The Benefits of Converting Starch at the Paper Mill Using a Continuous Enzymatic Process

ProFlow
Division of Burt Process Equipment

ANAB ACCREDITED MANAGEMENT SYSTEMS CERTIFICATION BODY
Certified to ISO 9001:2015
TÜVRheinland Precisely Right.

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Overview

From the wet end, all the way through to the size press, starch is widely used in the process of making paper. It can be used as an additive to support internal sizing, dry strength, or surface sizing. It's often used as a binder in coating formulas, or as an adhesive in corrugated board. As a coating, it helps to ensure consistent and high-quality ink application. Pulp and paper mills use millions of tons of starch in their processes each year, and with the right equipment they may be able to substitute lower-cost native starch for expensive derivative starch.

Challenge

To be used in the paper-making process, starch must be cooked, or treated, properly. Traditionally, paper mills buy the starch pre-treated (sometimes referred to as derivative starch) but doing so comes with several challenges. The industry is moving towards a focus on sustainability and reduced environmental impact. The pre-treatment of starches through oxidation, hydrolysis, or etherification is not environmentally friendly and can be expensive. Pre-treatment materials must also be handled properly to ensure worker safety. Starch by itself is one of the largest operating expenses and can vary with the grade of paper being produced. Mills wants to have flexibility and not be locked into just one starch supplier. These different challenges can translate to significant incremental costs in raw materials. At a time when digital solutions are replacing paper products, and paper mills around the world are shutting down permanently, anything that adds to the overall operating costs needs to be addressed.

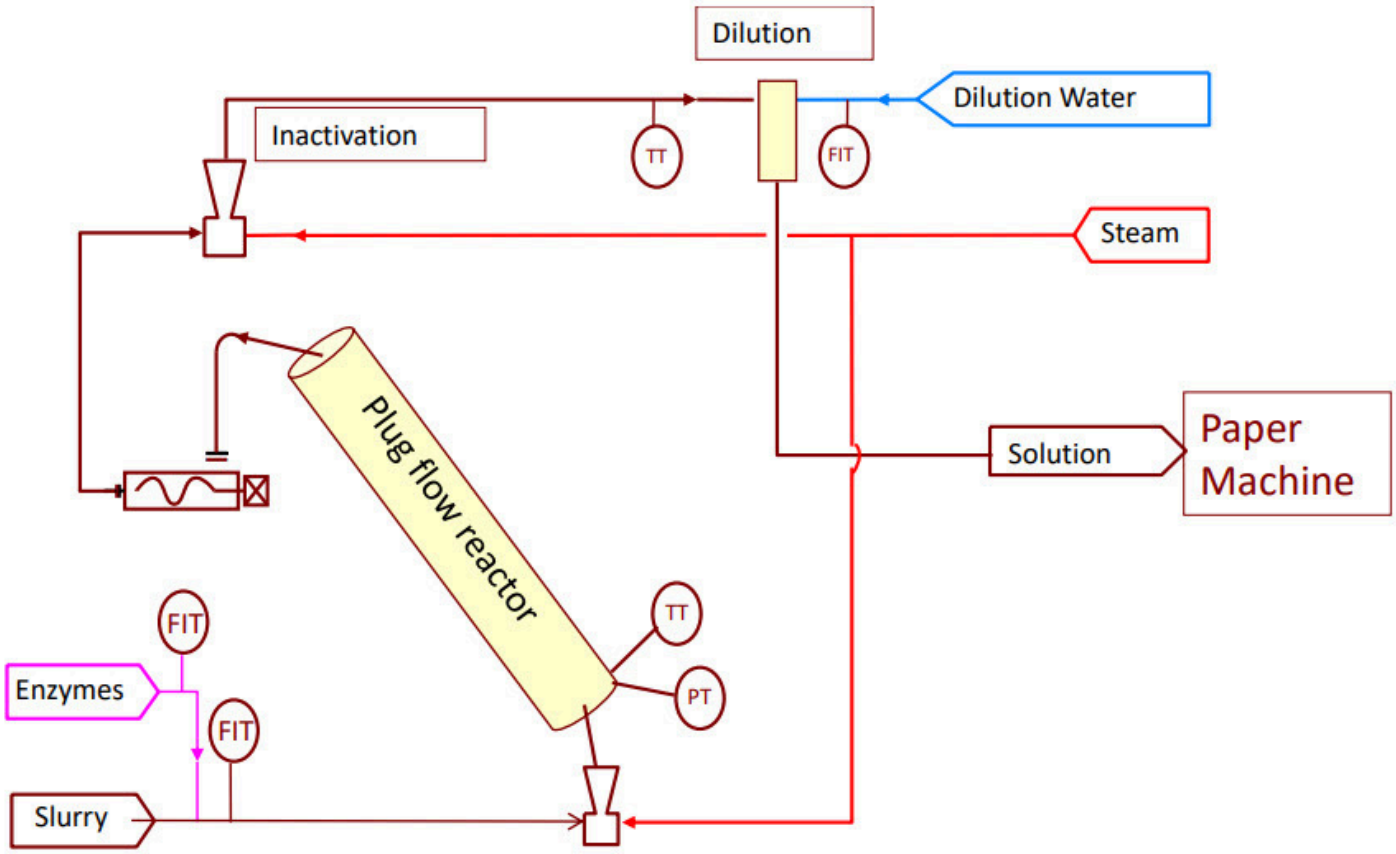
Since pre-treated starch is so costly, paper mills are looking for alternative solutions. The most obvious solution is to buy raw starch and convert it themselves. While converting starch on site is a good solution for containing operational costs, it creates other challenges for the plant. The typical starch enzymatic conversion method is a batch process that requires enzymes, water, time, temperature, and an agitated vessel. Steam typically heats a slurry of starch and water in an agitated tank at elevated temperatures. The starch slurry becomes viscous with the consistency of peanut butter and low-viscosity enzymes are then mixed in.

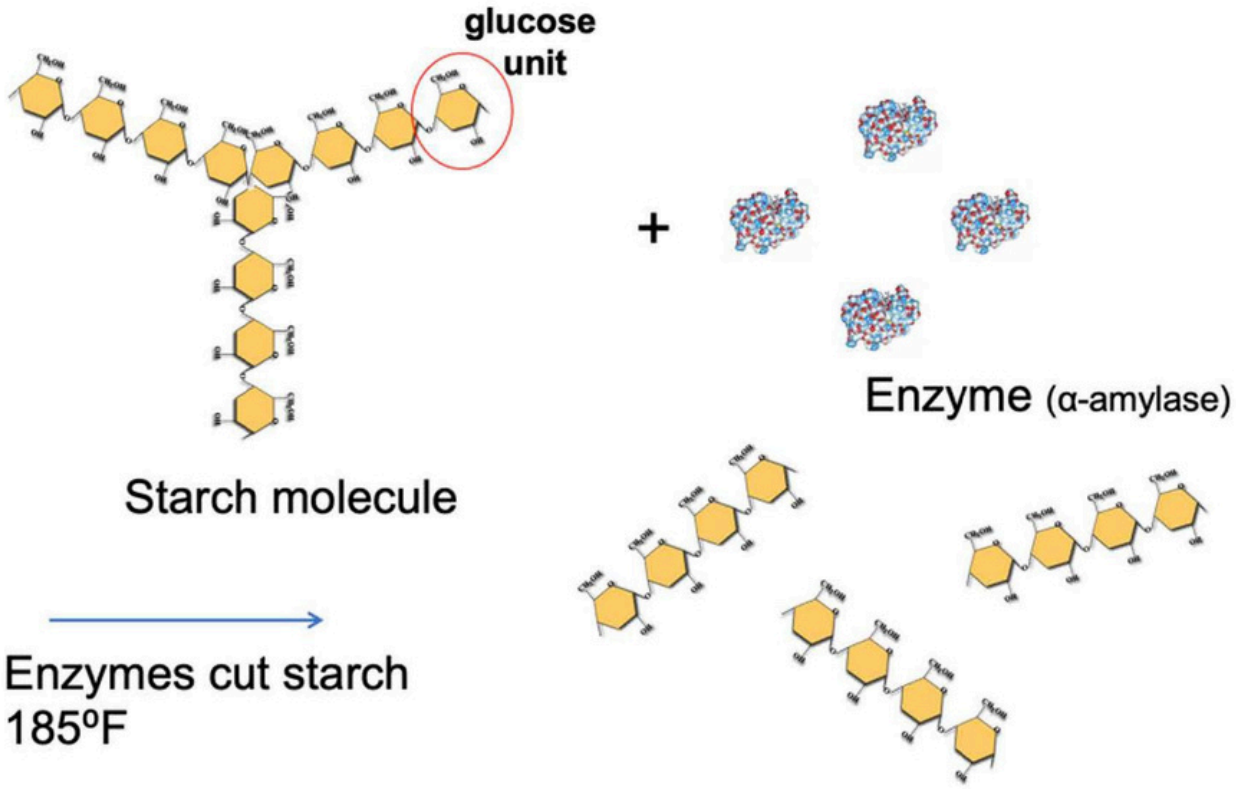
It’s very difficult to get consistent mixing in this situation, and different areas in the mixing vessel will often have differing levels of contact with the enzymes. This inconsistency in material is problematic because it ultimately impacts the starch solution quality. The enzymes will break up the starch chains into smaller pieces, but the pieces will not be of uniform size.

Because this method is by its nature a batch process, if there is a problem in a portion of the batch, the entire batch may need to be discarded. If another batch needs to be started, it will take at least 25 minutes to reproduce the batch after cleaning out the vessel. Not only does this negate the cost benefit of converting starch on site, but this could result in extended and costly plant shutdowns.

A Solution Based on Continuous Enzymatic Conversion

Continuous enzymatic conversion addresses these challenges by allowing mills to use the more cost-effective unprocessed pearl starch by continuously converting the starch directly into the process on demand. ProFlow's continuous enzymatic conversion system uses a unique plug flow principle to minimize viscosity fluctuations, resulting in a stable size press operation. Other suppliers that claim to use a continuous process utilize a batch reaction cycle where batches are automatically repeated. These continuous batch systems typically have longer reaction times due to less effective mixing rates, and they increase the risk of glucose formation.





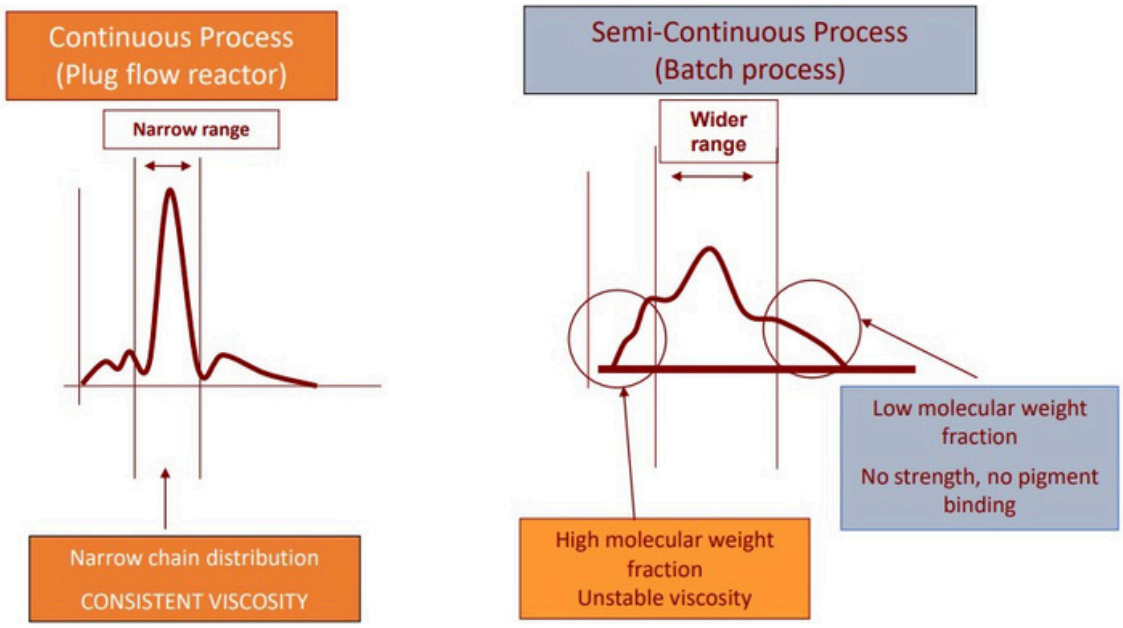
A continuous enzymatic conversion system begins with any kind of raw starch – corn, waxy maize, tapioca, potato, etc. The starch is mixed with water to form a slurry. The slurry and enzymes are added to the process and sent through flowmeters to ensure the mix is correct. An activation jet initiates the heating process, and the mixture travels through the plug flow reactor, where it gets thicker before eventually thinning out. It continues through a deactivation process, which ensures low sugar levels of <0.1%, before dilution water is added. From there, it is sent through another run tank to be fed into a paper machine.

A continuous enzymatic conversion process can be considered complete when the enzymes are fully inactivated after the enzyme reaction has taken place. Complete inactivation is very important to avoid viscosity breakdown in the storage tank.

During the enzyme reaction, the α-amylase enzymes cut the starch molecules evenly, which reduces viscosity
fluctuations and maximize paper quality.

Narrow Molecular Weight Translates into Consistent Viscosity

When you get evenly cut molecules, which occurs with the continuous process using a plug flow reactor, you will attain a narrow molecular weight distribution – and a highly consistent viscosity. With a high or low molecular weight fraction, which occurs in a semi-continuous batch process due to uneven mixing, you can get unstable viscosity, less strength, or less pigment binding that is required to hold the paper's color.



The continuous process produces an extremely tight molecular weight distribution, which allows the system to maintain a highly consistent viscosity and ensures a high-quality product and improved control at the press operation within the paper machine. As a continuous process, only the starch that is needed is converted. In the event of an unplanned system shutdown, the system will flush automatically, and only the starch slurry mix that was in the reactor is lost. Upon system re-start, you can produce more converted starch in 10 minutes or less.

ProFlow's Continuous Enzymatic Starch Converter

ProFlow, in partnership with Henan Process Systems BV, makes it possible for pulp and paper mills to safely and effectively bring the starch converting process in-house through the continuous enzymatic starch converter. ProFlow's continuous enzymatic starch converter can handle between 500-5000 pounds of starch per hour, with a 99.9% conversion yield, keeping glucose at negligible levels. The system responds to variation in machine demand within 10 minutes and can handle different recipes for different grades of paper. The system has a small footprint and can be engineered in a horizontal or vertical design to fit the requirements of the paper mill.

Financial Justification

A fully automated ProFlow continuous enzyme conversion system installed at the paper mill can pay for itself in as little as one year through:

- Eliminating the need for expensive, factory-processed starch. It uses any type of starch including corn, potato, tapioca, etc.
- Minimizing variability in converted starch quality
- Reducing the hassle surrounding batch processing, such as maintenance of rotating equipment, space limitations for large tanks, and storage tank cleanliness
- Securing stable size press operation

Table 1: Example of operating cost savings of installing a continuous enzyme converter instead of purchasing treated starch

REPLACE DERIVATIVES			Cost in US$	
	MT	price/Mt	Existing	New
Derivative	1.500	600	900.000	
Native starch	1.500	380		570.000
Enzymes	1,5	3.000		4.500
TOTAL cost			900.000	574.500
Annual saving				325.500
Investment				*300.000*
* including installation cost (standard machine)				

The price of derivative (treated) starch can fluctuate based on current market conditions at any given time. However, it is always significantly more expensive than raw starch – in the range of over $300,000 annually for some mills. Depending on options selected, a ProFlow/Henan continuous enzyme converter can deliver a return on investment within one year.

Table 2: Example of operating cost savings of replacing a semi-continuous batch process system with a ProFlow continuous enzyme converter

REPLACE CHEMICAL CONVERSION			Cost in US$	
	MT	price/Mt	Existing	New
Native starch	6.500	380	2.470.000	2.223.000
Steam		20	146.250	117.000
Chemicals	98	350	34.125	
Enzymes	6,5	3.000		19.500
TOTAL cost			2.650.375	2.359.500
Annual saving				290.875
Investment				*300.000*
* including installation cost (standard machine)				

A ProFlow continuous enzymatic starch converter operates more efficiently than a semi-continuous batch system. Because the ProFlow continuous enzyme starch converter is a truly continuous process, rather than a batch process, you get higher yields with less starch loss and more consistent viscosities. When problems arise in the semi-continuous batch process, the entire batch needs to be discarded. Semi-continuous batch processes also experience more quality issues, such as a lack of strength and no pigment binding, than the ProFlow continuous enzymatic conversion system, as the converted starch produced by a semi-continuous batch process has a higher likelihood of being lower in quality due to uneven mixing, uneven starch conversion, and wider molecular weight distribution.

Conclusion

Despite being challenged by the trend of digital output replacing printed materials, the pulp and paper industry continues to thrive, albeit in different ways than it has in the past. The pulp and paper industry – known for its staunch resistance to change – is finding it necessary to innovate to meet the changing demands of their customers. One of the ways this is happening is using new technologies to optimize productivity and contain operating costs. ProFlow's continuous enzymatic starch conversion system is one example of the technologies that pulp, and paper mills are using to manage their bottom-line and improve profitability. Just taking on the process of converting pearl starch in-house delivers cost savings, but doing so using a continuous process ensures minimal waste, lower utility costs, and high-quality end-products. The continuous enzymatic starch converter is easy to use and can stand alone or communicate with a DCS or PLC. The continuous enzymatic starch converter system is installed in mills all over the world and demonstrates high reliability and very low unplanned downtime. Whether a mill is using ProFlow's continuous enzymatic starch converter to move away from buying high-priced treated starch, or if they are replacing a less efficient, less reliable batch enzymatic starch conversion system, the ProFlow's continuous enzymatic starch converter demonstrates a return on investment in as little as one year

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ABOUT PROFLOW

ProFlow specializes in fluid handling systems and solutions serving critical applications in a variety of industries, including pulp and paper, chemical, bio-pharmaceuticals, personal care, and other industrial markets.

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Inquiry Number: _____
Date Entered: _____
Source: _____

INQUIRY – COOKING SKID

303 State Street
North Haven. CT 06473
Tel: (203) 230-4700,
email: sales@proflow-inc.com

Completed By: _____ **For:** _____
Of: _____ **Contact Name:** _____
_____ **Address:** _____
_____ _____
_____ **Tel:** _____ **Fax:** _____

Application: _____
_____
_____

DEFINITION OF PROJECT APPLICATION

☐ **Pulp & Paper** ☐ **Food Processing** ☐ **Textiles** ☐ **Fuel Ethanol** ☐ **Other** _____
_____
_____

ADHESIVE OR STARCH COOKING

☐ Modified Starch for: Wet End ☐ Surface Size ☐ Coating Binder ☐ Calendar Size ☐
☐ Pearl Starch Daily Bone Dry Consumption Rate _____ in ☐ lbs. ☐ kgs.
☐ Other Cooking: _____
_____

Specify your objective: _____
_____
_____

PRODUCTIVITY DESIRED:

Flow Rate: _____ gpm/lpm at _____% Solids at a skid duty cycle of _____ hrs/day.

UTILITIES AVAILABLE:

Water Supply at _____ gpm/lpm at _____ psig; Temperature: _____ °F (min); _____ °F (max)
Steam Supply _____ lbs./hr. at _____ psig ☐ Saturated; ☐ Superheated
Power Supply: _____ VAC; _____ Hz; _____ Phase.

OPERATION REQUIRED:

Manual: ☐ Yes Batch: ☐ Yes_____ gals. Continuous: ☐ Yes Batch/Continuous ☐ Yes
Automatic: ☐ Yes PLC Ref: _____ Remote DCS: _____ ☐ Yes

OTHER DETAILS: Available tanks and mixers, pre-supplied starch, etc.
Attach a sketch or drawing if available _____
_____