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Optimization of Paper Machine Vacuum Systems Using Turboblowers: Industrial Implementation and Energy Savings

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Abstract: Vacuum system on paper machine line is one of the main drivers for electricity consumption. By optimizing vacuum usage, optimizing water flow measurement, and implementing Turboblowers, mills can significantly reduce energy consumption in the vacuum system. Furthermore, exhaust heat recovery, regular maintenance, and tailored dewatering solutions help achieve remarkable energy savings, ultimately benefiting both the environment and operational efficiency.

Keywords: vacuum system; liquid water ring pump; Turboblower

1. Introduction

The production of paper and board is an energy intensive process. One of the main drivers for electricity consumption is vacuum system on the paper line. In the paper mill described below, the vacuum system electricity consumption is 5 ÷ 11% of specific electricity consumption of the paper machine lines.

Vacuum systems are essential for paper machines, primarily driving dewatering in the forming and press sections to increase sheet dryness, as well as managing felt conditioning and sheet transfer. By utilizing liquid-ring pumps or blowers to create suction, these systems improve sheet formation, reduce dryer steam consumption, and enhance overall machine efficiency [1].

In the forming section (dewatering) vacuum is applied to suction boxes and rolls to remove water from the wet fibre slurry as it forms on the wire, typically achieving a dryness of 20% and higher.

In the press section (dewatering & transfer) vacuum assists in removing water from the paper sheet and the felt, which acts as a carrier. It also aids in guiding the sheet through the press rolls, typically achieving a dryness of around 50% [2].

For felt conditioning (cleaning) vacuum is used in Uhle boxes to remove water and contaminants from the press felts, ensuring consistent water removal from the paper.

For sheet transfer vacuum holds and controls the paper web, particularly when transferring it between different sections of the machine.[3]

1.1 Common Technologies Used

Liquid Ring Vacuum Pumps: The industry standard due to their ability to handle large volumes of water-laden air, often used to create different vacuum levels in combination.

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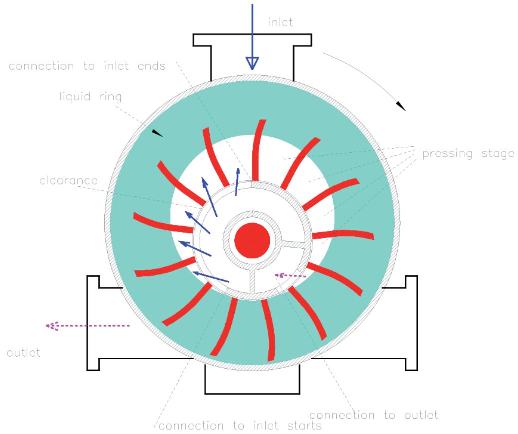


Figure1: Liquid ring pump

Figure 2: Liquid ring pump

Figure 1 describes the operating principle of liquid ring pump [4].

A rotor is fitted on pump shaft. It has blades which are curved to rotational direction. (red parts). The shaft and pump casing are not concentric, i.e. they do not have the same central axis. Static inlet/outlet cones are fitted on the casing. When seal water is pumped to rotating pump, it forms rotating liquid ring. Static cone has an opening which is leading air from inlet to opening space between blades and liquid ring. Finally, connection to inlet is ending and liquid ring starts to compress air 9 (pressing stage). At the end of pressing stage there is opening on cone to the outlet and sucked (and further compressed) gas flows out. All liquid ring pumps are working with this principle. Some models have no cone to direct the gas.

Typical features of liquid ring pump:

– *The volume of the vacuum gas remains quite constant, but vacuum level can vary 0 ÷ 90 kPa (maximum vacuum depends on seal water temperature)*

– *Mass flow varies considerably depending on vacuum level.*

– *A lot of seal water is needed.*

– *Water separation is needed at inlet and at outlet.*

– *Seal water treatment is needed at outlet side*

– *Pump should be started with open valves*

– *The pump starts operating after 1 ÷ 3 minutes when liquid ring is formed*

– *Efficiency of the pump depends greatly on speed. At high speed, friction between liquid ring and casing creates losses.*

– *Liquid ring is always compressing gas. That's why pump is always inefficient at low vacuum (below 20 kPa).*

– *Gas compression creates heat. Heat is transported to seal water. If seal water is recycled, it must be cooled. In praxis, the temperature of seal water should be below 40°C. If process gas and seal water has a temperature difference, moist in process gas condenses. This phenomenon increases volume capacity, it depends on temperature difference*

– *Inside liquid ring pump there are small clearances between static and rotating parts. Corrosion and erosion are enlarging these clearances resulting capacity reduction.*

Turboblowers: Used for higher efficiency and energy savings, offering better air flow control compared to traditional pumps.

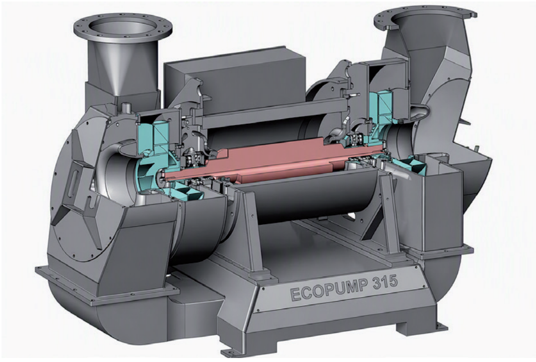


Figure 3: Turboblower

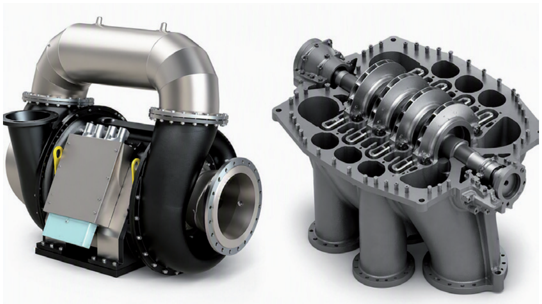


Figure 4: Trboblower 2 stage and multistage

Figure 3 describes the operating principle of Turboblower

Turboblower has two closed impellers made of titanium. Impellers are fitted on electric motor. The bearings are conventional oil-lubricated ball bearings. At speeds of 5,000–10,000 rpm vacuum levels of paper, board and pulp machine can be created.

Typical features of this machine:

– *No seal water needed. Air cooling*
– *Low power consumption due to speed control (frequency converter) and good impeller efficiency. Vast operating range.*
– *No corrosion problems due to titanium impeller and stainless-steel casing*
– *Lightweight construction, less space needed*
– *Noise protection hood as standard*
– *No gearboxes or couplings; the machine requires less maintenance*
– *Impellers and bearings can be serviced without opening piping*

2. Modern energy efficient solution for vacuum system

By optimizing vacuum usage, optimizing water flow measurement, and implementing Turboblowers, mills can reduce energy consumption by 30÷70% in the vacuum system itself. Furthermore, exhaust heat recovery, regular maintenance, and tailored dewatering solutions help achieve remarkable energy savings, ultimately benefiting both the environment and operational efficiency.

Turboblowers are designed to operate efficiently across a wide range of vacuum levels and air flows, allowing paper mills to optimize vacuum levels. High speed motors driven by frequency converters, allow Turboblower to provide vacuum levels between 30 and 70 kPa. A wide range of impeller designs allows highly efficient levels across the operating range. This system operates without water, enhancing reliability and significantly cutting CO_2 emissions.

In addition, Turboblower generates a substantial amount of exhaust heat, ranging from 100°C to 180°C.

Recovering this heat enables you to reduce steam consumption on the paper machine. Given that steam production is a costly process in papermaking by utilizing recovered heat to warm shower waters

or dryer hoods, you can achieve substantial cost savings. This approach is not only economically advantageous but also aligns with sustainability goals as it reduces the need for primary energy sources [5].

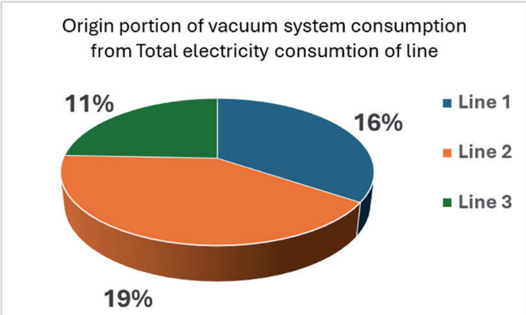
3. Turboblowers installation in the Paper Mill

In the paper mill, rebuilds of the vacuum systems on 3 paper machine lines were carried out as hybrid systems or as systems consisting only of Turboblowers, and a system consisting only of Turboblowers was installed on a new paper machine.

The main driver for these rebuilds was energy saving. On the 3 rebuilt lines, total electricity savings were 13.2 GWh/year. From the economic point of view, there is a significant reduction of operating costs.

Table 1: Concept of vacuum system on the Rebuild and New lines and decrease of specific electricity consumption on the Rebuild lines

	Origin concept	**After rebuild**	**Decrease of Specific electricity consumption on the line**
Line 1	6 liquid water ring pumps	2 Turboblowers	7%
Line 2	6 liquid water ring pumps	2 liquid water ring pumps + 1 Turboblower	8%
Line 3	9 liquid water ring pumps	1 liquid water ring pump + 3 Turboblowers	6%
Line 4		5 Turboblowers	new line



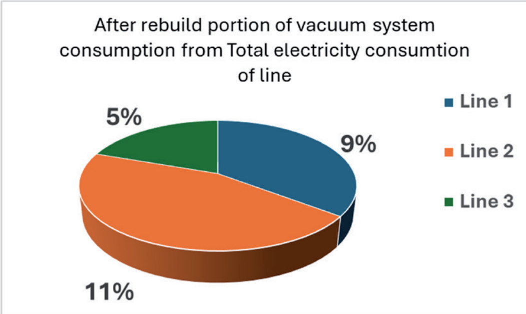


Figure 5: Portion of vacuum system electricity consumtion from Total electricity consumption of line

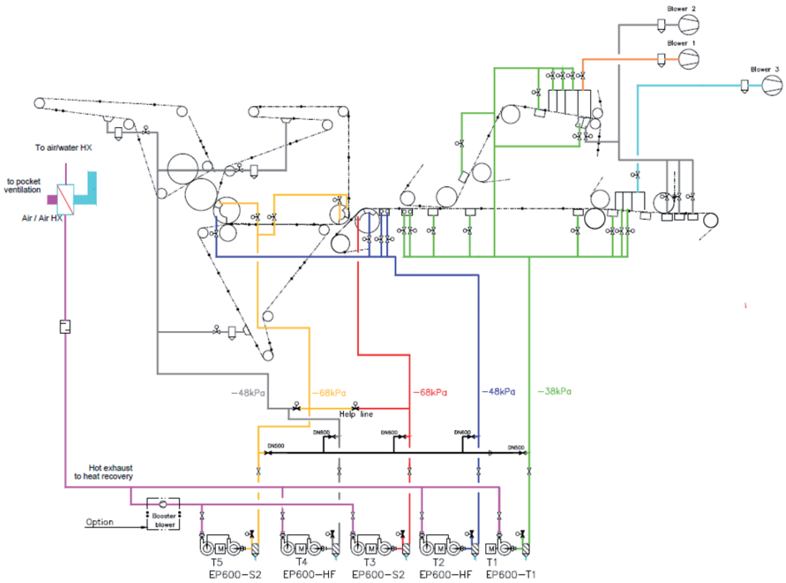


Figure 6: New Paper machine line Energy efficient concept

Table 1 shows Vacuum system concepts of paper machine lines and decrease of specific electricity consumption of the lines.

Figure 5 shows the difference between original consumption of vacuum system and after rebuild consumption.

New Line 4 (greenfield project) consumes 9% of specific electricity consumption for vacuum system.

Figure 6 shows the most energy-efficient concept of vacuum system for the paper mill (BAT). This system combines Turboblowers (single and multistage impeller) for dewatering with usage of excess heat exhaust from Turboblowers for paper machine line ventilation. The mentioned concept also recovers heat for paper machine hood ventilation.

4. Discussion

The mentioned optimisation of vacuum systems on the paper lines improved the energy efficiency of existing lines and positively influenced the line costs. The new line uses BAT technologies, which results in lower operating costs and high operational efficiency.

Turboblowers are optimized to deliver maximum efficiency and performance in a wide range of industrial and municipal applications.

From experience of usage hybrid or complete Turboblower system we confirmed that it is smart vacuum system with higher capacity, vacuum levels are optimized to the needs, press sections can operate towards maximized nip-dewatering strategy.

Summary of the main benefits:

– *Energy saving*
– *Speed range from 0÷100% without limitations*
– *Smaller units provide a maximum system flexibility*
– *Redundant capacity*
– *Compact size due to the integrated motor for new machines and rebuilds*
– *Easy maintenance*

5. Conclusions

The completed rebuilds of vacuum systems on three paper machine lines into hybrid systems or systems consisting only of Turboblowers, together with the construction of one new line with a complete Turboblower system, have demonstrated significant technical, environmental and economic benefits. The implementation of Turboblowers technology with measuring water flow and optimising vacuum usage reduced electricity and heat consumption during the paper making process. The electricity measurements fully confirm the estimated savings in electricity consumption. A system consisting only of Turboblowers fully meets the requirements of best available techniques. From the energy consumption perspective, it strengthens the paper mill's competitive position on the market.

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