Mechanical Challenges when Designing a Separator

Frames Separation Technologies
Outline

- Introduction to Separation
- Oil/Gas/Water Separation basics
- Challenges and impact Separation on vessel design
- R&D and Testing trajectories, CFD
- Conclusion
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Definition of Separating:

The act of separating, or the state of being separated, or separate.

- **Why Separation in Upstream Oil and Gas Industry?**
  
  Separating main components, gas, oil and water to specification at the source to minimize transportation efforts and loading on downstream systems

- Overboard water (separated to Environmental Specifications)
- Load on compressors/pumps (besides capacity also avoiding damage solids/liquids)
- Pipe line and downstream equipment capacity (sizing)
- Local energy utilization supporting Process (local)
Frames has designed and fabricated upstream Process Separators for the Oil and Gas Industry for over 20 years.

**Primary target process design criteria**

1. Maximise separation efficiency
2. Minimize pressure loss during separation process
3. Maximize online availability equipment (robustness)

**Secondary target design criteria**

1. Minimize size (plot space)
2. Minimize weight (related to costs equipment and foundation)
3. Minimize investment costs (maximizing revenue on investment)
4. Minimize delivery time (minimizing time revenue on investment)
Mechanical impact a process design has on the separating equipment

Separation of the flammable content takes place under elevated pressure

- Law requirements for pressurized equipment (PED/CE/ATEX/….)
- Design code requirements (ASME/BS5500/Rtod/AD/EN13445/….)
- Client Pressure vessel specifications

Separating enhancers (Process Internals)

- Designed for separating purpose
- Mechanically considered Non-pressurized (pressure drop few mbar)
- Installed/removable trough man way (generally 24” ~ 600mm)
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Separation principles of FST are based on physical properties of process flow

Separation principles

1. Gravity ($\Delta \rho$, $\mu$)
2. Centrifugal force ($m$, $a_{rot}$)
3. Particle Size Difference ($\mu$)
Gas/Liquid Separation

Separation of liquid components out of gas stream

- Vessel Inlet
- Between Inlet and Outlet
- Vessel Gas Outlet
Liquid/Liquid Separation
Separating of different liquids from each other

- Vessel Inlet
- Separation Compartment

Vessel Inlet

Cyclonic inlet device

Separation Compartment

Open Settling (Stokes)
Flow Baffles
Coalescence enhancers

Droplet Growing

Coalescence Internals

Coalescing filters
Coalescing plate packs
Wire mesh agglomerator
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After process design, interaction with the mechanical design takes place.
• **Some limitations due to Mechanical requirements**

<table>
<thead>
<tr>
<th>Locations and size of nozzles</th>
<th>Other Mechanical considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld to weld distance (space)</td>
<td>Loading external piping</td>
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<tr>
<td>Needed reinforcement due to pressure</td>
<td>Heat Treatment (stress relieving)</td>
</tr>
<tr>
<td>Code limitations (opening : shell : head)</td>
<td>Mechanical loading in internals</td>
</tr>
<tr>
<td>Location external piping connection</td>
<td>Choice of materials</td>
</tr>
</tbody>
</table>
• **Weld to weld distance (space)**
  - Lowest level nozzles (small size vertical separators)
  - Lowest man way (short vertical separators)
  - Series of level nozzles in separation compartment (3 phase separator)
• **Needed reinforcement due to pressure**

*Due to flow velocity and dynamic pressure process determines Inside Diameter nozzles*

- **Standard schedule pipes reinforce to the inside**
  - Higher pressure -> smaller ID pipe

- **Self reinforced, with fixed ID reinforce to outside**
  - More weld pace needed
  - Possible problems with discontinuity connecting piping
• Code limitations (opening : shell : head)

Difference in design codes pressure vessels limiting large nozzles in heads and shells

- Possible nozzle location in knuckle zone of a formed head
  - Way to calculate nozzles loads (FEA analyses)
• **Loading external piping**

Nozzle loadings external piping transferred to support vessel

- Large nozzle loadings can impact saddle design and vessel supporting
  - Transfer all loadings onto saddle supporting
• **Heat Treatment (stress relieving)**

**Fabrication sequence**

- Stress relieving according to code requirements can impact the fabrication schedule when it comes to welded internals

**Possible problems with Heat Treatment ferrite internals**

- Temperature to 650 °C can cause buckling of thin SS 316L internals
  1. Dimensional unreliability
  2. Cracking of weld due to deformation stress

**Sigma Phase**

- The delta ferrite can transform to a very brittle phase phase”, if heated above 550°C for very prolonged per
**Mechanical loading in internals**

- Internals designed as non-pressure parts.
- Flow impact can have great effect on the internals design and it’s supporting

\[ f_{nat} > f_{flow} \]

\[ \sigma_{yield} >> \sigma_{mat \ flow} \]

The natural frequencies cyclone assembly including supporting calculated.

Max rotating frequency \( f_{flow} = 2,567 \) Hz

Total Liquid Flow 1050 MB/d (7000 m³/h)
Gas flow 95 MMSCFD (2.5 MMNm³/d)
Several supporting studies

Max. Displacement: 7 mm
Max. Stress: 164 MPa

Max. Displacement: 2 mm
Max. Stress: 64 MPa

Challenges and impact Separation on vessel design
Challenges and impact Separation on vessel design

Normal system modes calculation

**Normal Mode 1**
- **4.89 Hz**
- **7.4 Hz**

**Normal Mode 2**
- **8.86 Hz**
- **11.6 Hz**

Presentation Frames Separation Technologies
Eventual design based on studies

Challenges and impact Separation on vessel design

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• **Choice of materials**

When designing a separator and selecting the appropriate materials of construction, there is always a balance between

<table>
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<tr>
<th>Strength of material</th>
<th>High yield -&gt; light design</th>
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<tbody>
<tr>
<td>Weldability</td>
<td>Cracking/Microstructure/Properties change at Temp.</td>
</tr>
<tr>
<td>Corrosion/erosion</td>
<td>Allowance/Austenitic-Ferritic/Alloys/ (HIC, NACE,SSC..)</td>
</tr>
<tr>
<td>Availability</td>
<td>Short delivery time</td>
</tr>
<tr>
<td>Cost</td>
<td>Short period revenue on investment</td>
</tr>
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Exact choice of combination of the above highly depends on the market. Flexibility is the key to success for a market attractive design.
• **Using FEA for areas outside Codes**

FEA used for situations where the common vessel code calculations do *not* provide the confidence in the mechanical integrity.

*Definition of the model is the key to the result*
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• **R&D on Separation Principles and Internals satisfying continuous changing demand**

**Main targets in R&D FST**

1. Better separation efficiency
2. Less pressure loss during separation
• **Field Testing**

**Actual conditions at platform in the North Sea**

Liquid droplets sizes in Gas Stream around Separator

<table>
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<tr>
<th>Impact on probe tip</th>
<th>Droplet sizes measurement</th>
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<tr>
<td>Upstream/Downstream Probe</td>
<td>Grade efficiency internals</td>
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![Graph showing droplet size distribution](image)

*Netherlands (Dutch)*

Figuur 1: Druppeldiameterverdeling gemeten met de monitor stroomafwaarts van V-A2050.

*Graph showing droplet size distribution*
• **Laboratory Research**

Research on Axial Cyclone with university of Delft

- Gas/Liquid Separation

- Laser Doppler Anemometry
- Phase Doppler Anemometry
- CFD Modelling

- Velocity profiles
- Droplet size distribution
• Laboratory Research

Research on Inlet Cyclone with universities of Edinburgh

- Liquid Flow
- Gas/Liquid Flow
- Gas/Liquid Flow
- Coalescer effect cyclone
- Foaming effect
- Gas/Liquid Separation
- CFD Modelling

Dynaflow Research Group

Presentation Frames Separation Technologies
• **CFD Analyses Pressure Drop**

Impact the type of vessel head has on the pressure drop

- Pressure drop at outlet head gas flow
- Gradient in velocity profile flow

**Case 1: Elliptical head.**  
Pressure drop: 7.03e03 (Pa)

**Case 2: Conical head**  
Pressure drop: 5.55e03 (Pa)
• CFD Analyses Liquid Draining

Maximum drain capacity internal system

- Increase loading on internals
- Gas/Liquid separation limited by draining
• **CFD Analyses**

CFD evaluating assembly internals in vessels

- Flow profiles
- Loading areas on internals
- Optimising assembly
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- When designing and fabricating a Process Vessel, Mechanical requirements constantly interact with the Process design
  - Constant improvements demanded
  - “Lessons Learnt” are essential to be secured

- Conservative industry where application of modern techniques and tools can be challenging to implement

- FEA is used more regularly to analyze the mechanical integrity of the system but mostly beyond the codes

- The criticality of our industrial application do not allow mistakes to be made

- Flexibility in solving at hand issues using all sorts of techniques are crucial
Thank you for your attention