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Superheated Steam Dryer application for drying of sticky and pasty materials – particular referents to distillers wet grain and soluble (DWGS)

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Abstract
Swedish Exergy AB commercialised superheated steam drying technology – an invention from Chalmers University of Technology. New application for drying and valorisation of DWGS has been successfully developed and deployed at one of the sites in Europe. The technology has been adapted to this application. Key development includes novel and innovative concept of back-mixing in pressurised loop.

Keywords: *Super-heated steam drying; PSSD, DWGS, DDGS, Back-mixing.*

1. Introduction

Pressurised Super-heated steam drying (PSSD) technology was re-invented by Claes Svensson Münter at Chalmers University of Technology, Gothenburg, Sweden. This novel and innovative technology found commercial application from research laboratory. In 1979, first full scale commercial plant was built and commissioned for drying of CTMP at a small paper mill in Sweden. Many other premier institutions have done research work on use of steam for drying and modification of product properties. TNO in Holland has done notable work on modification of product properties using steam at different pressures and conditions. NUS under leadership of Dr Mujumdar [1] has done extensive research work in the field of superheated steam drying and product quality modifications. All the research shows tremendous benefits for the technology. With net heat consumption 150 kWh/ton water evaporation; PSSD is world's most energy efficient drying process. Swedish Exergy AB since inception has been working on commercializing this technology with mixed success. High capital expenditure is biggest hinder. However, Swedish Exergy has successfully applied PSSD in one of the most difficult applications. Purpose of this paper to present this application and highlight results achieved.

2. Materials and Methods

2.1. Application Industry and Process Description

The application industry is grain based distillery plant. Process of ethanol from grain based distillery is briefly described below.

Grain from storage silos is milled either as dry milling or wet milling. Fig.1 shows process with wet milling. Slurry after wet milling is cooked in jet cookers before fermentation process. Sugar are converted into alcohol in fermentation and separated in distillation process. Remains from bottom of distillation process containing solids rich in protein is de-cantered. Separated solids are mixed with thin phase concentrated in an evaporator plant. This mix (DWGS) with 75% moisture content is dried in PSSD. Heat energy to PSSD is supplied from high pressure steam, thermal oil, natural gas or bio-gas. For every ton evaporated water, 750 kW thermal energy is put into the PSSD indirectly. Out of this 600 kW is recovered as low pressure (2-4 barg) steam and used for jet cooking, distillation and evaporation. Dried product (DDGS) with 10% moisture content is cooled after the dryer and sold as animal feed.

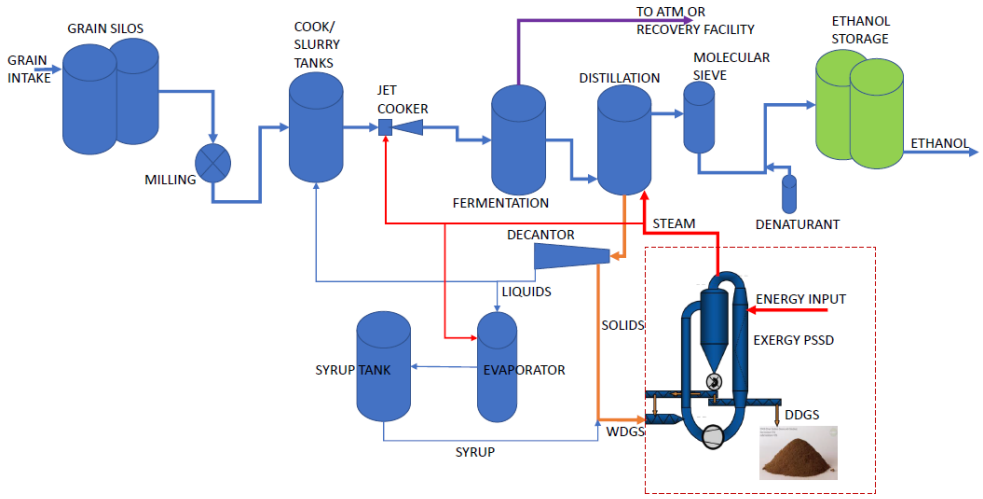

Fig. 1: Grain based distillery integrated with PSSD.

PSSD technology is closed loop system consisting of a circulation fan, heat exchanger, drying conduits, cyclone, feeding rotary valve and discharge rotary valve. Drying media is kept in closed loop circulation and drying energy is added indirectly through the heat exchanger. We product is fed through feeding rotary valve to the closed loop system. Drying takes place in drying conduits in very short time of less than 10 seconds. Product is separated in a cyclone from circulating drying media and discharged through bottom of the cyclone via discharge rotary valve. Separated drying media is circulated back to the heat exchanger for addition of drying energy. The process continues in this manner. As more and more moisture is evaporated in the closed loop, pressure increases inside the closed loop. Some of the evaporated moisture is bled-off through a control valve keeping constant pressure inside the closed loop. See fig. 2 for PSSD components.

Sticky and pasty material is handled in the dryer by back-mixing system. Fig 3 is picture of commercial plant installed in an ethanol plant in Italy.

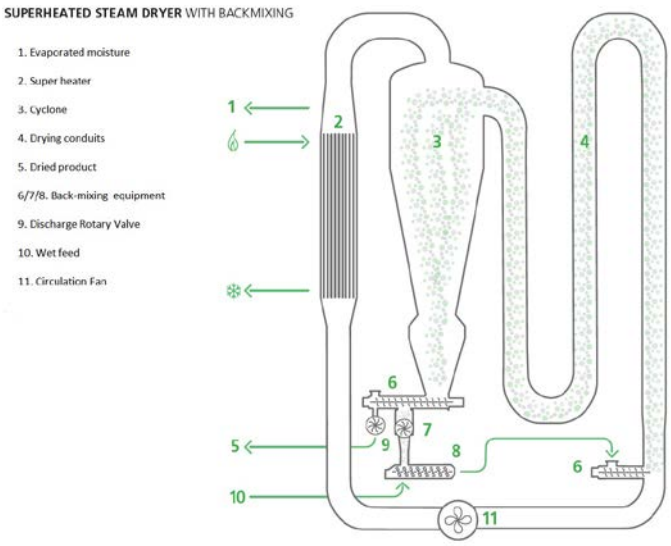

Fig. 2: Schematic of PSSD used for DDGS production

Fig. 3: Picture of PSSD commercial plant

2.2. Process Integration and energy efficiency

PSSD energy recovery potential makes it best candidate to integrate with other processes in the distillery. Steam generated from DWGS moisture is used for jet-cooking, distillation and evaporation processes in the plant. A typical energy and mass balance for a 10 ton/h DWGS plant is shown in table 1.

Table 1: Heat and Mass Balance for 10 ton/h DWGS plant

Input to PSSD				
Media	**Pressure, MPa**	**Temperature, °C**	**Mass, kg/h**	**Heat, kW**
DWGS – 75% moisture	-	70	10 000	685
Net heat input	-	-	-	4 911
Heat from electricity used for rotating machinery	-	-	-	150
Total	-	-	10 000	5 746
Output from PSSD				
DDGS – 10% moisture content	-	100	2 777	136
Steam generated in the dryer and recovered as low pressure steam	0,3	145	7 000	5 341
Flash off and leakages	0	100	223	169
Thermal losses	-	-	-	100
Total	-	-	10 000	5 746

2.3. Product Quality Improvements

2.3.1. Sterilization

Closed loop PSSD works as continuous autoclave and product is 100% sterilized at the end of the PSSD process. Live tests with salmonella has been done to demonstrate this. This means product can be sold with guarantees which means higher value product.

2.3.2. Protein digestibility and by-pass protein

Product when used as animal feed for animals with multiple stomachs like cows, DDSG produced with PSSD process offers additional product quality benefits of improved protein digestibility and by-pass protein [2]. Product gets cooked during drying process.

2.3.3. No oxidation

Closed loop PSSD does not allow ingress of atmospheric air inside the PSSD which provides oxygen free process medium ensuring that product is not oxidized. O2 measurements conducted using sensitive O2 measuring probes have confirmed oxygen free media inside the PSSD. Product maintains excellent uniform color and texture. See product picture shown in fig 4.

Fig. 4: Picture of DDGS produced from PSSD process

2.4. Novel and innovative back mixing system

Swedish Exergy has developed and implemented at commercial stage a novel and innovative back mixing system operating at same pressure as PSSD operating pressure (fig 5.0). This unique back-mixing method offers many benefits over traditional back-mixing methods.

1. Very short mixing time.
2. Excellent mix production
3. Smaller equipment
4. Very uniform product dryness

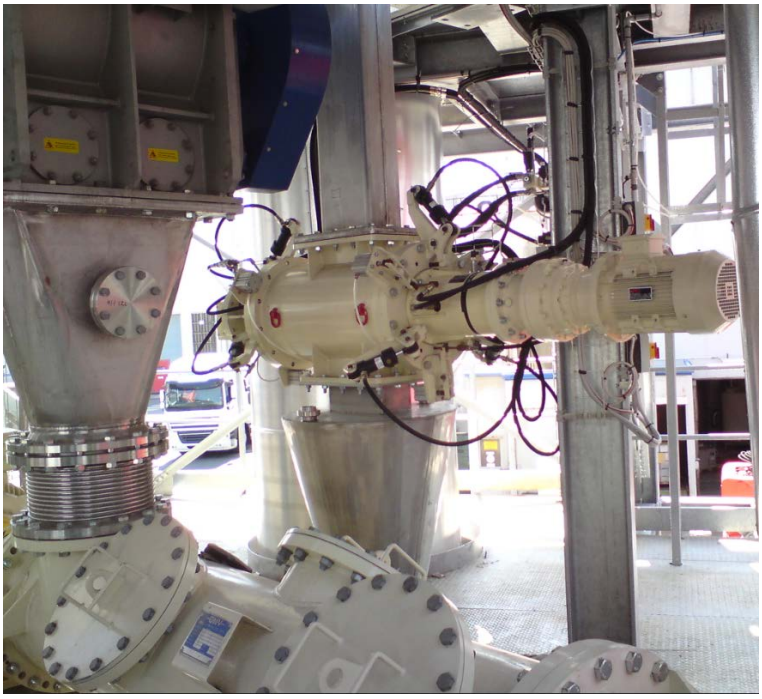

Fig. 5: Picture of novel and innovative back-mixing system as part of PSSD process

3. Conclusions

Commercialization of PSSD has been a challenge and still is. Swedish Exergy has successfully commercialized PSSD for production of animal feed from waste stream in ethanol production process. Valorization of waste streams or by-products is big focus for the industry. PSSD has big potential to help industry to valorize the waste and by-products.

Example illustrated in this paper is concrete evidence. Other potential industries who can benefit from PSSD technology are breweries, food and feed industry, oil seeds industry etc.

4. Nomenclature

CTMP	Chemical Thermo Mechanical Pulp
SHSD	Super-heated steam drying
DWGS	Distiller Wet Grain and soluble
DDGS	Distillers Dry Grain and Soluble
PSSD	Pressurised Super-heated steam dryer

5. References

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