PTA production: Lowering OPEX without compromising on quality

WHITEPAPER

Rotary pressure filter as a single-step solution for PTA production - How the right separation technology can deliver lower OPEX without compromising on quality
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Abstract

You have to spend money to make money. Never has the old adage been truer than in today’s world of Industry 4.0, smart engineering advances, and fiercely competitive markets. In the past, to achieve high-quality separation and high purity of certain substances, producers needed to use centrifuge technology to guarantee the requisite product quality. Unfortunately, the very high speeds generated by the machine not only result in high energy bills, but mounting costs from frequent maintenance and repairs.

One such substance that previously relied on centrifugation to separate its liquid and solid phases is purified terephthalic acid (PTA), a crucial chemical in the petrochemical industry used for PET bottles and polyester fibers, whose rise in global demand shows no signs of slowing. However, volatile crude prices and rising costs for energy and production facilities mean that market prices for PTA can fluctuate wildly. Smaller plants with a nameplate capacity of less than 800 MT per year are at risk of being sunk by bigger competitors during low-price periods unless they have managed to optimize their process and cut OPEX.

This paper looks at how the earlier PTA production method involving a multi-stage process with pressure and atmospheric centrifuges and a re-slurry tank can be replaced with one stand-alone device – the rotary pressure filter (RPF). An optimized RPF enables complete filtration between the PTA crystallization and drying stages to be realized in a single, closed step. Using the ANDRITZ Krauss-Maffei pressure drum filter TDF as a reference, the paper looks in detail at the design, operating principle, and performance of a state-of-the-art RPF.

Reference projects from Indonesia and Russia show how the right separation technology can deliver low OPEX while maintaining the same quality, enabling PTA producers to remain competitive even when prices fluctuate. The obvious choice for greenfield projects, this paper shows that switching over to a single RPF process can also be the right option for existing plants looking to future-proof their business by cutting costs without compromising on the quality of their product.

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Introduction

Prized for its excellent weathering properties, hardness, flexibility, and outstanding fluidization characteristics\(^1\), purified terephthalic acid (PTA) is used as a raw material in the production of polyethylene terephthalate (PET) and polyester fibers, making it one of the most important chemicals in the petrochemical industry\(^2\). Growing applications of PTA for the production of polyester resins in several end-use industries such as packaging, textile, and automotive are expected to boost the PTA market in the coming years\(^3\).

The main process steps\(^4\) in producing PTA traditionally involve paraxylene oxidation to synthesize the crude terephthalic acid (CTA) before crystallization, followed by centrifugation or filtration, then CTA drying and dissolution, and finally hydrogenation, where the CTA is purified to PTA. In earlier PTA plants, decanter centrifuges (pressure and atmospheric) were used to separate the PTA crystals from the PTA slurry in between the final key PTA crystallization and drying stages.

This centrifuge approach is an age-old separation method and one that is highly effective in terms of quality. Unfortunately, it has distinct disadvantages, not least because of the very high speed generated by the machine. To survive on today’s competitive market, producers need to reduce the maintenance needs and downtime of the machinery, at the same time as cutting operating costs (OPEX). Lowering the wash ratio and power consumption are also key factors in reducing OPEX.

Valued at around USD 57 bn in 2016\(^5\), the global PTA market is growing rapidly as the result of burgeoning demand. However, fierce competition coupled with volatile crude prices and rising costs for energy and production facilities mean that market prices for PTA are subject to fluctuation. This makes low OPEX a crucial survival factor during periods when a low global price level prevails. Smaller plants with a nameplate capacity of less than 800 MT PTA per year can often only compete with big producers if they have optimized their process to secure lower OPEX.

This is why international technology group ANDRITZ went back to the drawing board. A PTA production process that previously required a pressure centrifuge, re-slurry tank, and atmospheric centrifuge has been optimized thanks to technological advances in its rotary pressure filter (RPF). As seen in figure 1, what used to be a two-step process can now be realized in a single stage – with the benefits of a lower equipment footprint, lower maintenance requirements, lower consumption of steam and power, and lower investment for greenfield projects. Ultimately, a single-step process equals lower production costs per ton without adversely affecting the quality of this essential chemical.

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3) https://www.zionmarketresearch.com/sample/purified-terephthalic-acid-market
5) https://www.grandviewresearch.com/industry-analysis/purified-terephthalic-acid-market
FIG. 1
The rotary pressure filter eliminates the need for additional equipment in between the crystallizer and dryer stages of PTA production.
Technology overview: 
The rotary pressure filter

Also known as a pressure drum filter, the rotary pressure filter is a continuously operating unit for all-in-one pressure filtration, cake washing, and drying of slurries with solids of up to 50%. The main components of the RPF are the pressure casing, filter drum, filter cloth mounted on the external surface of the drum, control head, agitator, screw conveyor for material transfer, and rotary valve (see figure 2). The process area is easy to access and the pressure vessel locks fast with a clamp ring.

The surface of the drum is divided into several longitudinal filter cells and the filter circumference in turn is divided into various process zones as shown in figure 3. The cells on the filter drum run through the filter zones by rotating the drum. These filter zones (e.g. for cake filtration, intermediate drying, washing, cake discharge, and bubbling) are connected through a piped connection to the control head.
The control head is used to separate filtrates coming from different zones and to apply different pressure levels to each process zone. The filter drum is placed in the trough (feeding zone), which is in turn connected to the slurry feed line and overflow. The trough has an agitator to prevent the sedimentation of the solids in the slurry and the discharge device – usually a scraper blade – is also installed in the trough. A screw conveyor is placed under the discharge device. The complete filter is installed in a pressure casing, whereby the pressure can be maintained by process gas or steam.

Not only is the closed design suitable for effective steam pressurization, but the differential pressure can be adjusted for every individual filtration zone. This means that the cake thickness can be varied by adjusting the pressure difference between RPF and filtrate vessels or by the drum speed.

Even though the RPF achieves very low residual moisture, the overall cycle time for filtration, cake washing, and drying typically takes less than 60 seconds.
The RPF operates with overpressure inside the pressure casing, forcing the liquid from the PTA slurry to pass through the filter cloth. The drum surface is divided into different process steps inside the control head: cake formation, cake wash, drying, discharge, and cloth wash. In the course of one revolution, each point of the drum area passes through these zones in succession.

The process of separating the PTA solids first requires the cake to be formed. To achieve this, the slurry is fed continuously under pressure to the filter trough of the RPF. A certain percentage (usually around 30%) of the drum surface is submerged inside the slurry, which is constantly fed into the trough and kept in suspension by means of an agitator. The trough level can be controlled by a level control device or the filter operates under overflow.

An adjustable pressure difference between the pressure casing and filtrate separators causes filter cake to build up on the filter cloth. The mother filtrate is then drained off by the filtrate drainage system. Throughput can be changed by adjusting the speed, whereby an increase in filter speed will increase the throughput and vice versa.

Once the filtrate has been drained off through hydraulically optimized suction cells, filtrate pipes, a control head, and a separator, the filtered solids layer (the PTA cake) emerges from the slurry as the drum rotates. The filter cake is washed immediately via multiple dedicated wash pipes. Depending on the specific requirements, washing can take place in one or more stages. Each pipe is equipped with adjustable wash nozzles and its position and angle can be easily adapted to process requirements.

This wash filtrate is drained through the pipe system to the control head, where it can be collected in unmixed form, separate from the mother filtrate, as seen in figure 5 where the yellow and blue liquids emerge in disparate streams.

After the cake wash, the cake is dewatered with the help of process gas and/or steam. The filtrate is once again collected separately from the preceding filtrates and can be used for a first-stage counter-current wash, helping to reduce wash water consumption.

Operating principle: How the rotary pressure filter separates PTA slurry from cake

FIG. 4
The filtration capacity of an ANDRITZ Krauss-Maffei pressure drum filter TDF can reach up to 10,000 l/m²h
The final step involves the discharge of the filter cake. The discharge device covers the entire drum length and is tailored to the cake thickness, consistency, and structure. For PTA this usually involves either back-blowing or scraping. The PTA cake falls down to the screw conveyor and is transported out of the pressure casing to the rotary valve, which equalizes the pressure level. As the drum rotates, it is then re-immersed into the suspension.

As seen in figure 5, filtrate outlets from various process zones are connected internally to a control head where each stream can be directed to different filtrate separator tanks based on user requirements. This allows for better process control, as well as facilitating the reuse of wash water. After automatic cake discharge, the filter cloth is washed, either with spray nozzles or bubbling. The clean filter cloth then re-enters the feeding and filtration zone, thereby continuing the process.

**FIG. 5**
The different filtrates emerge from individual zones and are collected separately.
How the rotary pressure filter performs in the real world

These PTA filtration developments have been put to the test in recent years. While the single-step process is clearly advantageous for greenfield projects in light of the lower initial equipment investment and footprint, is it worth the upgrade for existing operations?

Asia-Pacific is one of the fastest growing regions for PTA production owing to increased end-segment demand and accounted for some 77% of the global PTA market share in 2016. A plant in Indonesia was using two pressure centrifuges and two atmospheric centrifuges for PTA separation to meet its production capacity of approximately 58 TPH. The main problems with this type of set-up arise with the high-pressure decanter centrifuge. The high speeds required by the equipment not only consume a lot of energy, they also require more maintenance, incur higher downtime, and call for more replacement parts such as seals.

Added to this is the time and extra equipment needed for dousing the PTA in a re-slurry tank before separating it again. A cost-benefit analysis conducted by the Indonesian company led to the decision to execute a retrofit project to improve production and process efficiency. The performance specification of the ANDRITZ Krauss-Maffei pressure drum filter TDF with its proven ability to deliver low residual moisture at high capacities made it the reliable choice to replace the existing installed centrifuge technology.

Retrofitting the PTA separation set-up is expected to lead to a significant reduction in OPEX for this medium-sized Indonesian producer, due to an inevitable decline in power consumption as two atmospheric and two pressure centrifuges with high-tension drives are replaced by the single RPF with low-tension drives.

Another upgrade took place in Russia in a PTA plant fitted with four centrifuges for their oxidation unit, where the CTA is produced, and a further four centrifuges for their purification facility (PTA). In view of the high energy consumption of the centrifuges and the elevated downtime repeatedly required for maintenance, the user decided to install an RPF in parallel to the existing centrifuges.

Once the RPF was successfully commissioned, there was an immediate reduction in the residual moisture in the cake, which in turn reduced the load on the downstream PTA dryer. The improved wash-water ratio, coupled with lower steam consumption and lower maintenance requirements were all powerful additional factors in the decision to switch over exclusively to the RPF.

In effect, a single RPF has replaced all of the centrifuges, which remain installed only in case they are needed as back-up. The energy consumption of this Russian petrochemical provider has decreased significantly along with their production costs per ton of PTA.

Conclusion

In a market with a bright future in terms of demand, but where OPEX is essential to future survival, optimizing PTA production equipment is an investment well worth considering. For years it was only possible to achieve the purity of terephthalic acid required for certain applications and effective cake dryness by using a multi-stage process with pressure and atmospheric centrifuges and a re-slurry tank. The disadvantages of using centrifuges in PTA production mainly lie in the power consumption caused by the high speed of the machine, as well as the higher maintenance, replacement parts, and downtime incurred by the centrifuge technology.

An optimized RPF enables complete filtration between the PTA crystallization and drying stages to be realized in a single, closed step. The fact that one stand-alone device is all that is needed reduces the space required and the capital investment for greenfield projects – an easy choice. For existing PTA producers the decision may initially seem tougher, but case studies show that it is an investment worth evaluating, especially for smaller producers struggling to compete.

Built from duplex and stainless steel, the ANDRITZ Krauss-Maffei pressure drum filter TDF is ideally suited to fine and ultra-fine-grained products such as PTA and can operate at pressures of up to 10 bar. The different process steps inside the control head – cake building, washing, drying, discharge and cleaning – typically take less than 60 seconds before the drum is re-immersed and the process begins again.

The multi-stage drying, adjustable pressure zones, and multitude of cleaning-in-place features combine to deliver PTA cake with very low residual moisture while reducing maintenance and downtime thanks to the low speeds of the filter. Lower residual moisture reduces the load on the PTA dryers downstream and can be achieved at the same time as lowering steam consumption. Keeping the filtrates separate at every stage of the process improves the wash-water ratio and allows filtrate to be reused for counter-current washing, ultimately reducing water as well as power consumption.

Multiple case studies show that the right separation technology can deliver lower production costs without compromising on quality, enabling PTA producers to remain competitive even when prices fluctuate. Cost savings with an all-in-one rotary pressure filter extend beyond savings on power and water consumption to lower replacement-part and maintenance costs while retaining high output and quality levels.
ANDRITZ GROUP
ANDRITZ is an international technology group providing plants, systems, equipment, and services for various industries. The company is one of the technology and global market leaders in the hydropower business, the pulp and paper industry, the metal working and steel industries, and in solid/liquid separation in the municipal and industrial segments. Other important fields of business are animal feed and biomass pelleting, as well as automation, where ANDRITZ offers a wide range of innovative products and services in the IIoT (Industrial Internet of Things) sector under the brand name of Metris. In addition, the company is active in power generation (steam boiler plants, biomass power plants, recovery boilers, and gasification plants) and environmental technology (flue gas and exhaust gas cleaning plants) and offers equipment for the production of nonwovens, dissolving pulp, and panelboard, as well as recycling plants.

ANDRITZ stands for passion, partnership, perspectives and versatility – core values to which the company is committed. The listed Group is headquartered in Graz, Austria. With almost 170 years of experience, 29,600 employees, and more than 280 locations in over 40 countries worldwide, ANDRITZ is a reliable and competent partner and helps its customers to achieve their corporate and sustainability goals.

ANDRITZ SEPARATION
ANDRITZ Separation is one of the leading separation technology specialists with the broadest technology portfolio in solid/liquid separation. The industries served include sectors ranging from environment to food, chemicals, and mining and minerals. The comprehensive product portfolio for solid/liquid separation comprises mechanical technologies such as centrifuges, filters, screens, thickeners, or separators, and thermal technologies such as dryers or coolers. The service sector focuses on customer support through local presence, prompt delivery of spare and wear parts, process monitoring and optimization, as well as operator training. In addition, the Separation business area offers technologies and services for the production of animal feed and biomass pellets.