Steam compressor for steam recycling at pulp drying with pressurized superheated steam dryer (PSSD)

Figure 1: Steam compressors during installation at paper mill, Sweden.

Summary of demonstration case

At a paper mill in Sweden, about 200 km west of Stockholm, pulp is dried with a pressurized superheated steam dryer (PSSD). The internal steam cycle of this dryer is superheated by a heat exchanger heated with 16 bar(a) steam. From the PSSD, exhaust steam from the dried pulp is evaporating with a pressure of ~ 3.5 bara. This exhaust steam, contaminated with particles, is used as heat source to produce clean steam in a so called "Reboiler", leaving it with ~ 3.2 bara. The 3.2 bara clean steam is now compressed to 16 bara again by two Spilling steam compressors (each with 6 cylinders, double stage), to supply the heat source for the dryer (see figure 2). Overall, the dryer/steam compressor combination is a self-suppling system, no additional steam from an external source is required. The only heat source input into the drying process is the electrical power demand to drive the two compressors.

The two 6-cylinder-steam compressors each consist of four low-pressure (LP) cylinders, compressing the incoming steam in a first stage from 3.2 bar(a) to ~8 bar(a), and two high-pressure (HP) cylinders, compressing in a second stage from ~8 to 16 bar(a). The compressors are equipped with condensate injection equipment for steam cooling at each stage. By this, while steam compression, the quantity of steam is increasing by ~ 10 % between suction side and discharge side.

For the paper mill, from an economical point of view, it was essential to install an energy efficient pulp drying system. The described solution with PSSD dryer and steam compressor for steam recycling (with a COP of ~4.2) is ideal for the mill. Not only is it very energy efficient, the electricity is also comparably cheap and fossil free, since they are using large-scale hydropower.

The nominal key figures for the two installed Spilling steam compressors are:

- Inlet steam: 3.2 bar(a) (saturated; ~ 135 °C)
- Outlet steam: 16 bar(a), (superheated with ~240 °C; sat. temp. ~201 °C)
- Steam flow rate (suction side): 2 x 8 t/h
- El. power demand: 2 x 1,325 kW
- Heat load steam (discharge side): ~2 x 5,600 kW*
- COP: >4.2

*condensing heat + heat from condensate subcooling down to 105 °C.

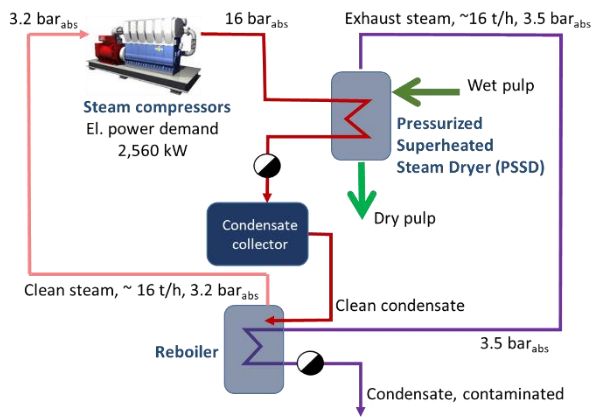

Figure 2: Steam compressor for steam recycling at pulp drying with PSSD dryer.

Operating experiences

In practice, the steam compressors have a better delivery rate than expected. They reach their nominal flow rates even at <900 RPM (instead of 1,000 RPM full speed). Also their specific electrical power consumption is about 10 % lower compared to the nominal figures as described above, so in practice the resulting COP of the compressor units is even better (with COP_{real} > 4.7).

By recycling the steam evaporated from the PSSD dryer, compared to a conventional steam production with natural gas fired boiler, and considering the real el. power demand/COP_{real}, CO_2-savings of around 14,000 t/year are resulting. This is based on 6,000 full load operating hours, and CO_2-emissions of Swedish electricity mix: ~0.013 kg/kWh

Special learnings

By optimizations at the PSSD dryer and temporary operation of the system with lower discharge pressures (down to ~13 bar(a) instead of ~16 bar(a)), the electrical power demand of the steam compressors is again lower than at nominal pressure parameters, and thus the COP/energy savings are even higher than described above.

FACTS ABOUT THE CASE

Installation year: 2016
Operating hours: Over 7,500 hours/a
Working fluid used: R-718 (water)
Compressor technology: Piston
System manufacturer: Spilling Technologies GmbH
Performance in design point:

- **Heat source:** 3.2 bar(a) steam with 133 °C
- **Heat sink:** 16 bar(a) steam, 240 °C (superheated), sat. temperature~ 201 °C
- **Heat supply capacity:** 11.2 MW
- **$COP_{Heating}$:** 4.2. This is based on condensing heat and heat from condensate subcooling to 105 °C in ratio to the compression power. The figure belongs to the contractual guaranteed max. electrical power demand of the compressor units, in practice it is even better with COP_{real} > 4.7. The electrical power demand and the heat load of the steam were validated by the customer during handover procedure.

Investment cost: 2,500,000 € without cost for integration.
Savings: unknown
Estimated annual CO_2 savings: 14,000 t/year

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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.