

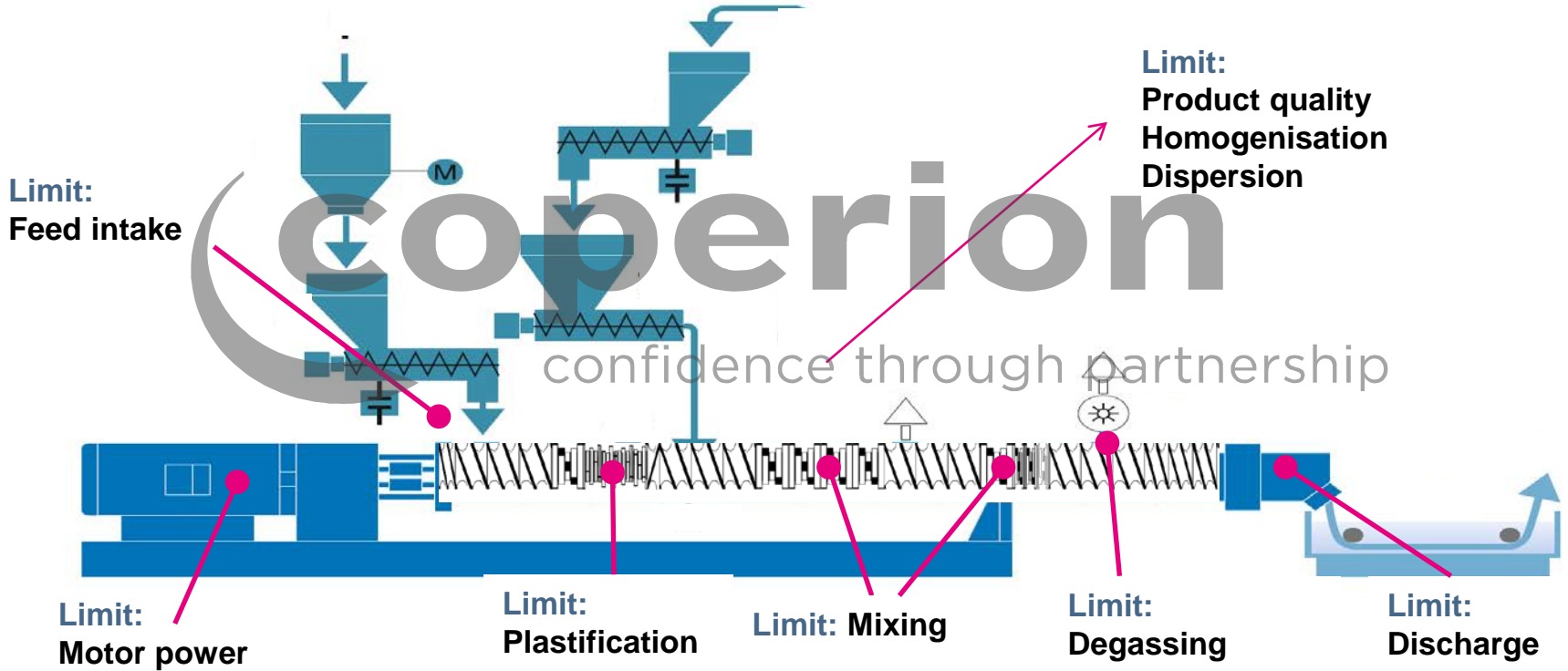
A 3D rendering of a multi-roller extrusion system. The rollers are grey and arranged in a line, with a stream of material being extruded from the right. The stream is composed of many small, overlapping spheres in shades of blue, pink, and purple, creating a vibrant, multi-colored effect. The background is white.

EXTRUSION DAYS EFFICIENCY IN COMPOUNDING

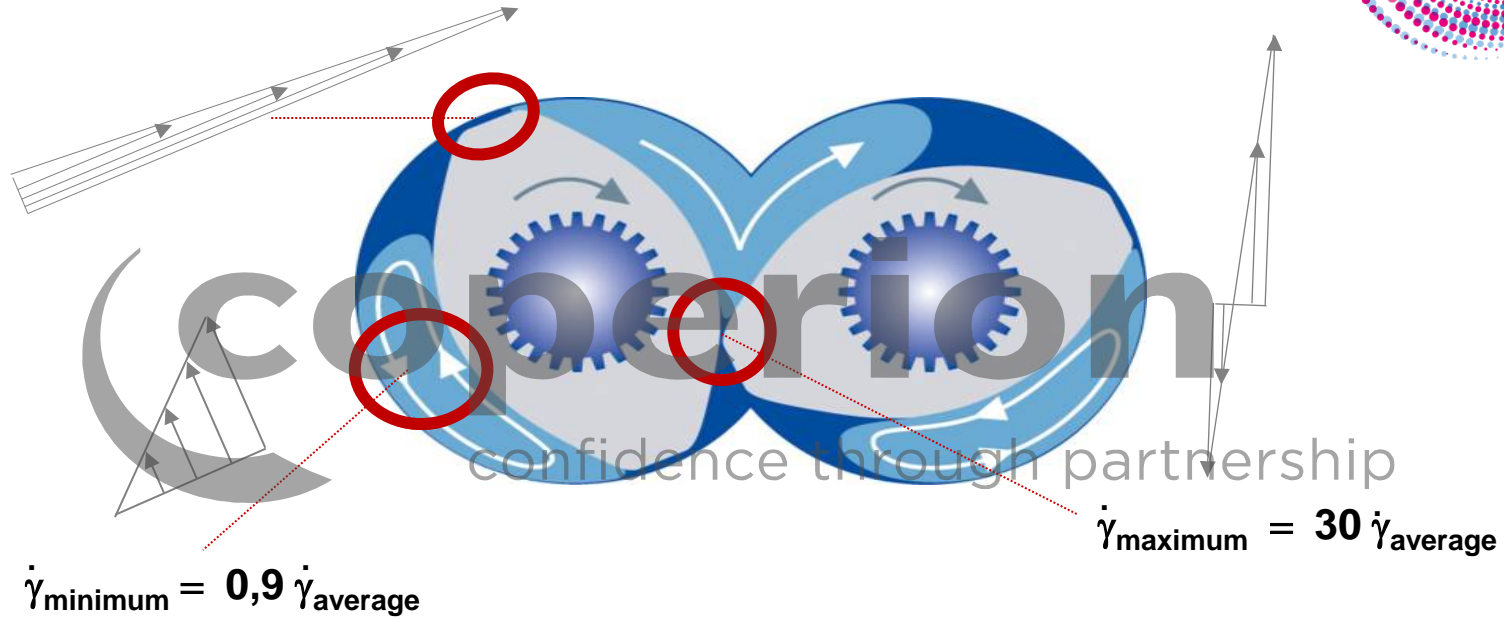
Rethinking Screw Element Designs to Deliver Improved Materials Throughputs and Quality

Marina Matta, B.Sc.
Senior process engineer Coperion GmbH

Main Factors Limiting the Capacity

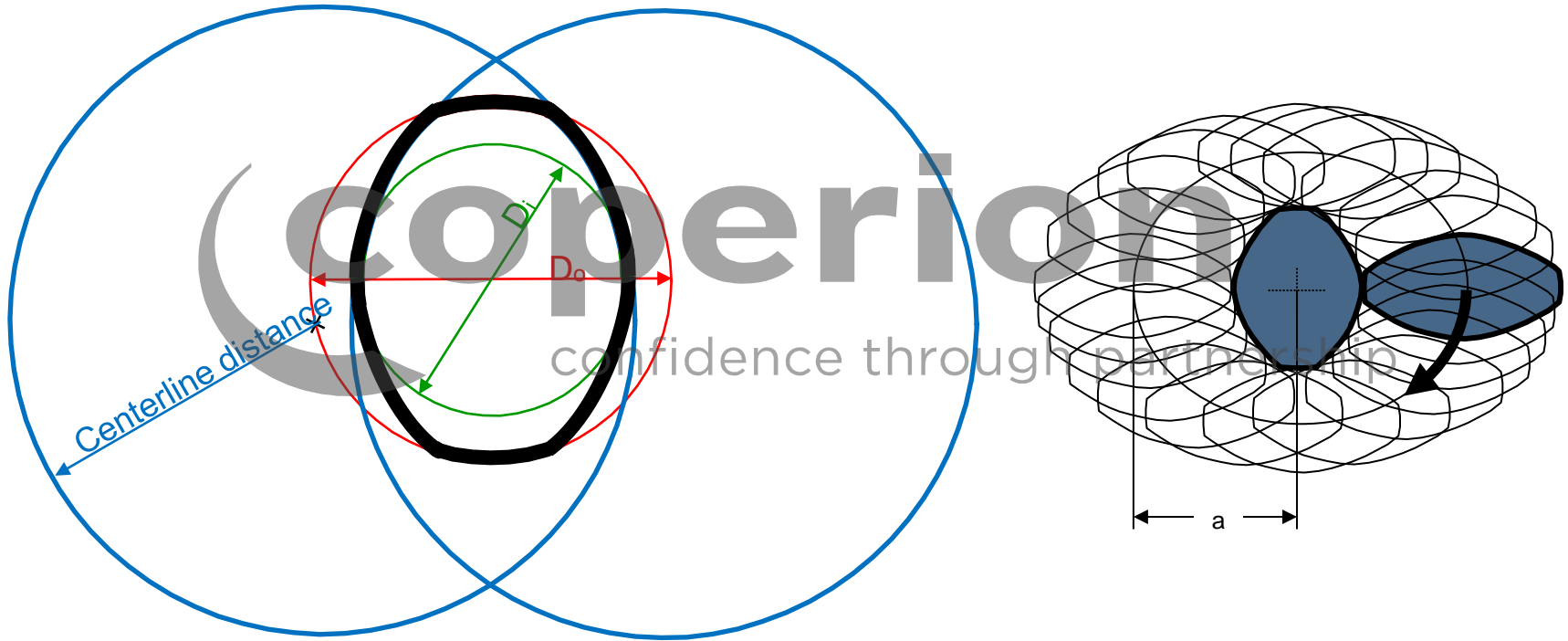


ZSK Mc¹⁸ – Shear Rate for ZSK



$$\text{Shear rate } \dot{\gamma} = \frac{\text{circumferential speed } v}{\text{channel depth}}$$

Self Cleaning Screw Profile Geometric Limits



Screw elements for different process tasks

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IN COMPOUNDING



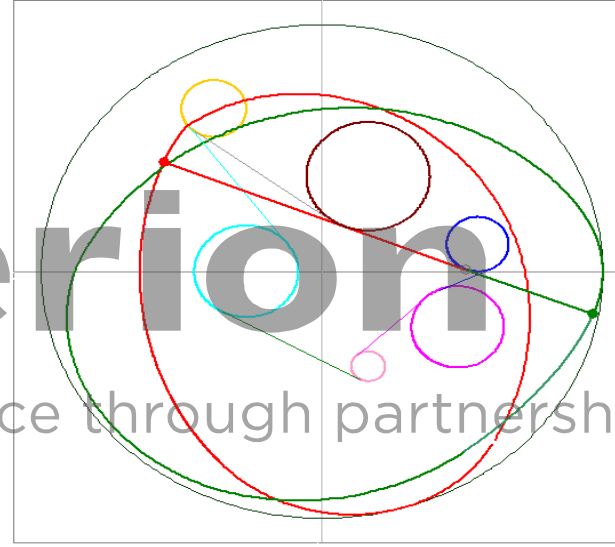
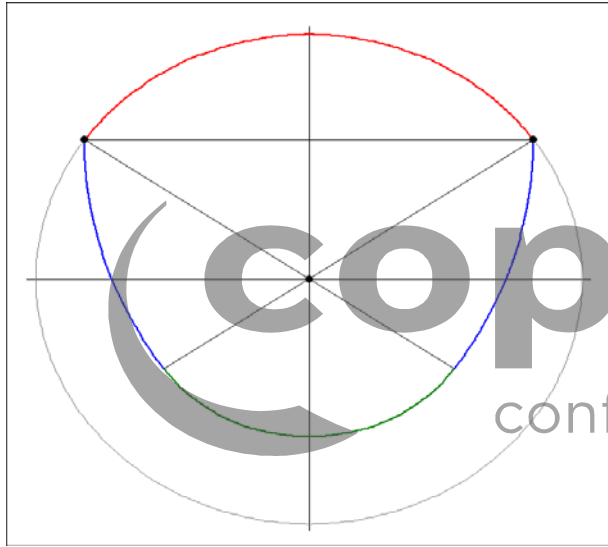
confidence through partnership

Incorporation Problems

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Involute Elements – New Design Principle



Profile design based on circular arcs

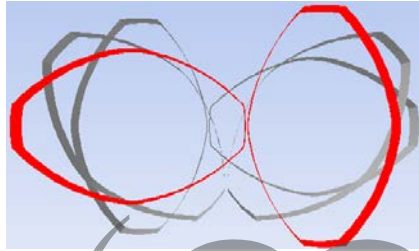
Profile design based on different math. curves

- >> New design principle not following the Erdmenger patent
- >> Many new screw geometries possible with self cleaning profile



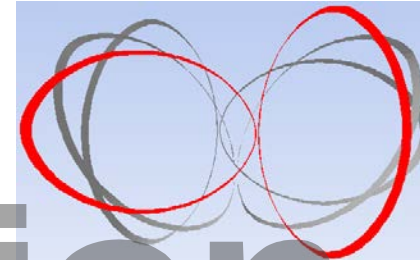
New Involute Screw Profile

Comparison of "Traditional" vs. "New" 2-lobe design



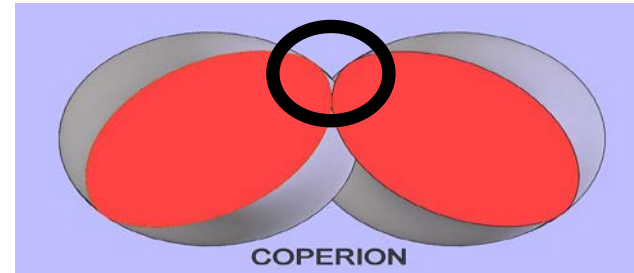
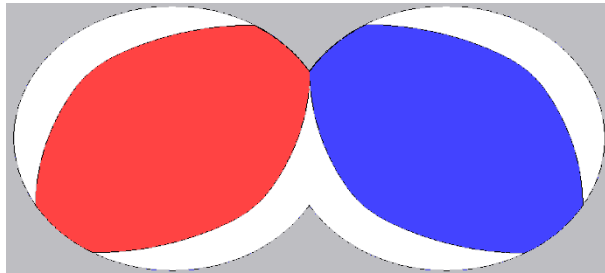
2 lobe Erdmenger profile

Closed area
 $A_{ZW/Min} = 0$



New Involute profile

Open Area
 $A_{ZW/Min} > 0$

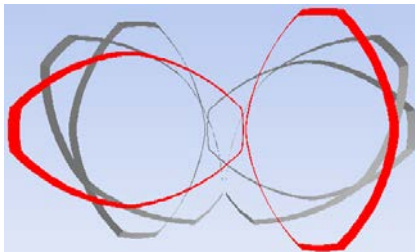
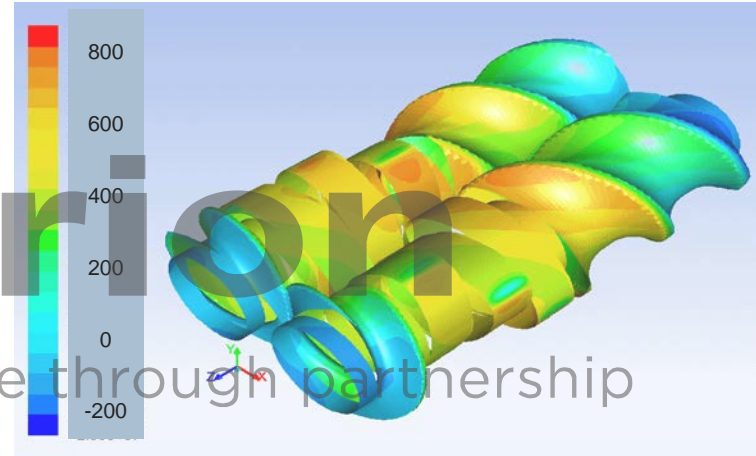
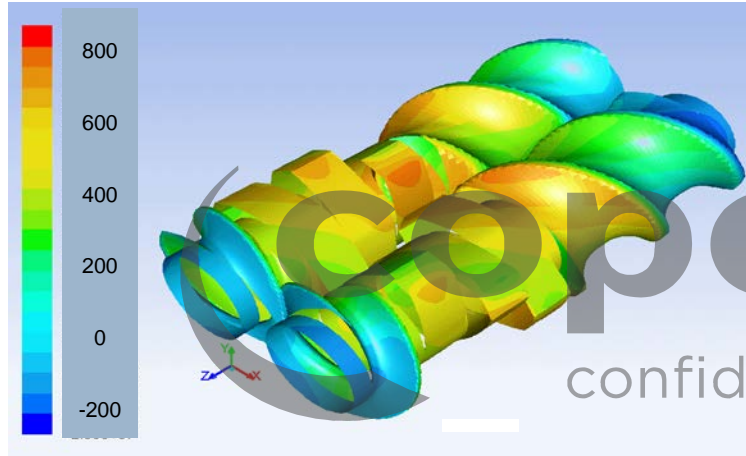


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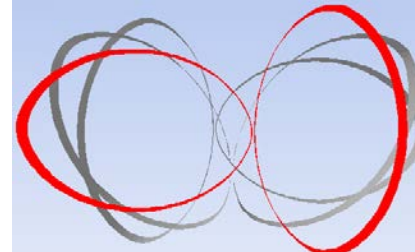
Simulation of Involute Screw Elements



ZSK 40 - 60 kg/h - 100 rpm – Pressure distribution (relative pressure [bar])



2 lobe
Erdmenger
profile



New Involute
profile provides
lower pressure in
the intermeshing
zone

Impact of Screw Design

PP Compounds – ZSK 40

| Formulation | Max. throughput standard screw profile (kg/h) | Max. throughput new screw profile (Involute) (kg/h) | Throughput increase [%] |
|----------------------------|---|---|-------------------------|
| PP + 55 % Talc | 180 | 220 | + 22% |
| PP + 70% CaCO ₃ | 180 | 250 | + 38% |



Breathable film– ZSK 40

| Formulation | Max. throughput standard screw profile (kg/h) | Max. throughput new screw profile (Involute) (kg/h) | Throughput increase [%] |
|---|---|---|-------------------------|
| LLDPE (MI 6) + 45% CaCO ₃ | 200 | 350 | +75% |
| LLDPE (MI 6) + 70% CaCO ₃ | 235 | 400 | + 70% |





Involute Screw Profile

Filled PP/PE compounds (Masterbatch) – ZSK 40

| Formulation | Max. Rate Standard-Screw profile (kg/h) | Max. Rate New Screw profile (Involute) (kg/h) | Increase [%] |
|---|---|---|--------------|
| LLDPE (MI 20) + 28% TiO ₂ + 42% CaCO ₃ | 110 | 290 | + 160% |
| PP (MI 12) + 70% CaCO ₃ | 130 | 300 | + 125% |



Automotive PP grades – ZSK 40

| Formulation | Max. Rate Standard-Screw profile (kg/h) | Max. Rate New Screw profile (Involute) (kg/h) | Increase [%] |
|---------------------------|---|---|--------------|
| PP + 71% Talc | 140 | 220 | +57% |
| PP + Elastomer + 70% Talc | 130 | 200 | +46% |





Involute Elements - Influence on Dispersion Quality

LDPE + 70% TiO₂, 30% Masterbatch diluted in the film

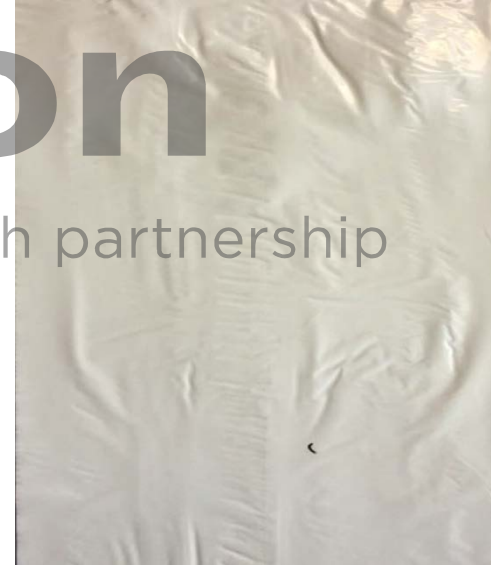
Not optimized screw configuration



Optimized screw configuration – **standard** elements



Optimized screw configuration – **new involute** elements



coperion
confidence through partnership

Feed Intake Problems

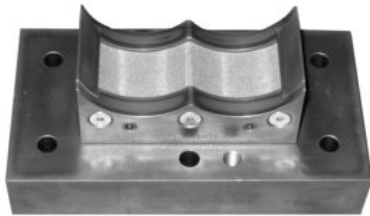
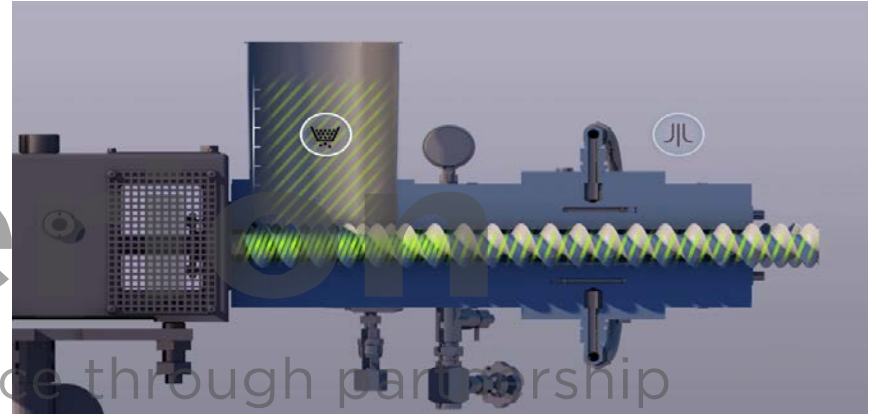


Feed Enhancement Technology

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- **FET:** Technology to increase the throughput of feed limited products
- Solids conveying is improved by applying vacuum in the feed zone to a wall section which is porous and permeable to gas.
- This wall section is realized by an insert with a filter membrane installed in an open barrel.



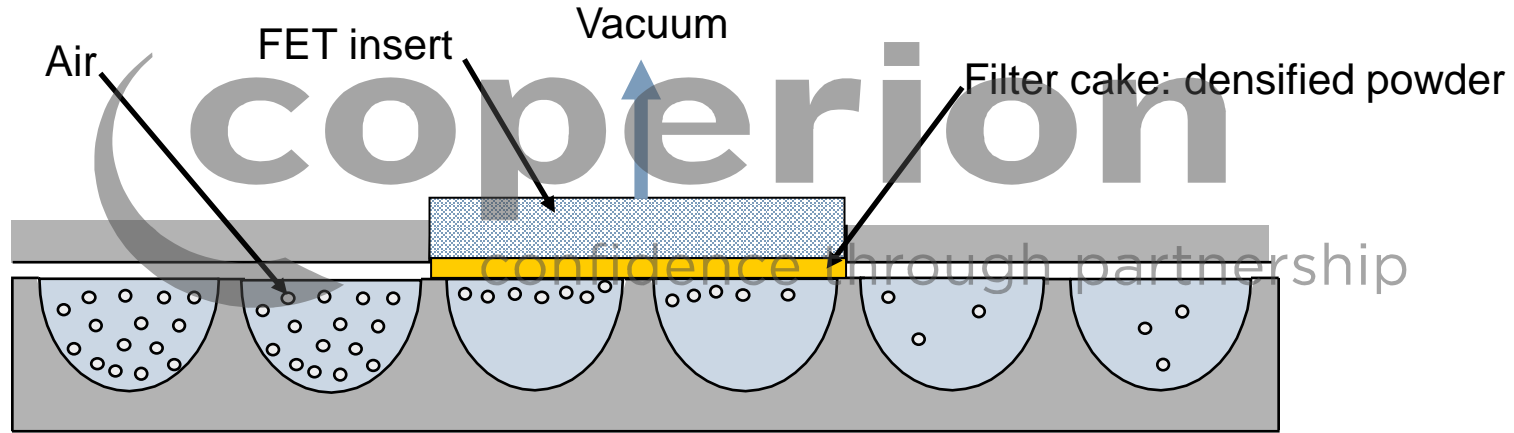
Already more than 150 ZSK
equipped with FET



Feed Enhancement Technology

Working Principle

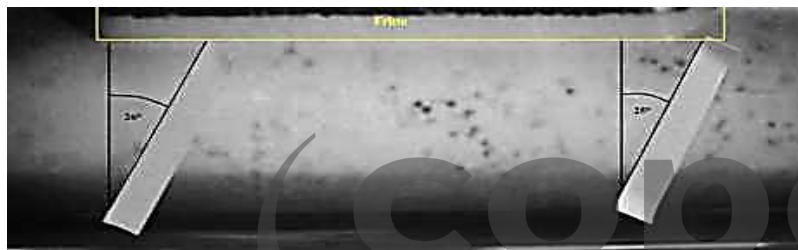
Solids conveying is improved by applying **vacuum** in the feed zone to a wall section which is porous and permeable to gas.



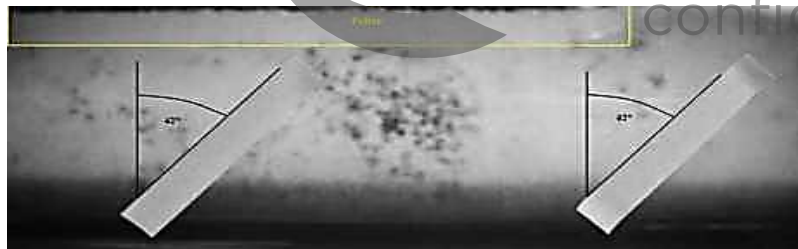
- Effects:**
- >> air is removed → higher bulk density
 - >> friction is changed in the area of insert

Feed Enhancement Technology Working Principle

FET **Off**: Conveying angle ~ 20°



FET **On**: Conveying angle ~ 40°

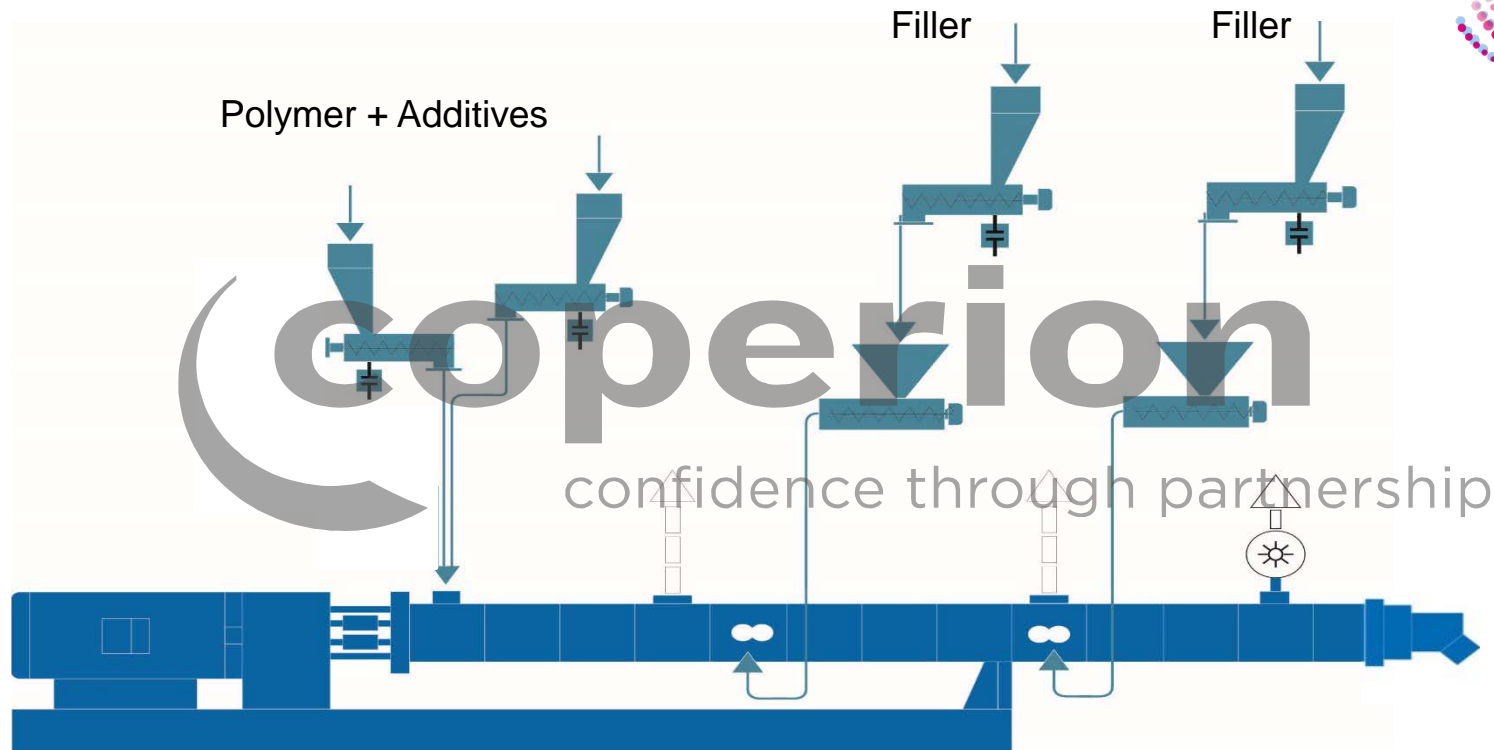



Flow Direction



FET Examples

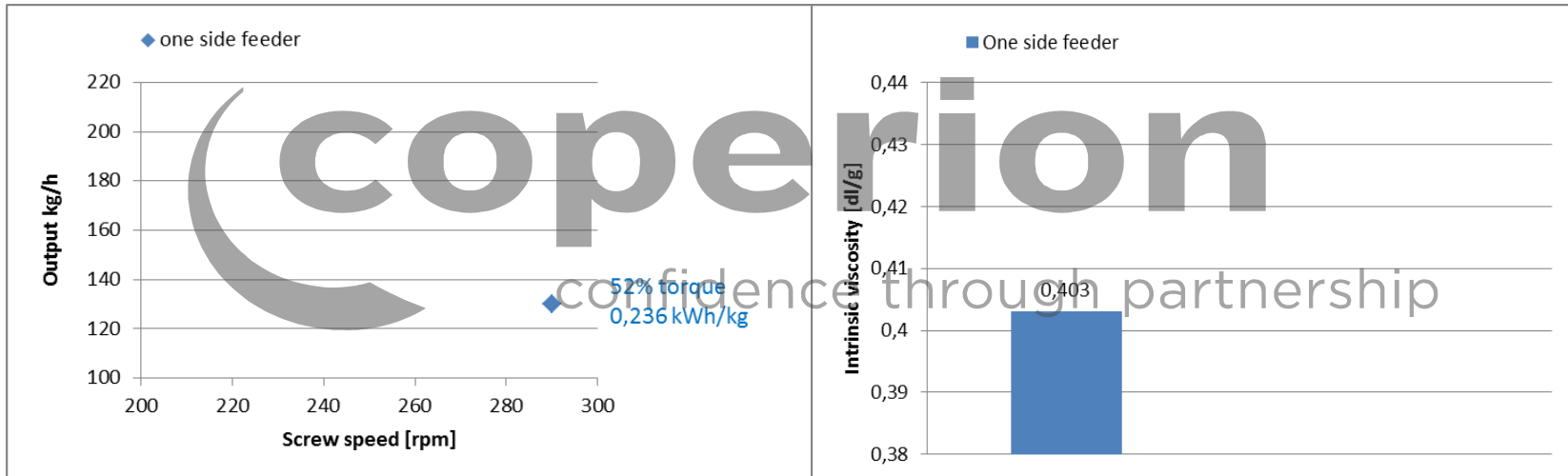
EXTRUSION DAYS
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FET Examples

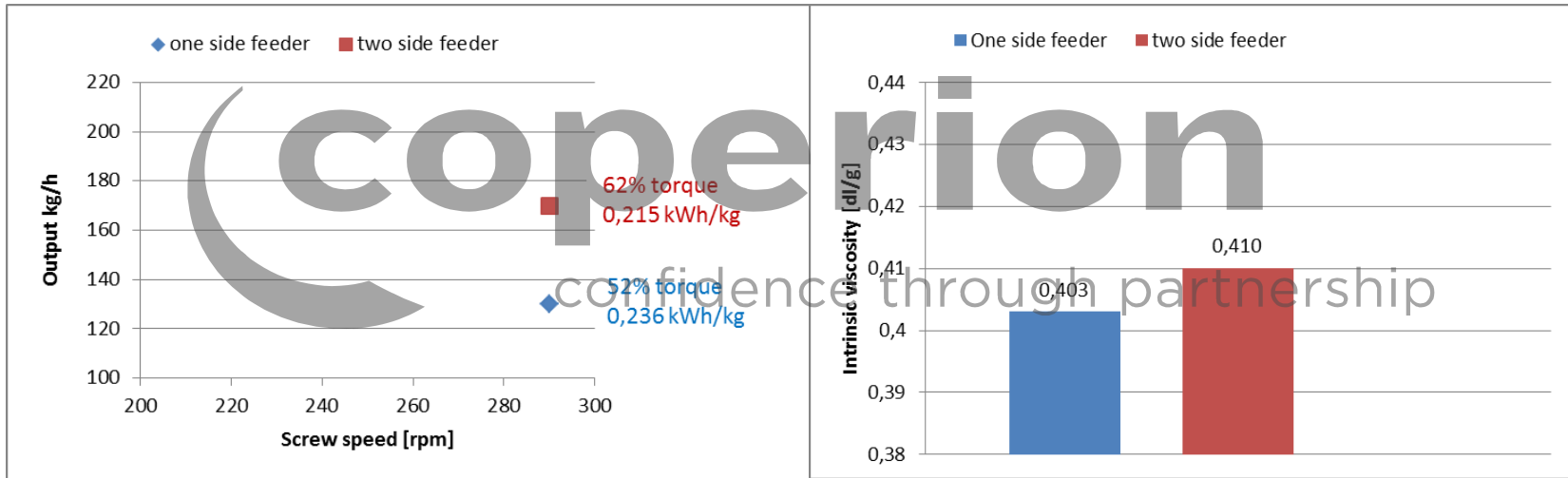
- >> ZSK 50 - PET + 20% synthetic SiO₂
- >> PET = shear sensitive polymer → low screw speed
- >> Synthetic SiO₂ = low bulk density, feed intake limitation → high screw speed





FET Examples

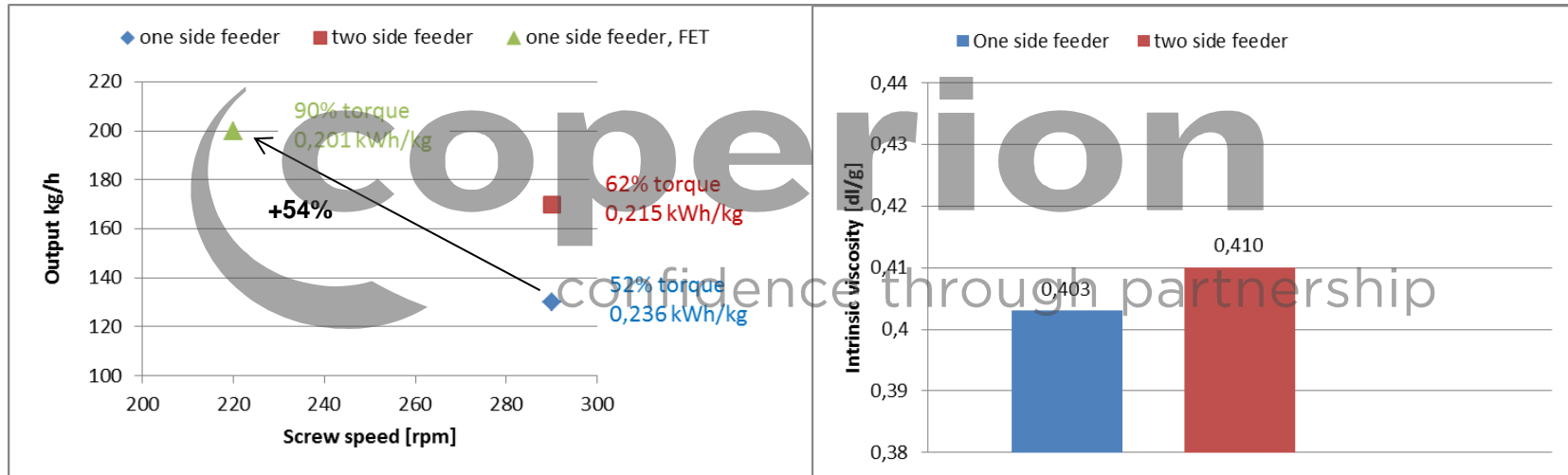
- >> Increased throughput by split-feed of SiO₂ with two side feeders
- >> Increased iV due to higher degree of fill, lowered dispersion due to split-feed
- >> Still feed-intake limitation





FET Examples

- >> Considerably increased throughput by using FET with only one side feeder
- >> Considerably increased iV due to higher degree of fill, good dispersion
- >> No feed-intake limitation, torque limit reached

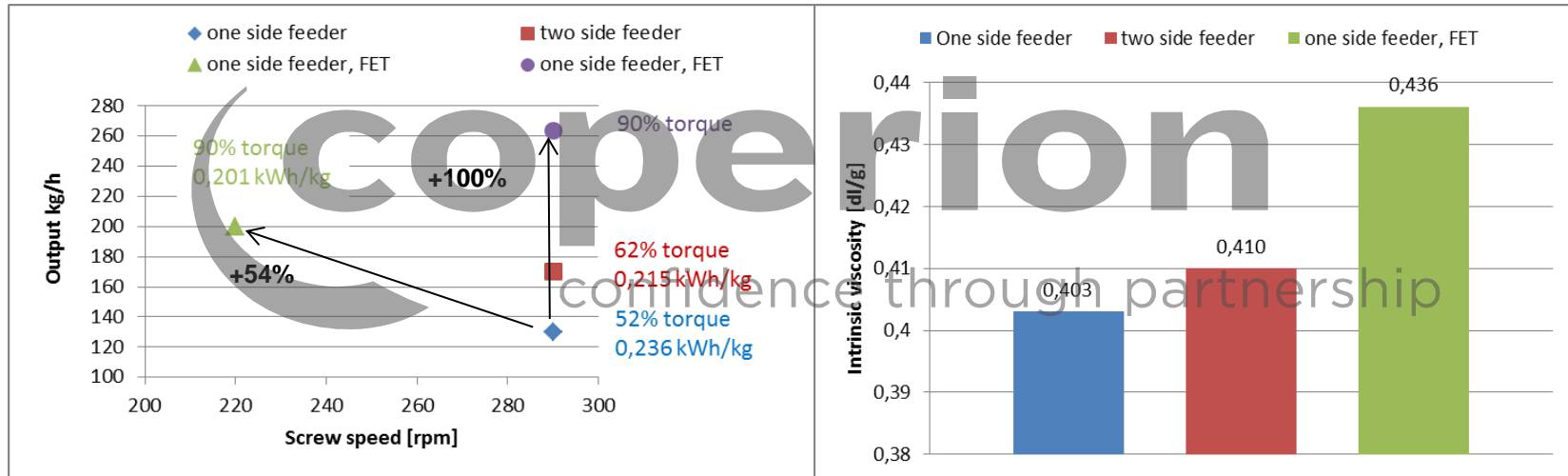


- >> Highest throughput by using FET
- >> Best quality in terms of intrinsic viscosity (iV) and dispersion by using FET
- >> Lowest specific energy (SEI) input by using FET



FET Examples

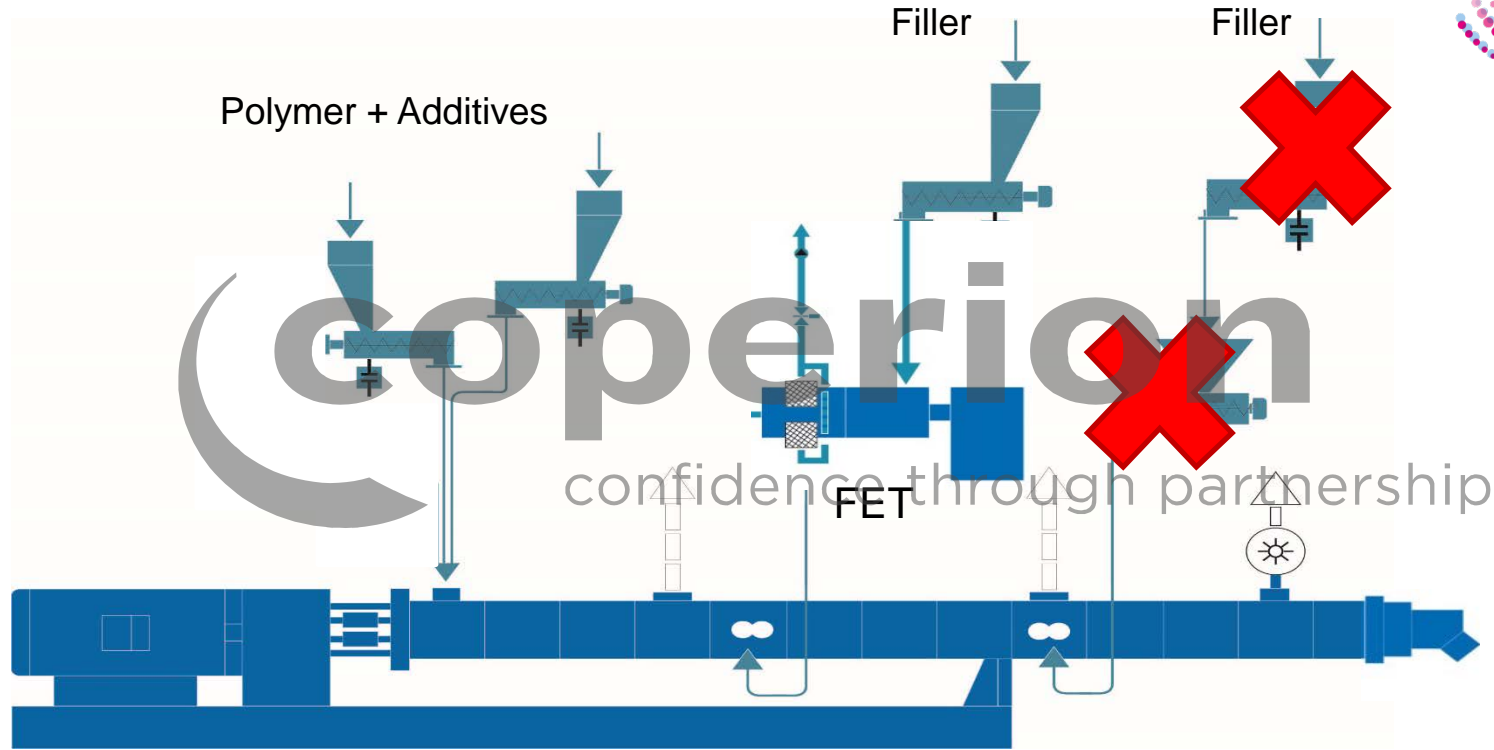
- >> Considerably increased throughput by using FET with only one side feeder
- >> Considerably increased iV due to higher degree of fill, good dispersion
- >> No feed-intake limitation, torque limit reached



- >> Highest throughput by using FET
- >> Best quality in terms of intrinsic viscosity (iV) and dispersion by using FET
- >> Lowest specific energy (SEI) input by using FET

Machine Set-up

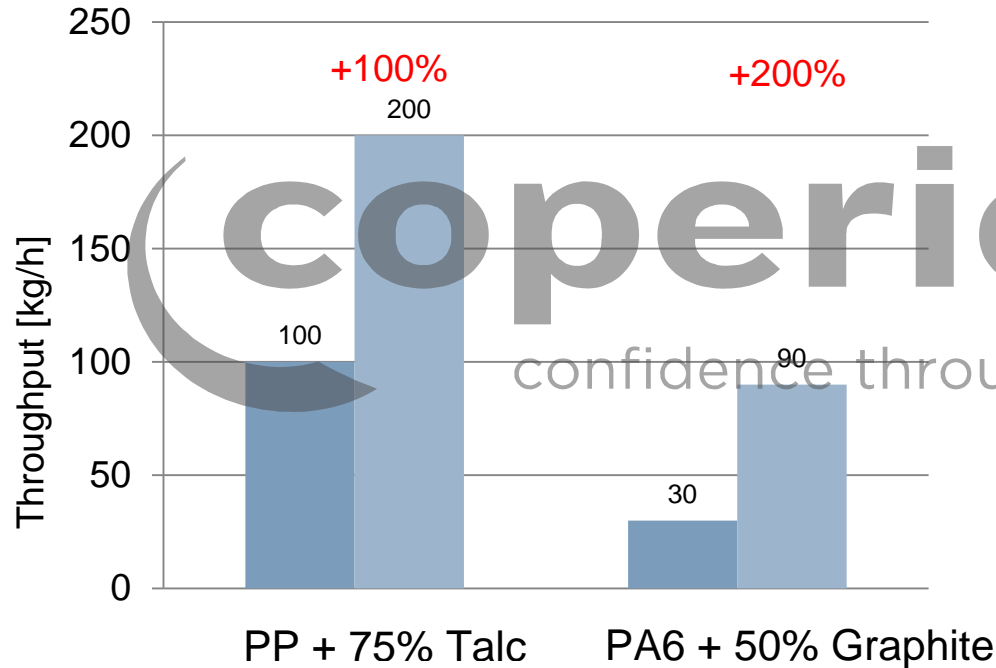
EXTRUSION DAYS
EFFICIENCY
IN COMPOUNDING



FET Examples



Test results on a ZSK 40



» Positive results achieved for many difficult to handle materials:

- » Talc
- » Synthetic silica
- » Graphite
- » Carbon Black
- » Effect pigments
- » ATH, MgOH
- » Hollow glass bubbles
- » Polymer powders (PVDF, PPS, ..)
- »



Summary

»» New Involute Elements

- higher throughput
- higher loadings of filler
- better dispersion and homogenization
- lower energy consumption (SEI in kWh/kg)

- > 30% for filled polymers
- physical limitation can be reached
- FPV lowered, better film results
- 10 – 20 K lower temperature

»» Feed Enhancement Technology

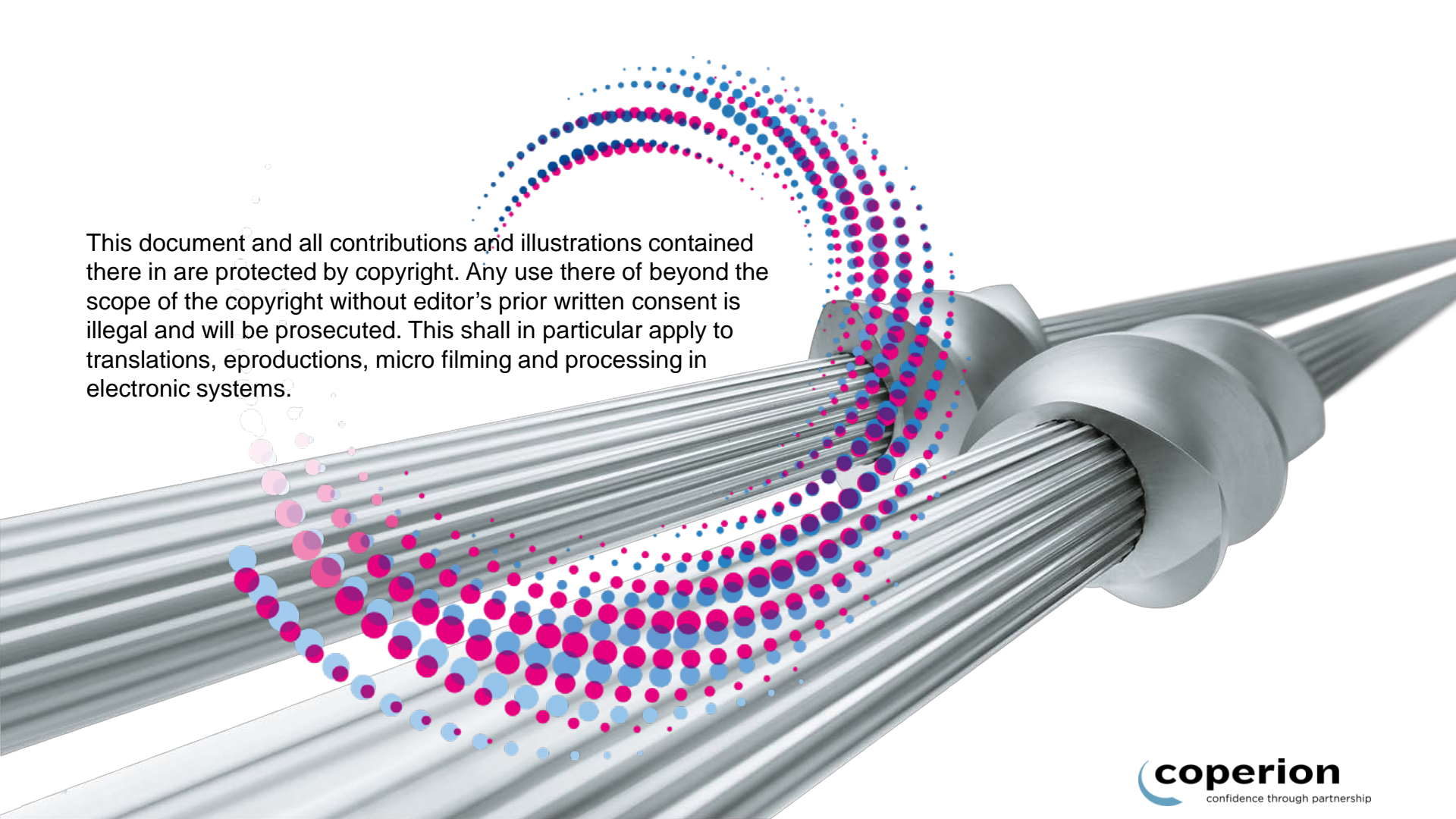
- higher throughput
- Higher loadings of filler
- lower energy consumption (SEI in kWh/kg)

- > 200% increase possible
- physical limitation can be reached
- 10 – 20 K lower temperature

»» High motor power

- higher throughput
- Improved compounding quality by gentle processing with a higher filling degree

Thank you very much
for your attention!



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