Open-loop MVR steam heat pump dryer – Scanship Waste management / DryFiciency project

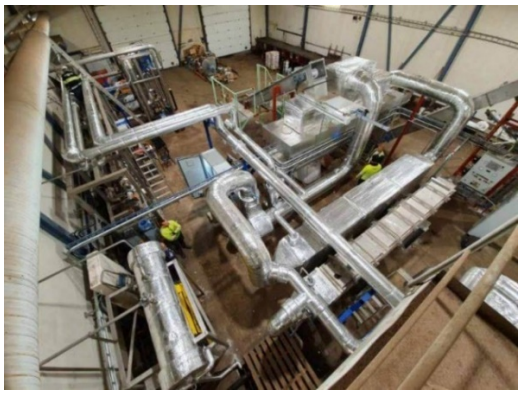

Figure 1: From the demonstration site at Scanship, Drammen, (Dryficiency.eu, 2020).

Summary of demonstration case

In the Dryficiency project a two-stage turbo-compressor steam heat pump system has been installed at Scanship's test site in Drammen. Scanship is a Norwegian based company, which produces advanced waste-water purification and management systems for the marine industry. The heat pump is integrated with an innovative dryer, which can be used for to dry bio-slugde, wood chips, garden compost etc.

The heat pump demonstrator is an open loop Mechanical Vapor Recompression (MVR) system. The heat pump, developed by the DryFiciency consortium uses advanced, low-cost turbo-compressor technology originating from the automotive sector. The demonstrator, as seen in Figure 2 aims to reduce the dryer's energy demand by up to 75% and eliminate the dryer to operate based on fossil fuels.

The turbo-compressors themselves are developed by Rotrex, a Danish technology SME., The rig is developed by Epcon Evaporation Technology and SINTEF. The working fluid is water, a natural refrigerant, which is a non-toxic, non-explosive, reliable and available in abundance. The compressors operate oil-free in two stages. The impeller design is customized for each stage. The rotational speed for the impellers is up to 90 000 rpm, which is enabled through a DC-motor via a planetary gearbox, which is oil cooled.

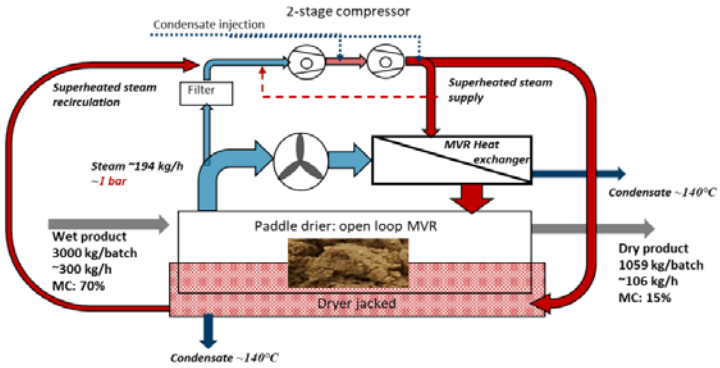

Figure 2: Schematic integration layout of MVR-dryer for sludge drying (Schneeberger et al., 2021).

To reduce the temperature prior to the next compressor stage a de-superheating system is installed. This is done by direct water injection, which is sprayed into heat pump after 1st and 2nd stage. The added water is precisely controlled to avoid sub-cooling and droplet formation inside the compressors.

The steam heat pump stages compress surplus steam coming directly from the dryer from ambient (100°C, 1 bara) up to pressures of 4.2 bara, giving a pressure ratio per compressor stage up to 2.1. The demonstrated isentropic efficiency of the turbo-compressors are between 0.7-0.8. The saturated steam from the compressor rig then supplies heat to

the steam to be used in the dryer via an MVR heat exchanger. The condensate holds around 140°C and can potentially be used for other heating purposes.

The demonstrator has achieved a capacity of 500 kW_{th}, and utilizes up to 1 ton steam per hour, while the heat pump rig has sufficient capacity to support two driers.

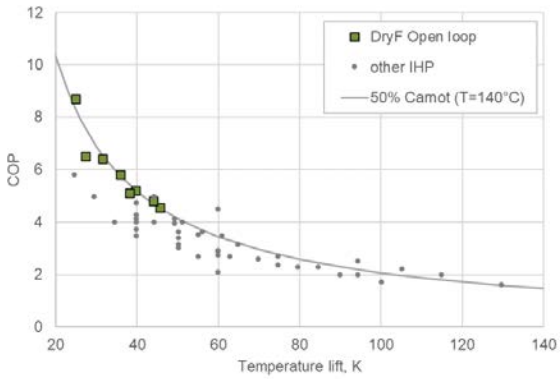

Figure 3: Performance of the DryF test-rig (Wilk, V., et al 2022)

The rig was tested at various operating conditions, ranging from supply temperatures from 125°C – 146°C. Good performance was achieved with COP-values from 4.5 up to 8.7, (Carnot efficiencies of around 50%) depending on the temperature lift, see Figure 3.

Operating experiences

Through operation a fully functional drying system was validated with 2-5 bar steam pressure delivered, drying 50 tons of garden waste during site acceptance tests. The open loop heat pump was able to deliver at least 4.5 bar.

There were some operational start-up challenges to integrate the turbo-compressor heat pump with the steam dryer in terms of maintaining superheated steam coming from the dryer, which in turn reduced the capacity of the heat pump.

FACTS ABOUT THE CASE

Intallation year: 2020

Operating hours: N/A

Working fluid used: Water

Compressor technology: Turbo-compressor

System manufacturer: Rotrex, Epcon Evaporation Technology, Scanship

Performance in design point:

- **Heat source:** 100°C steam
- **Heat sink:** 125-146°C steam
- **Heat supply capacity:** 500 KW_{th}
- **$COP_{Heating}$:** From on-site testing: 4.5 (T_supply: 146°C, 8.7 (T_supply: 125°C). Both with T_source: 100°C

Investment cost: N/A

Savings: Energy costs reduced by approximately 82%

Estimated annual CO_2 savings: N/A, (primary energy consumption reduced by 76%)

Link to webpage or report:

(DryFiciency.eu, 2022): https://dryficiency.eu/demonstrations/scanship-waste-management/

(Schneeberger et al., 2020) – Schneeberger, A., Helminger, F., Bantle, M., 2021 DryFiciency D4.3 – "Integrated Heat Pump Systems"

(Wilk et al., 2022) – Wilk, V., Bantle, M., Schneeberger, A., 2022 DryFiciency - D5.4 – "Final report on the heat pump technologies developed"

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All information were provided by the supplier without third-party validation. The infomation was provided as an indicative basis and may be different in final installations depending on application specific parameters.