THE BIG *goal*

Ralf Notz, BASF SE, Germany, considers how to reduce emissions from international shipping.

Recent trends in the gas treatment industry have seen the design and construction of acid gas removal units (AGRU) on floating vessels. In such plants, absorption columns are used to purify gas as it flows from bottom to top by contacting it with a scrubbing liquid in countercurrent flow. BASF has developed unique tools and know-how to design AGRUs on moving floating vessels for applications such as floating LNG (FLNG), floating production storage and offloading (FPSO) and onboard carbon capture and storage (OCCS), ensuring proper contacting of gas and liquid in moving columns to ensure treated specifications are met.

Wave motion has a huge impact on maritime gas purification. 15 years ago, BASF began to investigate how the inclination of the columns caused by the motion of the sea impacts the process. Ultimately, this approach addresses the key issue for the performance of the scrubbing process under specific offshore conditions.

BASF was able to demonstrate undesirable effects as a function of the column height, diameter and inclination, because areas at the edges of the column are no longer wetted with scrubbing liquid (maldistribution). No mass transfer takes place here, which has consequences for the CO_2 content of the gas. For example, in an LNG plant, a maximum CO_2 concentration of 50 vol. ppm is required in the treated gas, but even a small 'dry' area of less than 1% in a model column can cause this concentration to exceed 400 vol. ppm. Once the CO_2 content is above 100 vol. ppm, the CO_2 desublimates on the cryogenic heat exchangers and blocks the liquefaction process. Operation on this basis is therefore not tolerable, because the dry ice that forms significantly impairs the capacity of the cooling systems, resulting in major problems. The actual height of the column and additional inclination reinforce the described effects, leading to further deterioration of the CO_2 washout.

Computer model describes the effect of wave motion on the scrubbing process

In order to simulate the effect of the inclination and motion on the flow of the liquid in the column with internals such as structured packings, BASF has developed a computational fluid dynamic (CFD) model. As described above, sufficient contact between gas and liquid is essential to the design of absorption columns. The flow is influenced by gravity and inertial effects alongside the column geometry. The inertial effects of the liquid were included in the model. They can only be neglected to the extent that the force of gravity predominates, which is normally the case at average acceleration levels. However, the inertial effect increases with higher acceleration due to the more pronounced movement of the column or its increase in height. Under typical operating conditions, the liquid flow is controlled primarily by gravity, whereas the gas flow depends on the pressure difference. As a result, the column inclination primarily affects the liquid flow. Any liquid maldistribution therefore also results in gas maldistribution.

The CFD model has been validated experimentally. In cooperation with a partner, hydraulic tests were carried out on a real column, which could be set with both a static and a periodically fluctuating inclination. The test rig consisted of a column with a diameter of 1 m and a bed height of up to 4.4 m. The column was either continuously or periodically inclined at an angle of up to 10°. This facilitated confirmation of segments with a scrubbing intensity greater than 100%, as well as segments with a significantly below-average transfer between gas and scrubbing liquid. The most common sea conditions were fed into the models.[1]

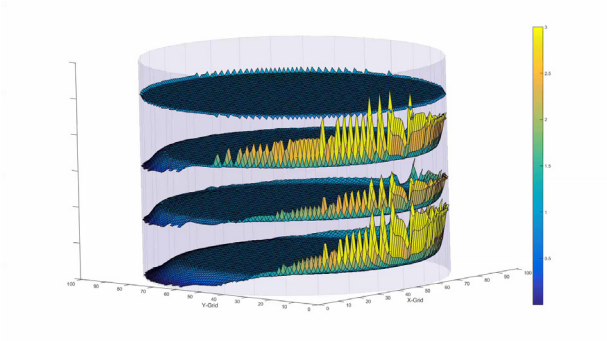

Figure 1. This 3D diagram shows the calculation result of the CFD model of the maldistribution of liquid as a function of the column height. The further the liquid flows downwards from the top through the column internals, the greater the liquid maldistribution becomes. Source: BASF SE.

Study conducted on 'marinisation' (influence of ship movements) of gas scrubbing

The position of the scrubbing columns on the vessel is also very important, as pivot points and lever ratios have to be taken into account for optimum placement. Close interaction between shipbuilding and plant engineering is required in order to find the best possible approach for the liquefaction and scrubbing units on board. Many variables need to be taken into account, including the weight of the vessel and its mass distribution. BASF has carried out a study on the 'marinisation' of gas scrubbing in order to base the services offered specifically on the knowledge gained. The company has developed special calculation tools that also take the dependency on the specific drilling location into account, as each borehole is different.

Experience from major projects

The floating plant for extracting natural gas operated by the Malaysian oil and gas company, PETRONAS, uses BASF's OASE® purple process for removing acid gas components.[2] PETRONAS and the Japanese engineering partner, JGC Corp., started up the project in February 2021, successfully concluding its test run in May 2021, at which point it entered commercial production. The floating LNG (FLNG) plant opens up a new source of clean energy, as it is designed for the extraction of natural gas from deep-sea gas deposits.

BASF's know-how also plays a key role in the gas scrubbing required on the FLNG plant that Italian energy company, Eni, is using to tap the Coral gas field in the extremely deep waters of the Rovuma Basin off the coast of Mozambique. The first delivery of gas left the field on 13 November 2022. Coral South FLNG has a gas liquefaction capacity of 3.4 million tpy and will produce LNG from the 450 billion m^3 of gas held by the Coral reservoir. The project commenced production after just five years of preparation, in line with the original budget and schedule. The first shipment of LNG from the Coral South project, and from Mozambique, is a new and significant step forward in Eni's strategy to leverage gas as a source that can contribute in a significant way to Europe's energy security.[3] BASF's AGRU is important in ensuring that the strict specifications for the feed gas entering the liquefaction section of the plant are met. The system is crucial for stable and reliable production.

The OASE products are solutions for a variety of different industrial applications that make a significant contribution to sustainability in the value chain. Gas scrubbing is indispensable when using natural gas and synthesis gas, as certain components need to be removed reliably before the gases are used. Further applications

include acid gas removal from flue gases, refinery exhaust gases and biogas. Compared to conventional technologies, OASE plays an important part in conserving resources and lowering emissions through energy savings.

Capture CO_2 from marine engine flue gases

The latest developments for on-board AGRUs see the application of the OASE technology to capture CO_2 from marine engine flue gases. The two lines of work for FLNG gas scrubbing units and for flue gas treatment intercept here. The developments in these areas over the last few years (OASE purple for FLNG applications and OASE® blue for flue gas) will be important for the new task of maritime gas scrubbing. Currently, BASF is, amongst others, active in two collaborations with world-class shipbuilders to develop OCCS solutions:

In September 2022, BASF and Samsung Heavy Industries Co. Ltd (SHI) announced that they were to conduct a joint feasibility study on capturing CO_2 onboard maritime vessels using BASF's OASE blue technology,[4] signing a Memorandum of Understanding (MoU) for the OCCS technology at the Gastech 2022 trade fair in Milan, Italy.

In June 2024, BASF also signed a framework agreement with CSSC Power (Group) Corp. Ltd (CPGC) at the Shanghai International Carbon Neutrality Expo (CNE) 2024. CPGC is a subsidiary of China State Shipbuilding Corp., one of the biggest shipbuilding companies globally. The framework agreement enables CPGC to install its advanced OCCS on multiple LNG carriers and utilise BASF's OASE blue technology. CPGC's OCCS aims to steer the low-carbon transformation and foster the sustainable development of the shipping industry. This marks another significant milestone in the partnership of both companies, which comes on the heels of a MoU signed by both parties at the Shanghai Expo in 2023 and the completion of the system prototype testing. Currently, CPGC and BASF are working on optimising the design of the OCCS unit based on actual ship conditions, to achieve commercial applications for different types of ships. Over the past year, CPGC and BASF have conducted technical performance tests on the system prototype. The performance test runs have been validated by marine classification societies, which include the American Bureau of Shipping, Bureau Veritas and Nippon Kaiji Kyokai.

Figure 2. PETRONAS' latest floating plant for natural gas extraction (PFLNG DUA). The plant opens up a new source of clean energy, as it is designed for the extraction of natural gas from deep-sea gas deposits with a depth of up to 1500 m. It has a capacity of 1.5 million tpy of LNG. Source: BASF SE.

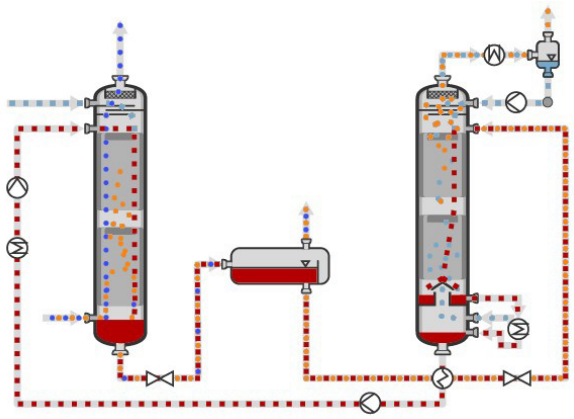

Figure 3. An example of the key equipment used in a gas scrubbing process for the removal of CO_2 at increased pressure, such as when purifying natural gases. In the absorption column (left-hand column), the gas to be purified flows from bottom to top, coming into contact with the scrubbing liquid in the countercurrent flow. The scrubbing liquid loaded with CO_2 is unloaded in a decompression stage (centre) and in a regeneration column (right) and is fed back into the absorption column. Source: BASF SE.

Conclusion

International shipping is to become climate-neutral by 2050. Estimates from the fourth IMO Greenhouse Gas Study in 2020 show that the shipping sector emitted 1056 million t of CO_2 in 2018, making up around 2.89% of all anthropogenic CO_2worldwide. By 2030, the total annual greenhouse gas emissions from the international maritime shipping sector are to be lowered by at least 20% compared to 2008 – and ideally by 30%. Various technologies are being pursued to achieve this ambitious goal. One of these is OCCS. Gas scrubbing technology is one of the most advanced processes for separating CO_2 from gas streams and in order to remove the CO_2 produced from the engine exhaust gases, the most efficient gas scrubbing possible is essential.

References

1. KATZ, T., NOTZ, R., and JOYOWARDOYO, G., 'Solutions for the High Seas,' LNG Industry, (February 2015).
2. 'First Floating LNG project for BASF's Gas Treatment technology' BASF press release, (September 2021).
3. https://www.eni.com/en-IT/media/press-release/2022/11/eni-coral-first-cargo.html
4. 'BASF and Samsung Heavy Industries collaborate on Carbon Capture & Storage onboard maritime vessels', joint press release, (September 2022).
5. 'CPGC and BASF sign Framework Agreement on actual ship application of Onboard Carbon Capture System', joint press release, (June 2024).