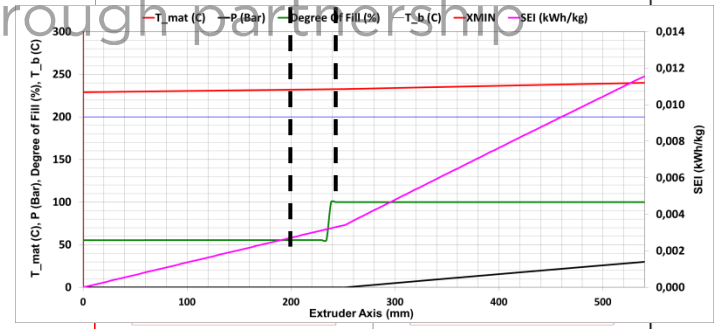
Product: PP, MI2=3[g/10min]

Pressure Section: Calculation vs. Practice





H/D=0,8

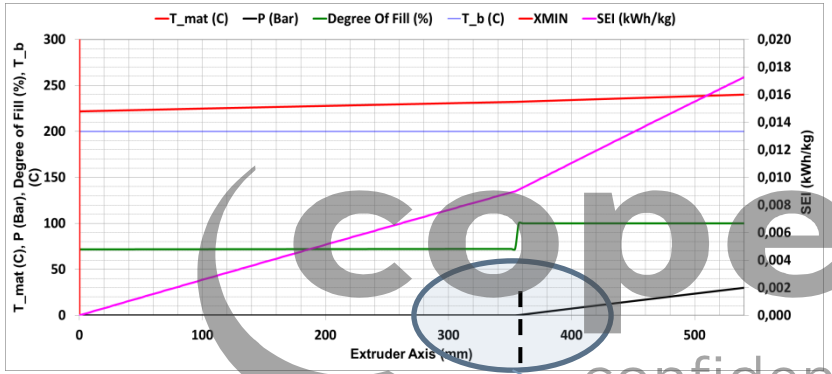


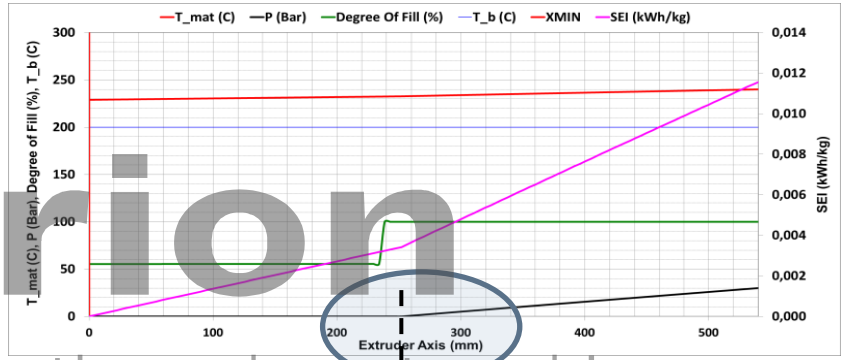
H/D=1,3

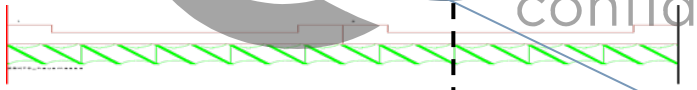
ZSK 70, double-flighted, 600 rpm, m=2 t/h

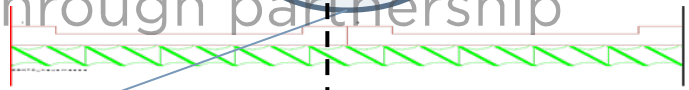
Product: PP, MI2=3 [g/10min]

Pressure Section: Calculation vs. Practice



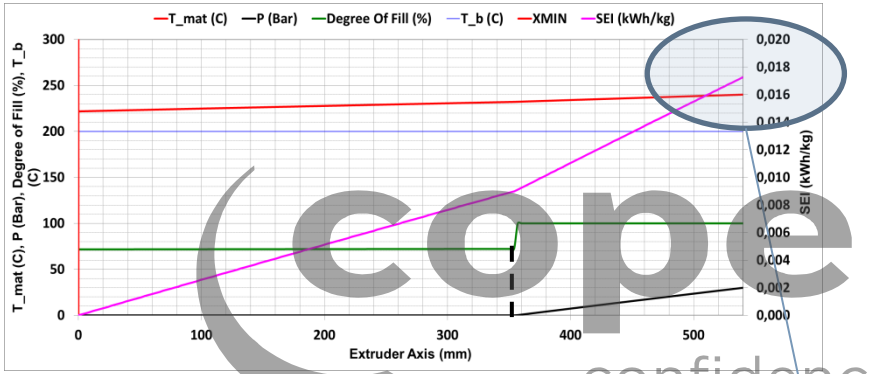


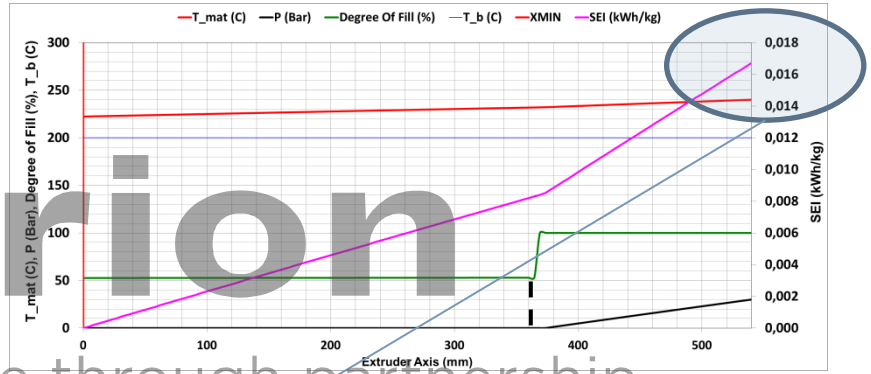




Shorter back-up length ≠

Pressure Section: Calculation vs. Practice



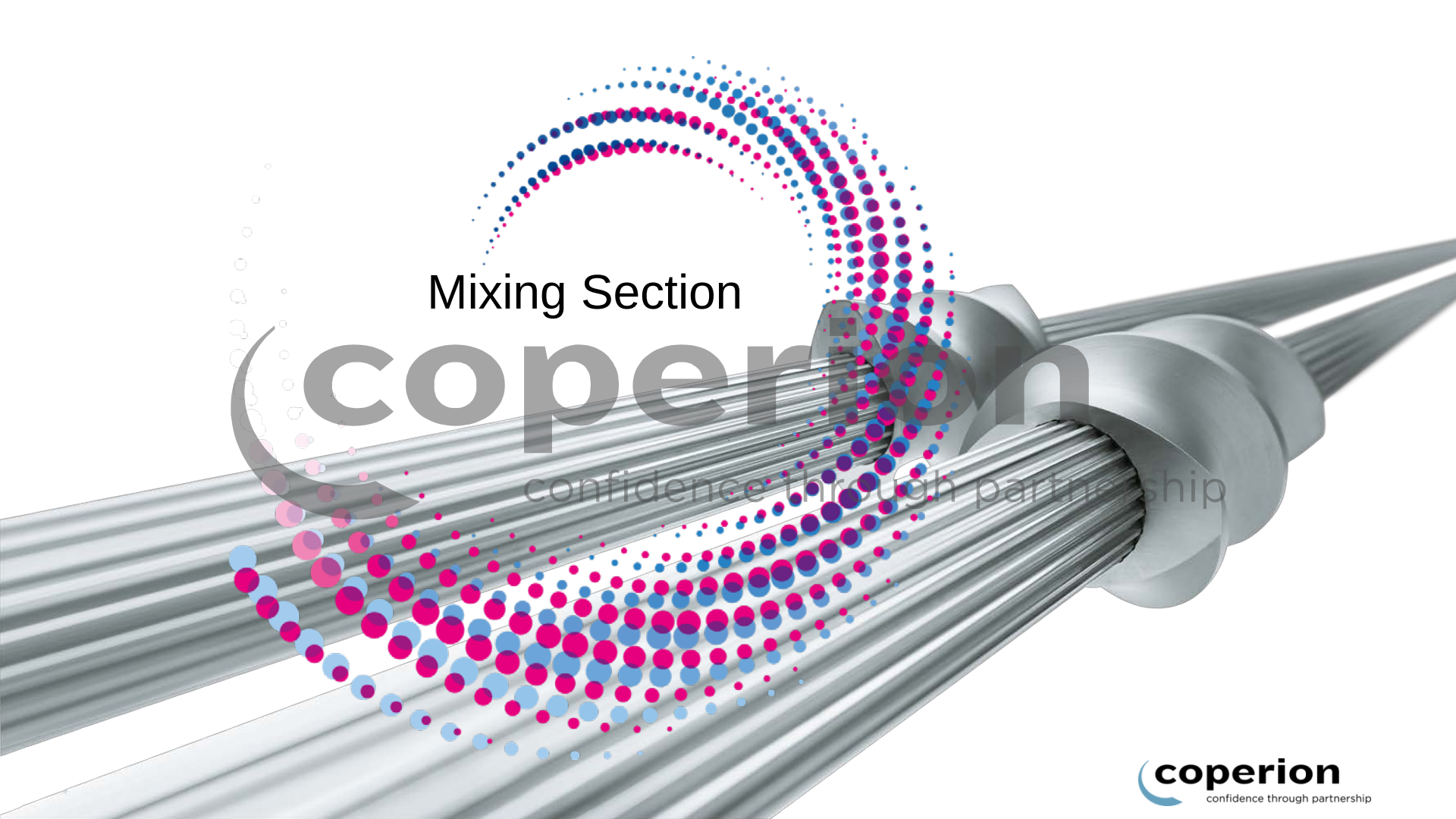


H/D=1,3

H/D=0,8

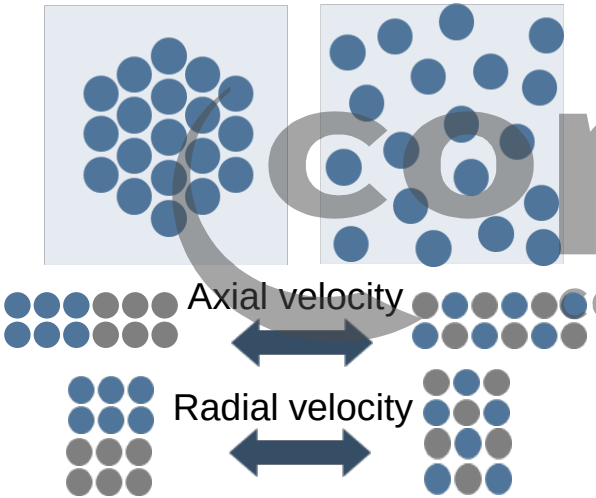
ΔSEI = 0,001

Mixing Section



Mixing Section: Theory

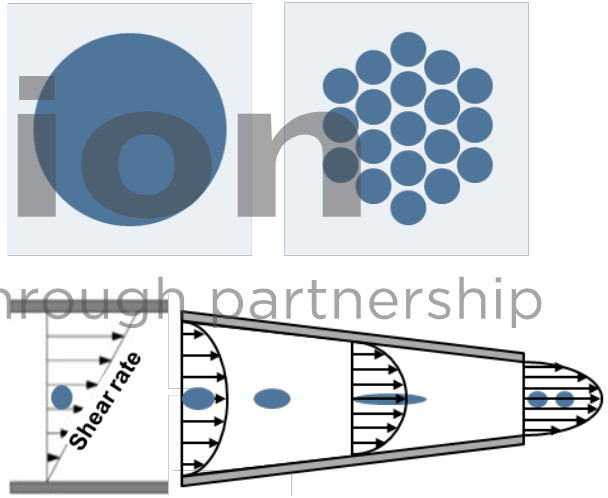
Distributive Mixing = Equal concentration



Mixing mechanism:

Distribution of primary particles

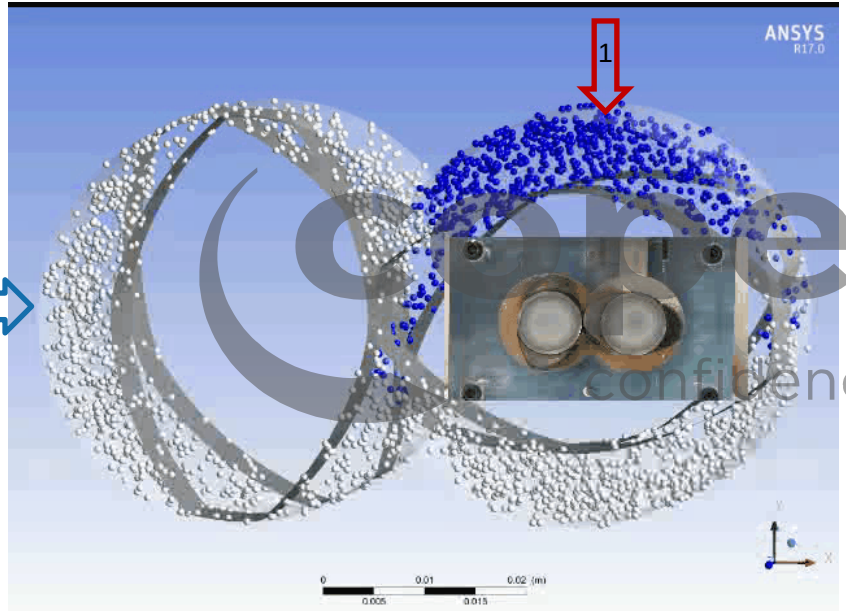
Dispersive mixing = Deagglomeration

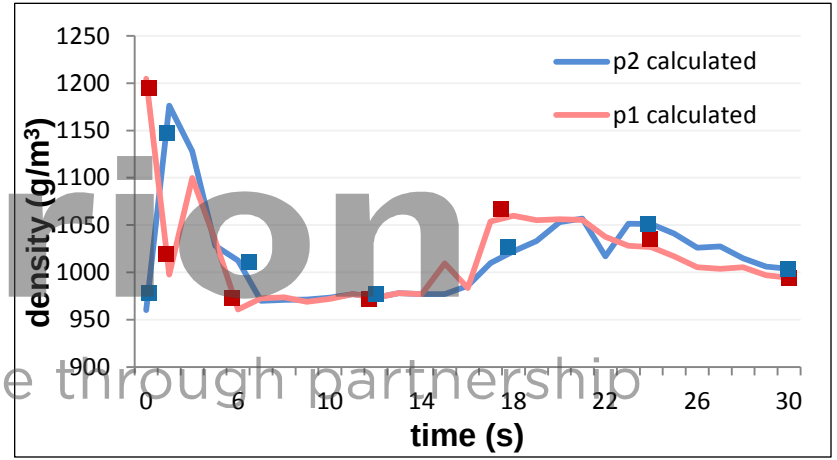


Mixing mechanism:

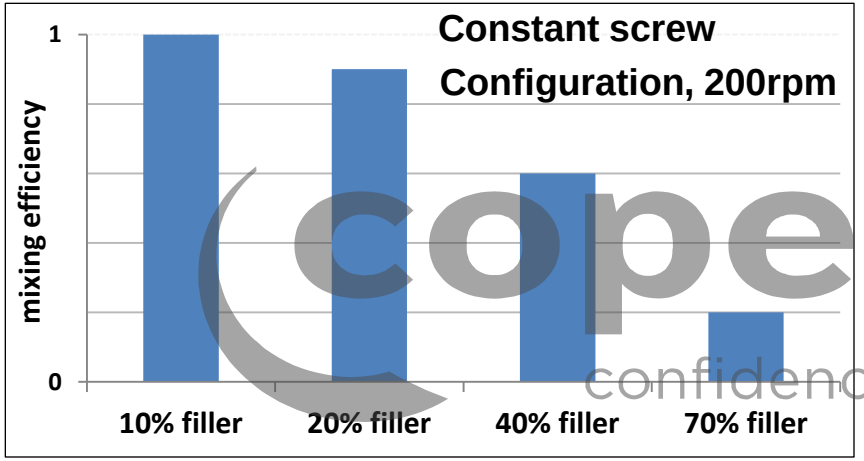
Dispersion of agglomerates and aggregates

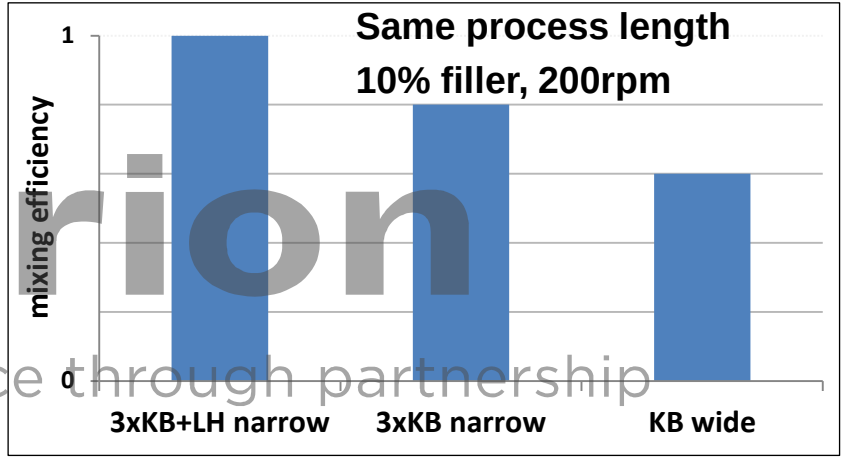
Mixing Section: Calculation

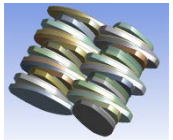




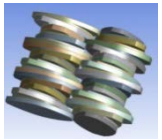
Mixing Section: Calculation



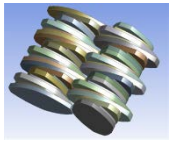




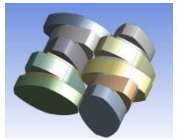
3 x KB 45/5/18



2 x KB45/5/18, KB45/5/18 LH



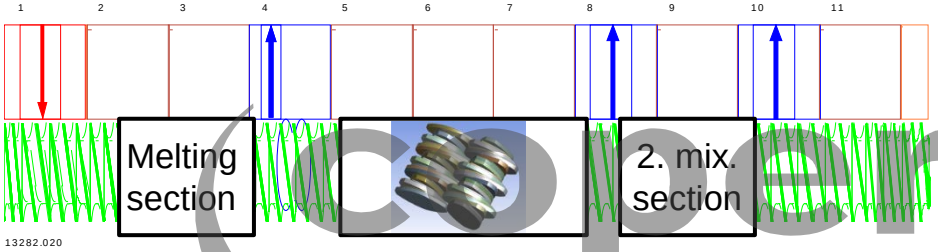
3 x KB 45/5/18



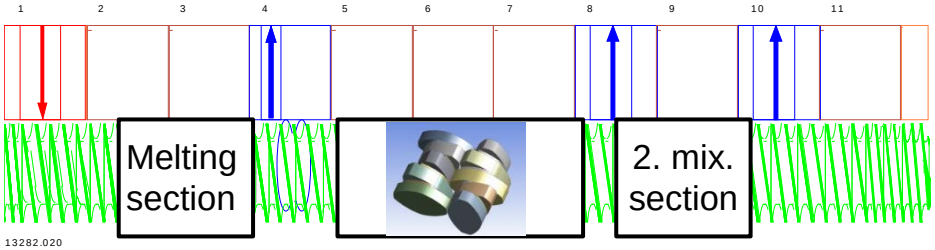
KB 45/5/54

Mixing Section: Practice Background

Screw 1: Mixing section with narrow discs



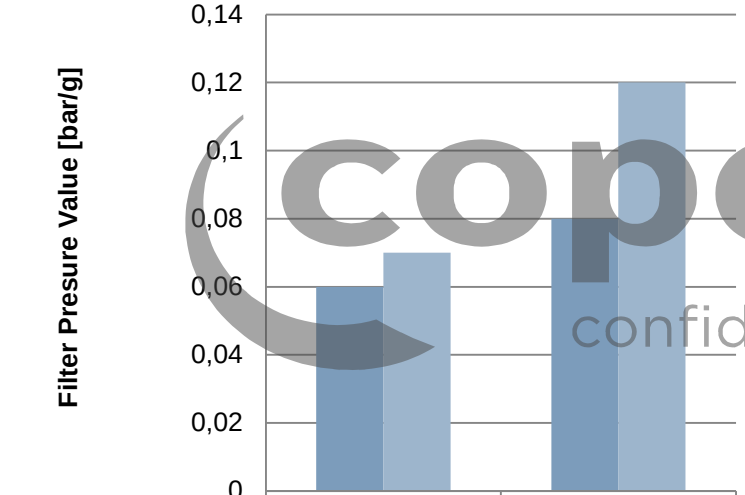
Screw 2: Mixing section with wide discs



- ZSK 40 Mc PLUS
- PP + 70% TiO_2 (via side feeder)
- Mixing section with constant length
- Same process conditions
- Problem: distributive mixing can not be separated from dispersive mixing

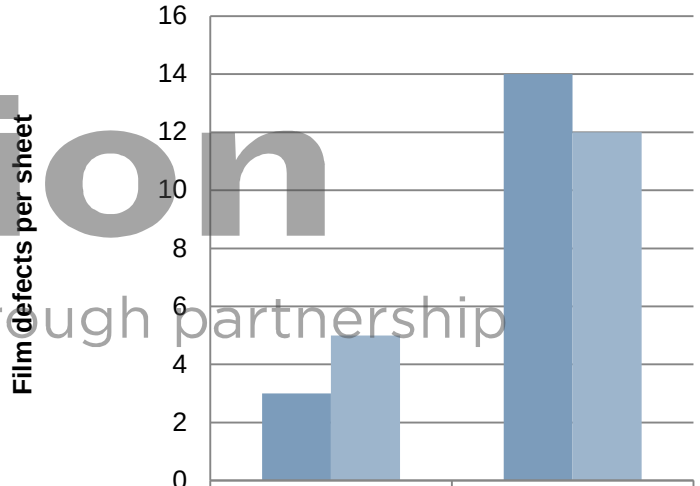
Mixing Section: Practice Results

Filter Pressure Value



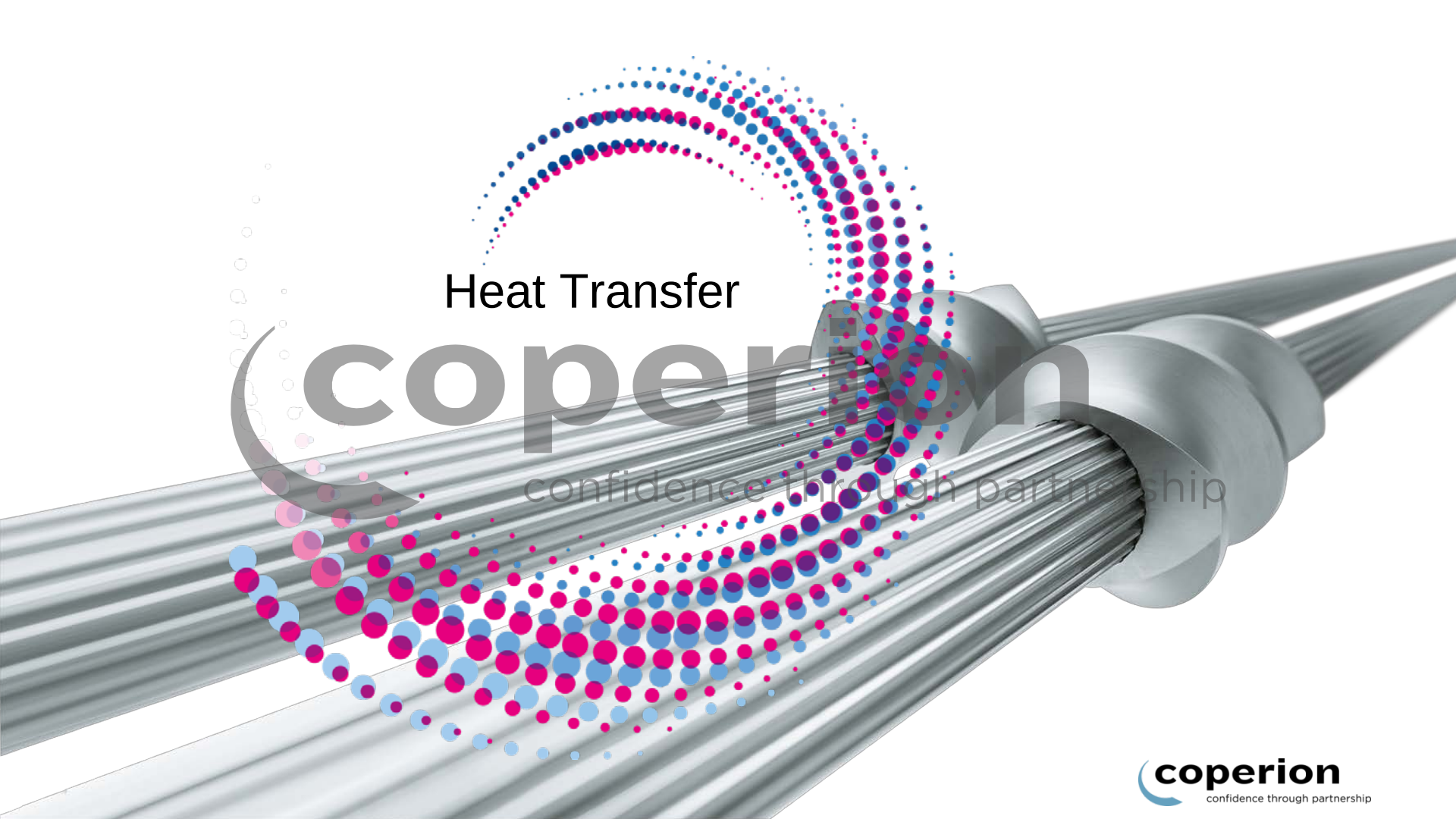
	1	2
300 kg/h - 250 rpm	0,06	0,08
300 kg/h - 500 rpm	0,07	0,12

Film defects

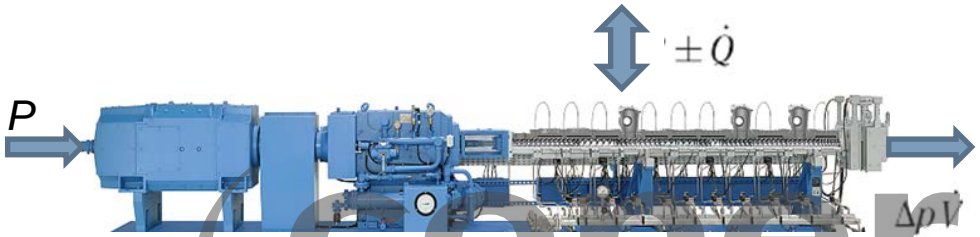


	1	2
300 kg/h - 250 rpm	3	14
300 kg/h - 500 rpm	5	12

Heat Transfer



Heat Transfer: Theory

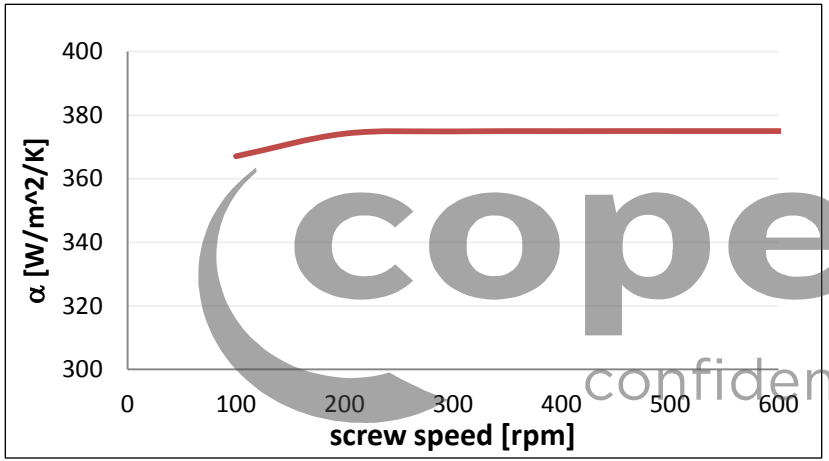


$$P \pm \dot{Q} = \dot{m}\, c_v \Delta T + \Delta p \dot{V}$$

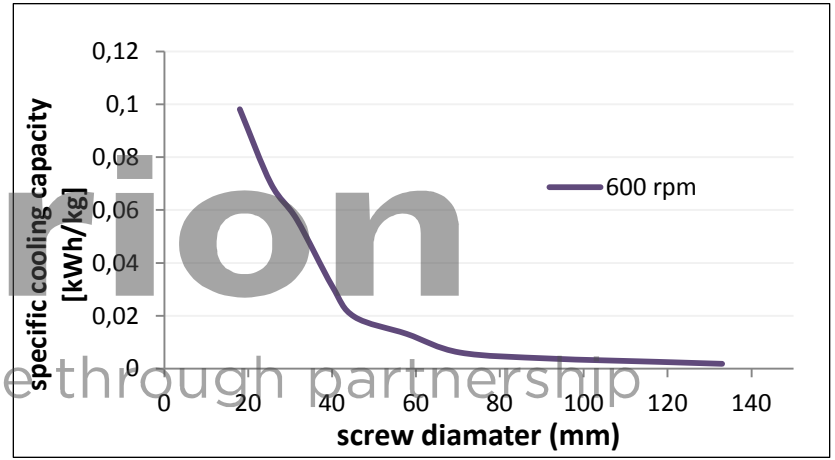
$$\dot{Q} = \alpha \cdot A_{barrel} \cdot \Delta T$$

- Heat transfer from product to barrel is the limiting factor for cooling or heating
- Influence of the heat transfer coefficent (product-barrel) on the cooling

Heat Transfer: Calculation



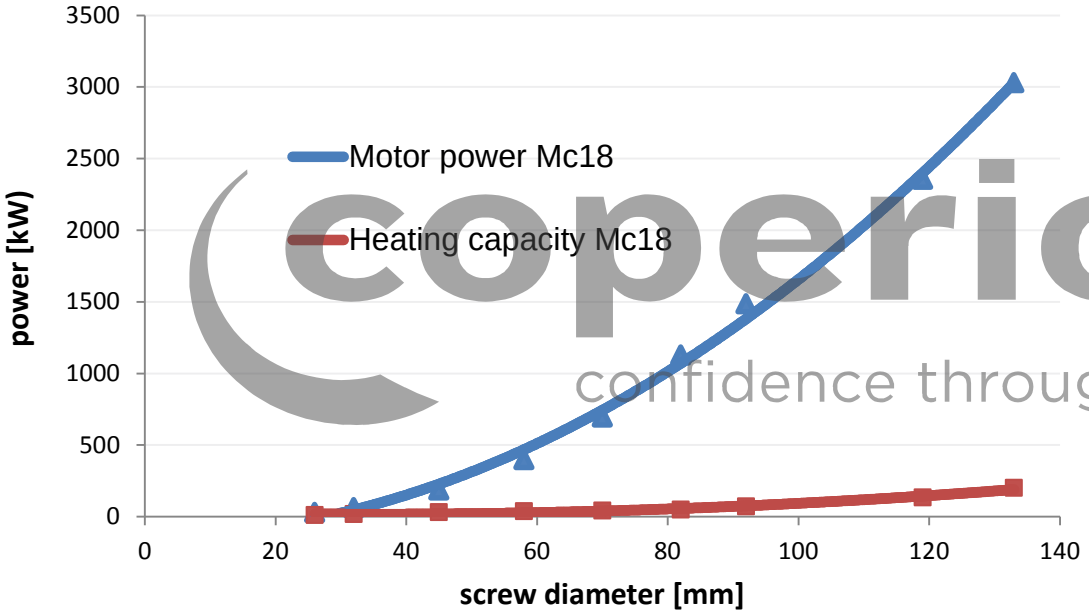
Caclulated heat transfer coefficient according to Janeschitz-Kriegl for ZSK 70



Caclulated specific cooling capacity for 9 barrels (volumetric scale-up of throughput to other machine sizes, baseline ZSK 70)

Cooling capacity is decreasing significantly with machine size

Heat Transfer: Practice



- Heating capacity increases with inner surface area
- Motor power increases with inner volume

Heat Transfer: Example from Practice

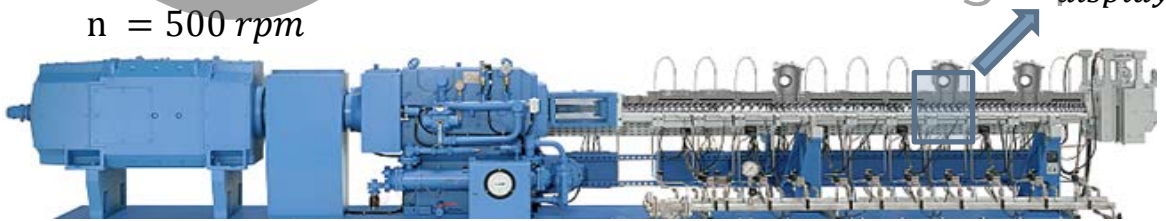
Customer complaint: displayed temperature in kombi barrel of ZSK 133 (no cooling) higher than set-point

- $\dot{m} = 4500\,\mathrm{kg}/h$
- $\alpha = 375\,\mathrm{W}/\mathrm{m}^2 \cdot \mathrm{K}$
- $c_p = 2400\,\mathrm{J}/\mathrm{kg} \cdot \mathrm{K}$

$T_{set} = 230°\mathrm{C}$

$T_{display} = 255°\mathrm{C}$

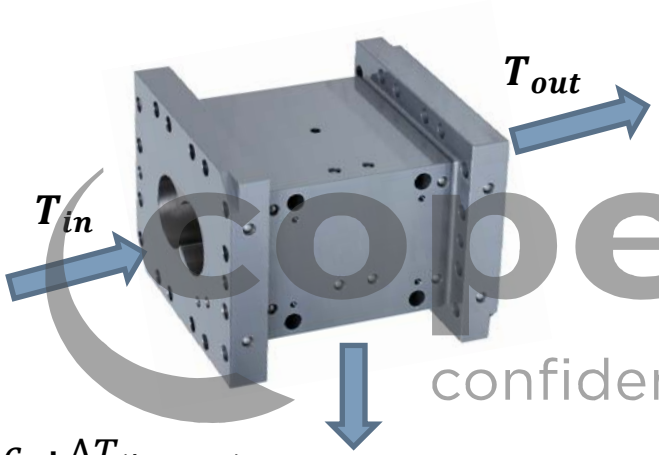
$\mathrm{n} = 500\,rpm$



$T_{melt} = 260°\mathrm{C}$

$\dot{m} = 4500\,\mathrm{kg}/h$

Heat Transfer: Example from Practice



$$\dot{E} = \dot{m} \cdot c_p \cdot \Delta T_{(in-out)}$$

$$\dot{Q} = \alpha \cdot Abar_{rel} \cdot \Delta T_{(melt-barrel)}$$

Effective under ideal conditions:

- Full-filled channels
- Negligible SEI from conveying

$\rightarrow \dot{E} = \dot{Q}$

For ZSK 133 :

$\rightarrow \Delta T_{(in-out)} = 0,5K$

For ZSK 70:

$\rightarrow \Delta T_{(in-out)} = 2,5K$

Summary

- Calculation of process conditions is getting more important and more accurate
- For single process sections simulation accuracy is sufficient for design
- Very good practical experience in the design of process sections still necessary
- Optimal design by combining calculation and experience


Thank you very much
for your attention!
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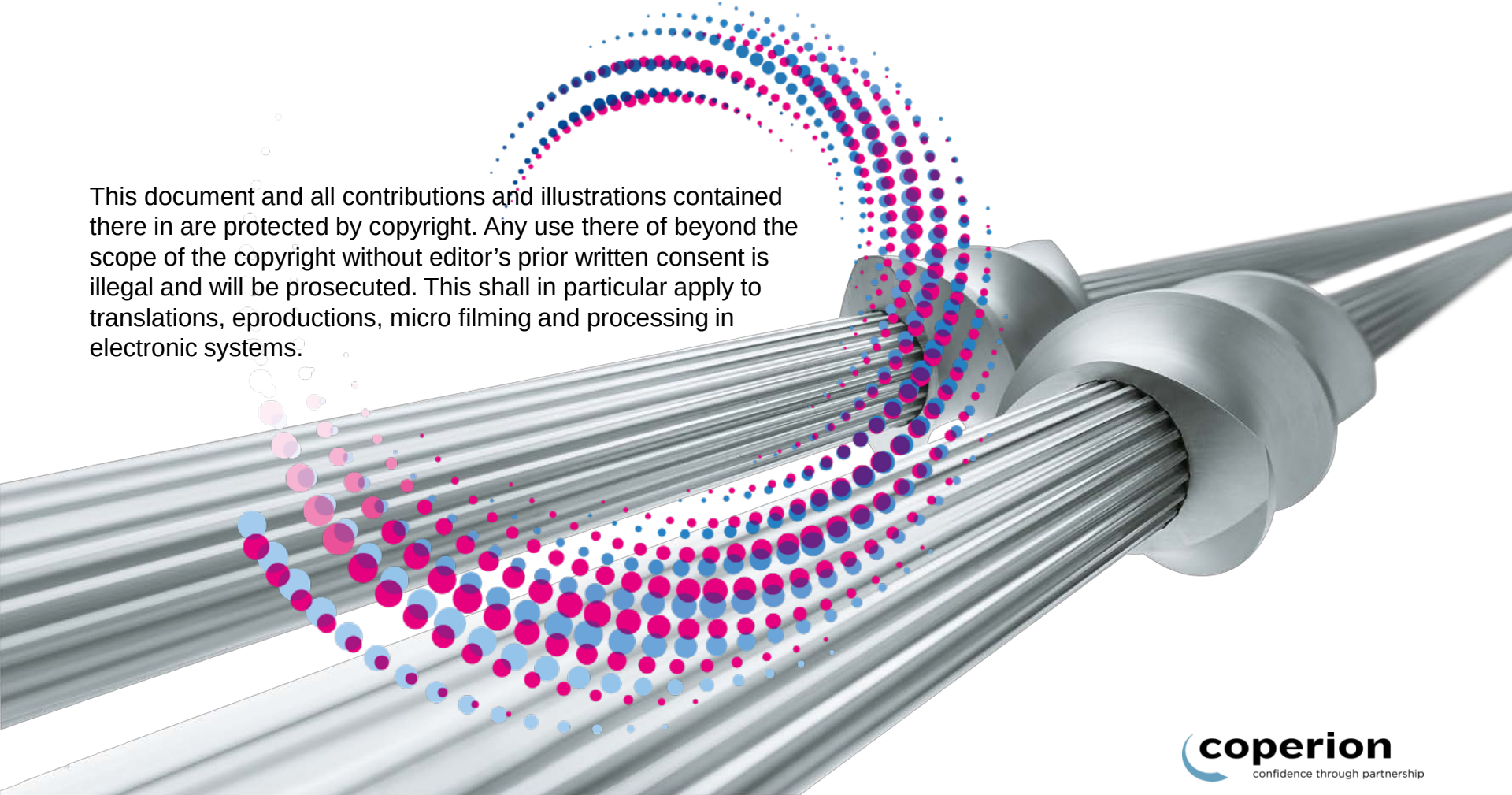

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