Technology Integration Opportunities along the PET Value Chain

UIF Polycondensation Technologies

August 2016 | Martin Hittorff
thyssenkrupp Industrial Solutions | Product Management

engineering.tomorrow.together.
Presentation outline TIO i.e.: Technology Integration Opportunity

- Uhde Inventa-Fischer as part of thyssenkrupp Industrial Solutions

- Experience & Trends
  - New PET projects and chances UIF  =>  TIO: Textile; TIO: PCASTEC®
  - Comparison MTR® vs latest SSP technology  =>  TIO: MTR® still ahead of the pack
  - Potential Synergies of PTA & PET  =>  TIO: Raw Material and U&O
  - Conversion of plants assets  =>  TIO: MTR® Revamp, make more of your
  - Integration of recycling  =>  FTR®, fulfill brand owners demands
  - Unique product properties  =>  Co-PET, PBT, PBS, ....
  - Pilot plant  =>  New developments
  - Services
  - Project Execution Strategie India & beyound  =>  tkIS India a strong partner

- Outlook and Trends
Uhde Inventa-Fischer as part of thyssenkrupp Industrial Solutions
The new dimension in Plant Engineering

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<th>Industrial Solutions</th>
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<td>Services</td>
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Regional Organisations

thyssenkrupp Industrial Solutions - UIF PolyconsensationTechnologies
August 2016 | INDIAN Polyester, Mumbai
### Uhde Inventa-Fischer „The Polycondensation People“

<table>
<thead>
<tr>
<th>Foundation:</th>
<th>1924/1947, as of 2004 a 100% subsidiary of tkIS</th>
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<tbody>
<tr>
<td>Workforce:</td>
<td>150 (~ 85 in Berlin / ~ 65 in Switzerland)</td>
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<tr>
<td>Scope of services:</td>
<td>Leading Technology Licensor (proprietary owned) and engineering company in the design and construction of polyester, polyamide and PLA plants</td>
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<tr>
<td>Product portfolio:</td>
<td><strong>Co-</strong> Polyesters (PET, PBT, PBS, PBAT, PEN, PTT, etc.) for textile, bottle, film and engineering plastic grades</td>
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<td>Polyamides (PA 6, PA 6.6, PA 11, PA 12) for textile applications, film and engineering plastics</td>
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<tr>
<td></td>
<td>Polylactic acid (PLA) and other Biopolymers for packaging, textile and compounds</td>
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<td></td>
<td>Special Equipment, Reactors, Column, spray, tumble and flash dryers, Viscosimeters</td>
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</table>
thyssenkrupp Industrial Solutions (India)
At a glance – Facts and Figures

Formation
- Erection Office 1965
- Branch Office 1970
- Indian Company 1977

Personnel Strength
- 1,000+ Permanent Employees

Engineering
- 2 Million man-hours per annum

Office Space
- Approx. 22,000 sq. m.

Projects Executed
- Over 650 projects

Types of Contracts
- EPC-LSTK / EPCM, PMC, Reimbursable Services, Open Book Estimates
Uhde Inventa-Fischer & tkIS India – “An association spanning a decade”

Uhde Inventa-Fischer

- Licenser & know-how provider for Polyester, Polyamide and Polylactic acid Technology including Basic Engineering and proprietary supplies.

tkIS India

- Detailed Feasibility Reports
- Engineering & Procurement Partner
- Construction Supervision

A exceptional win-win solution by Uhde Inventa-Fischer’s cutting edge technology & tkIS India’s engineering expertise

Customer

- Access to standalone technology.
- Indigenization of equipment’s & value engineering.
- Local know-how
- One single window from Concept to Commissioning.
18,000 t/a
techn. grade polymer
IV = 0.95; 0.04% TiO₂

Make use of DISCAGE® reactor design for up to 2,000 Pa·s ! => Why not enter into MTTY ?
UIF Polycondensation Technologies

MTSF® Melt-To-Staple Fibre
MTTF® Melt-To-Textile Filament

UIF expertise in

- Integration of machine suppliers as sub-vendors with UIF’s textile know how still available
- Design of melt distribution
- Specify requirements for U&O

PV-TEX, Vietnam
2R, 500 tpd
Filament &
2 Lines Staple Fibre
POY lines
In operation since 2012

Ivanovo, RU
2R, 500 tpd,
3 lines Staple Fibre
Basic Engineering done

Undisclosed,
2R, 1050 tpd
5 Lines Staple Fibre
Contract signed 07/2016

Make use of 2R large capacity plant and UIF textile integration expertise
UIF Polycondensation Technologies

2-Reactor Technology

Make use of 2R process equipment designed for textile plants with capacity up to 1,200 T/D
UIF Polycondensation Technologies
PCASTEC® is also MTR® = high IV process to 0.84

- First 5/6-reactor CP
- Polyester plant based on PTA

- First 4-reactor polyester CP

- First 2R CP

- First 2R MTR CP
- 2x750 tpd MTR

- 5R PET plant (1965 – 1988)

- 2R PET plant (from 2001)

- 1965

- 1988

- 2001

- 2007

- 2012

PCASTEC®
1500 / 3000 tpd

20??

Make use of unprecedented economies of scale
We are prepared to provide bigger than world scale plants for PET!
UIF Polycondensation Technologies
PCASTEC® is also MTR® Summary

Go BIG-PET

• Make use of MTR® efficiency
• Make use of known design principles and develop further process intensification methods
• Simplify reactor design and consider transportation issues
• Optimize each reactor to process requirements
• Make use of one Head two Ends design to increase flexibility
• Optimize space requirement

We are prepared to provide world scale plants for PET!
UIF Polycondensation Technologies
Melt-To-Resin technology

Go MTR® we truly believe….

… is the proven way to manufacture PET Bottle Grade Chips in highest quality and in the most economical way

• 5 out of 6 new major PET lines within last 5 years in Europe with a nameplate capacity > 1 mio tons/year

• More than 3 mio tons/year globally

Make use use of MTR® CAPEX, OPEX and down-stream benefits
UIF Polycondensation Technologies, MTR® vs SSP “old & new style”

**UIF’s MTR® Route**
- Bottle Grade
- PTA, PIA & MEG storage
- MTR® incl. Conditioning Silo
- PET resin IV = 0.84

**Conventional Route**
- Bottle Grade “old Style” SSP
- Conv. Polycondensation
- Interm. Silo SSP IV = 0.6
- PET resin IV = 0.84

**Conventional Route**
- Bottle Grade “new style” SSP
- Conv. Polycondensation w. UWG
- SSP
- PET resin IV = 0.84

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thyssenkrupp Industrial Solutions - UIF Polyconsensation Technologies
14 August 2016 | INDIAN Polyester, Mumbai
**UIF Polycondensation Technologies, MTR® vs SSP “old & new style”**

**Uhde Inventa-Fischer’s MTR® Technology**

**MTR®**

- ESPREE®
- DISCAG®
- Past®
- FTR®

**Conditioning Silo**

- Low Temperature Chips Cutting
  - Chips cutting needs to be re-heated
  - => energy loss

**Latent Heat Under Water Chips Cutting**
- Patented by UIF
- In use by UIF since 2006

**«old style» SSP**
- Source: Polymetrix website
- Crystallizer

**«new style» SSP**
- (Latent Heat) Source: Polymetrix website
- Pre-Heater
- Delta-Q Crystallizer

**Low Temperature Chips Cutting**
- Adapted by Polymetrix

+ Reference: In use in UIF Project Indorama Poland since 2015
UIF Polycondensation Technologies, MTR® vs SSP “old & new style”
CAPEX & OPEX comparison example 1 x 750 tpd, Malaysia

MTR® still ahead of the pack
## UIF Polycondensation Technologies

### MTR® - Summary!

<table>
<thead>
<tr>
<th>Features of MTR® Technology</th>
<th>Benefits</th>
</tr>
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<tbody>
<tr>
<td>No SSP plant</td>
<td>Saves equipment, building and erection cost</td>
</tr>
<tr>
<td>No nitrogen loop and catalytic oxidation</td>
<td>Saves nitrogen and electric energy for blowers, heaters etc.</td>
</tr>
<tr>
<td>Very efficient, integrated CP process</td>
<td>Conversion Cost 72% of conventional</td>
</tr>
<tr>
<td>No personal for operation of SSP</td>
<td>Saves labor cost</td>
</tr>
<tr>
<td>Very less dust &amp; volatiles formation</td>
<td>Saves raw material</td>
</tr>
<tr>
<td>Lower degree of crystallization</td>
<td>Saves drying &amp; re-melting energy</td>
</tr>
<tr>
<td>Possible combination with FTR®</td>
<td>Less AA-formation @ preforming</td>
</tr>
</tbody>
</table>

Puts on a green label on the product
UIF Polycondensation Technologies
Potential Synergies of PTA & PET

Process Integration

Target: significant reduction on OPEX and CAPEX

By: customized and integrated concepts based on specific site conditions, end product application and different utility cost situation

Make use of BP and Uhde Inventa-Fischer’s, the technology leaders for PTA and PET !!
### Integration opportunities

<table>
<thead>
<tr>
<th>Integration opportunities</th>
<th>CAPEX relevance</th>
<th>OPEX relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Utilities (Cooling Tower, N₂, WWTP, Demi Water, Heating Plant, etc.)</td>
<td>++</td>
<td>0/+</td>
</tr>
<tr>
<td>Energy optimization using off-gases, etc.</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Reduced &amp; combine storage facilities and handling syst.</td>
<td>++</td>
<td>0/+</td>
</tr>
<tr>
<td>Reduce number of personnel, common Maintenance, plant supervision, DCS, ERP systems, etc.</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Relaxed specification for Terephthalic Acid Technology Integration of PTA – PET process plant sections</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

Make use of integrated planning, optimized plot and further integration ideas ahead
UIF Polycondensation Technologies
MTR® Revamp – Conversion of existing plants

Esterification

MTR® Package

- Exchange DISCAGE® Increase IV from 0.3 to 0.84
- Modify DISCAGE® Increase IV from 0.6 to 0.84
- Add DISCAGE® Increase IV from 0.6 to 0.84

Make use unbeatable CAPEX per ton of additional capacity and safe project time
UIF Polycondensation Technologies
MTR® Revamp – Conversion of existing plants – DISCAGE®

Design 2016

- Optimized Pipe Ring design Discs
- Stripper rode from outside
- Closed Drum Structure
- CFD Flow Simulation for advanced detail design

Make use of our Technology for your competitive edge
UIF Polycondensation Technologies
MTR® Revamp – Conversion of existing plants – Chips production under water & latent heat

Design 1990
- Strand Cutting System (USG)
- Die Plate rectangular
- Chips outlet temperature 60 °C

Design 2016
- Under Water Cutting System (UWG)
- Die Plate round
- Latent heat cutting system, chips outlet temperature ≈160 °C

Make use of UIF’s profound experience in under water cutting material matters!
UIF Polycondensation Technologies
MTR® Revamp – Conversion of existing plants – Chips Conditioning

Design 1990
- SSP residence time 18 – 24 h
- Pre-Heating
- Crystallization
- Nitrogen circuit and cleaning
- AA removal by nitrogen
- IV increase 0.64 to 0.84

Design 2016
- Total residence time 12 - 14 h
- No external heating
- Constant mass-flow across diameter guaranteed
- Air for AA removal passes through heat exchanger*
- IV increase 0.78 to 0.84

* or nitrogen => MTR plus

Make use of improved OPEX of older and conventional plants !!
UIF Polycondensation Technologies - MTR® & FTR

virgin like PET Resin with recycling content

- Uniform product quality

- FTR® is an approved process by US Food and Drug Administration (FDA)

- FTR® is validated as chemical recycling by EFSA

- TCCC-approval

- Integration of recycling & state of the art Polycondensation plants

Make use of UIF’s recycling expertise
UIF Polycondensation Technologies - Unique Product Properties

PBT reference plants

Shinkong, Taiwan
120 T/D
2003 (1st ESPREE reactor)
Dual plant PBT & PET
Incl. THF recovery
Follow up project 2015: new line 180 T/D

BASF, Germany
180 T/D
2010
Bio degradable Co-PBT Ecoflex
Follow up project 2014: Revamp Schwarzheide 300 T/D

DuBay (JV DuPont & Lanxess), Germany
240 T/D LSTK
2004 (DMT), 2013 converted to PTA

SIPCHEM, KSA
180 T/D LSTK
2015
Incl. THF recovery

SABIC, Mt. Vernon US
180 T/D
2015
Revamp esterification (from DMT -> PTA)

Make use of UIF’s PBT expertise
UIF Polycondensation Technologies - Unique Product Properties

Examples

**PET-G**
- no crystallization, even at high wall thickness
  - with CHDM

**CoPET film grade**
- Shrinking film grade for labelling
  - With NPG

**PBT**
- Engineering plastic
  - With Butanediol

**Co-PBT e.g. Ecoflex® by BASF**
- Degradable packaging material
  - With Adipic acid

**PBS**
- Degradable & from renewable sources
  - With succinic acid

**PEF**
- Polyethylene-Furanoate, based on FDCA, Furan dicarbon Acid
  - Promising, but where is the raw material @ quality?

Make use of UIF’s speciality polymer expertise
UIF Polycondensation Technologies
R&D Facilities

Pilot Plants for:

- Polyesters in Berlin
  - Continuous operation; output: 50 kg/h
  - Bio-Polymers in Berlin
  - Continuous operation; output: 2 kg/h
- Polycondensation Products in Domat/Ems
  - Batch operation; output: 50 – 120 t/y

Laboratories for:

- Analyses (raw materials and polymers)
- Polymer synthesis (recipe, catalysts etc.)
- Physical Laboratory (Berlin)
- Chemical Laboratory (Berlin)

Make use of UIF‘s pilot plant complete 2R MTR®
**UIF Polycondensation Technologies**
**MTR® Successful on the World Market**

**Customers**
- 13 lines in operation
- 15 lines sold, repeat orders

**First Line**
- In operation since April 2007

**Plant Capacity**
- 400 – 750 t per day; total 3 mio t/a

**Market Share**
- 80 % outside

**China**
References

PET bottle resin

Customer: Micro Polypet
Capacity: 216,000 t/a
Technology: 2R MTR®
Start-up: November 2014
References

PET bottle resin

Customer: JBF Industries
Capacity: 2 x 216,000 t/a
Technology: 2R MTR®
Start-up: June 2014
D. Engineering: tkIS India

Production of PET with integrated FTR® technology; Europe`s biggest PET plant
Uhde Inventa-Fischer & tkIS India – “An association spanning a decade”

Customer: SIPCHEM  
Capacity: 63,000 t/a  
Technology: 2R Process PBT  
Start-up: 2015  
Engineering: tkIS India

Customer: Changle Highsun  
Capacity: 180,000 t/a  
Start-up: 2013  
Engineering: tkIS India

Saudi Arabia  
China
UIF Polycondensation Technologies
Summary, what is the predominant trend for you?

Integration
- Integration PTA / PET Logistic concepts?
- Integration analog textile for sheet/film MTS/MTF?
- PCASTEC® Jumbo Plants?

Green Trend
- Recycling?
- Raw materials from renewable resources, e.g. Bio MEG, PEF
- Degradable Co-polyesters, e.g. PBAT
- Sb-free / Sb reduced recipes, path forward

Specialties
- Co-Polyesters
- Engineering polymers, e.g. PBT
Thank You for Your Attention!

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thyssenkrupp
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