The New Technology of Condensed Rotational Separation

Bert Brouwers
Erik van Kemenade
www.mu-separation.com

presented by:
prof. dr ir J.J.H. (Bert) Brouwers
in behalf of
Mu-Separation
Romico Holding
Eindhoven University of Technology
E: j.j.h.brouwers@mu-separation.com
T: +31 6 51836093

co-author
dr ir H.P. (Erik) van Kemenade
E: h.p.v.kemenade@mu-separation.com
T: +31 6 22540199

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Innovation 1:
Fast cooling of mixture into the two phase region by expansion through J-T valve or turbine
One component becomes a mist of fine droplets.

Innovation 2:
The fine droplets are separated by the Rotational Particle Separator
The rotational phase separator (RPS) is a cyclonic device wherein a rotating element is placed. The rotating element is a simple cylinder consisting of a very large number of axial channels or pipes of a few millimeters in diameter.

The cylinder is freely mounted in an enclosed stationary housing. Rotation is generated by the tangential velocity of the gas entering the device.

The micron-sized droplets are centrifuged to form a liquid film at the channel-wall. The film is ripped off at the exit of the channel in the form of droplets; typically 50 micrometer or larger. These droplets are separated according the working principles of ordinary axial cyclones.

Large droplets are centrifugated to the wall in the inlet part of the device. They leave via outlet 1. The fine droplets (1 to 10 micrometer) enter the channels of the RPS, coagulate, leave the channels as large droplets and leave the RPS via outlet 2.

The characteristics of the RPS makes it possible to separate particles below 10 micrometer especially under pressure in large throughput installations.
The RPS offers economic advantages in processes as:

- Scrubbing systems
- Inlet separators
- Evaporators
- Turbo-expander suction drums
- Steam drums
- Dew-point separators
- Knock-out pots
- Compressor suction drums
- Inert gas scrubbers
- Glycol dehydration
- MSF/MED desalination
- Dew-point separators
- Inert gas scrubbers
- Sulfuric acid absorbers and dryers.

The RPS is particularly applicable to systems where reduction in size / weight is advantageous such as offshore production. The rotating equipment used in CRS eliminates the need for high structures on deck and is not affected by the motion of the platform.

In NGL and LNG plants the RPS improves efficiency by reducing liquid carry-over and equipment volume.

The RPS improves efficiency and reduces size in all processes where droplets < 20 micrometer occur.

The RPS enables the use of efficient high pressure expansion processes for large throughput plants.

For evaluating the cryogenic pressure distillation process of Condensed Rotational Separation two gas-liquid versions are realized: one at lab scale for real process conditions and one at real scale but atmospheric conditions.

For general testing a version is build with a magnetic coupling for an optional external drive. T = 20 °C, P = 8 bar, m = 0.3 kg/s

All versions perform according to the design specifications.
3 CRS for contaminated natural gas

Gas and liquid purification

CRS uses pressure instead of temperature distillation:
- Low energy consumption
- Compact installation

CRS is a breakthrough technology for bulk separation.

In CRS the gas mixture is chilled by a combination of cooling and expansion to a point in the phase diagram where the purity of the gas is maximal (A).
The liquid stream is subsequently heated and expanded to a point of maximum purity of liquid contaminant (B).

The gas from the second flash is compressed and referred to the first stage.
Requires enrichment of CO2 in the feed stream to only 50% (i.e., by membranes) for a CO2 recovery of 70%.

The energy penalty of CRS is only slightly higher than the energy required to compress gaseous CO2. CRS consumes little extra energy.

The advantage is that the capital and operation costs are relaxed on the enrichment step prior to CRS.

Net result: Size of installation and energy consumption because of CO2 capture become less when CRS is introduced.

CRS becomes more economical with increasing CO2 content in the flue gas (cement production, steel works etc).
Three sequential steps:

1. Cooling of syngas, leaving the coal gasifier, to -54°C. Part of the CO₂ condenses into droplets.

2. Separation of CO₂ droplets from the syngas stream with a Rotational Phase Separator (RPS).

3. Pressuring of the liquid CO₂ to the required sequestration pressure (110 bar). Furthermore, the CO₂ is heated up to the supercritical regime which is required for sequestration.

**6 CO₂ capture**

Topics:

A realistic target for CO₂ capture from coal fired units: emission of CO₂ the same as that of latest natural-gas fired units having no CO₂ capture. This criterion would imply a CO₂-capture efficiency of 60-70% for coal based power production.

Can the new technology of CRS become a game changer?

Captured CO₂ in liquid form: an interesting option for its transportation, storage, sequestration?
7 Conclusions

Rotational Particle Separator (RPS) ready for application in hydrocarbon based processes.

Condensed Rotational Separation (CRS): ready for field test in upgrading H2S/CO2 contaminated natural gas fields
  CO2 removal from flue gases
  CO2 removal in H2 production

Literature


More on: www.mu-separation.com
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5 从合成气中除去CO2的CRS
6 CO2捕集
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创新1:
通过J-T阀门或汽轮机膨胀将混合物快速冷却为两相区域。
一部分成为雾状的细小液滴。

创新2:
旋转颗粒分离器将细小液滴分离。
2 RPS设计

旋转相分离器（RPS）是一种气旋装置，其中设有一个旋转元件。旋转元件是一个由大量直径为几毫米的轴向通道或管道构成的简单的圆筒。

圆筒自由地安装在一个封闭的静止箱体内。通过进入装置的气体的切向速度，可以产生旋转。

微米级的液滴因为离心作用而在通道壁上形成一层液体薄膜。薄膜在通道出口处被撕开成为液滴的形状，典型直径为50微米或更大。根据普通轴向旋风分离器的原理，这些液滴被分离。

大的液滴因为离心力的作用汇集在装置入口部分的壁上，然后通过出口1离开。细小液滴（粒径1至10微米）进入RPS的通道，汇集之后作为大液滴通过出口2离开RPS。

RPS的设计使得它可以分离小于10微米的颗粒，特别是在吞吐量较大的装置中在一定压力下进行。
RPS工艺中的经济优势有:

- 气体系统
- 蒸发器
- 蒸汽锅筒
- 清箱罐
- 惰性气体涤气器
- MSF/MED脱盐
- 液酸吸收器和干燥器

RPS特别适用于需要较小尺寸/重量的系统，如离岸生产。CRS中使用的转动设备不需要在甲板上设立较高的结构，而且不会受到平台移动的影响。

在NGL和LNG厂中，RPS可以减小液体携带量和设备体积，从而提高效率。

在所有液滴小于20微米的工艺中，RPS都可以提高效率、减少尺寸。

RPS允许在大吞吐量装置中使用高效的高压膨胀工艺。
污染天然气的CRS

在CRS中，气液混合物被冷却和膨胀的组合作用冷却到相图中的气体纯度最高的一个点（A）。

CRS是一项突破性的大批量分离技术。

- 能耗低
- 装置紧凑

CRS使用压力蒸馏，而不是温度蒸馏：

CRS的气体与液体提纯

Oil & Gas J. (2006) 104(42)
污染天然气的CRS

沙特阿拉伯的废气厂

CRS可以使污染水平高达70%的气田的开发有利可图。
从烟道气中除去CO₂的CRS

进气流中的CO₂含量只要50%（即通过膜），就可以实现70%的CO₂回收率。

CRS的能耗只是略高于压缩气体CO₂所需的能量；CRS本身消耗的能量较少。

优点是放松了CRS之前的富集步骤的投和运行费用。

净结果：由于引入CRS后捕集了CO₂，因此装置规模和能耗都会减小。

如果烟道气中的CO₂含量提高（水泥生产、钢厂等），则CRS会变得更经济。
5. From synthesis gas, CO2 removal

Three sequential steps:

1. Synthesis gas leaving the gasifier is cooled to -54°C. Part of the CO2 condenses to a liquid.

2. The CO2 liquid is separated from the synthesis gas using a rotational phase separator (RPS).

3. The liquid CO2 is compressed to the required storage pressure (110 bar) and then further heated to the supercritical state.

**CO2 removal from syngas**

<table>
<thead>
<tr>
<th>Condensed Rotational Separation</th>
<th>Physical Absorption</th>
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</thead>
<tbody>
<tr>
<td>CO2 capture efficiency [%]</td>
<td>CO2 capture efficiency [%]</td>
</tr>
<tr>
<td>equipment size [-]</td>
<td>equipment size [-]</td>
</tr>
<tr>
<td>energy costs [kJ/kmol/kg CO2]</td>
<td>energy costs [kJ/kmol/kg CO2]</td>
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<td>80</td>
<td>95</td>
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<td>0.25</td>
<td>1</td>
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<tr>
<td>50</td>
<td>350</td>
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</tbody>
</table>

话题：

从燃煤装置中捕集CO2的现实目标：所CO2排放量与未采用CO2捕集措施的最新的燃天然气装置相同。此标准意味着煤基发电CO2捕集效率为60-70%。

CRS新技术是否会改变游戏规则？

以液体形式捕集的CO2：其输送、储存、封存的一个有趣选择？
适用于烃基工艺的旋转颗粒分离器（RPS）。

冷凝旋转分离（CRS）：适用于以下现场试验：
- H2S/CO2污染天然气田的升级
- 从烟道气中除去CO2
- 在氢气生产中除去CO2

文献
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Benthum, R.J. van, Kemenade, H.P. van, Brouwers, J.J.H & Golombock, M. (2011)。CO2的冷凝旋转分离。应用能源, 93, 457-460
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