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Abstract: **Value Added Pulping**

Pulp for paper furnish has been the dominant product in the Kraft pulp mills. The remaining 50-60% of the wood is burned for energy and chemical recovery. Sulfite pulp mill provides better platform for a forest based biorefinery. New sulfite based biorefinery concept is presented, integrating well proven commercial technologies. Ethanol is significant co-product increasing the revenues by 50% at low additional energy input.

American Value Added Pulping (AVAP™) utilizes alcohol sulfite cooking liquor to fractionate softwood chips into three lignocellulosic components. An addition of alcohol speeds the pulping, while preserving the cellulose strength. Volatile cooking chemicals are stripped and reused in the cooking process at a high recovery rate. Lignosulfonates are precipitated and burned to produce process energy. The remaining liquid fraction contains hydrolyzed hemicelluloses. This sugar rich solution is fermented to yield annually up to 22.6 million gallons of bioethanol. The value of converted hemicelluloses is 4-5 times greater for society as ethanol than as presently burned. Biomass from the surrounding wood processing plants as well as logging residues can provide energy self-sufficiency for the mill.

Process integration and efficient recovery of chemicals are the cornerstones for the low overall cost. Because ethanol processing occurs concurrently with pulping, the heat and chemical input are split between the two products, without sacrificing the yield on either product. Flexibility to swing yield between the two products provides financial stability over the market conditions. Additional biofuels and chemical are obtainable from the if the economics are favorable.

AVAP™ process design is presented in the context of converting an existing uneconomic pulp mill to a biorefinery. This presents a large commercial potential with ageing pulp mills that will have to replace a $100+ million recovery boiler in the near future.

Introduction

Since alkaline Kraft process displaced Acidic sulfite process as a dominant pulping method in the 1950's, the pulping industry focused in the economies-of-scale production of paper making furnish. The quest for ever lower cost has driven new production facilities from mature markets in North America and Europe to the Southern hemisphere. The aging pulp facilities are approaching the end of their practical life. Capital intensive upgrades would probably not provide sufficient competitiveness against low raw material and labor costs in the new mills. The slowing demand of paper and increased recycling of paper has led to overcapacity. Several pulp mills have been idled or have bankrupted in North America in this decade. These mills will be salvaged soon by the scrap dealers, leading to permanent shutdown.

The cost of demolition and environmental cleanup of a pulp mill is estimated to reach $50 million. Because the loss of direct and indirect employment is devastating in the small towns, the state governments are providing incentives to reopen these mills. Repurposing these pulp mills for biorefineries can provide employment with sustainability and profitability. This would also retain the infrastructure for large-scale biofuel production in the future.

Flexible forest-based biorefineries can provide co-production of pulp, biofuels and chemicals. Instead of tapping to waste steams, American Process has developed a process, AVAP™ (American Value Added Pulping) to integrate the production of pulp and biofuels in a simple closed process cycle. Capital intensive recovery boilers and caustizising cycles are replaced with a lignin gasifier and an ethanol plant. The resulting plant provides its own energy, while harnessing hemicelluloses for ethanol production. The process can be converted to break even the cellulose into ethanol, should the value of ethanol and pulp reverse

Technology

The AVAP™ technology produces pulp in the alcohol sulfite environment. Bleached chemical pulp is produced for the paper furnish. The spent liquor containing cooking alcohol, dissolved lignin and sugars is subjected to further hydrolysis to dissolve hemicelluloses into their monomers. Thereafter, sugars are fermentable without enzymatic hydrolysis.

Cooking alcohol is recycled by using the low energy ethanol separation stripper (LEESS™) process. The LEESS™ system includes a fully integrated evaporator and stripper using vapor recompression to achieve alcohol recovery without the use of steam energy.

Lignin is removed from the liquor in the form of lignosulfonate. This lignin can be gasified into synthesis gas to provide energy back to the process. By increasing the efficiency of the pulp and papermaking process, and harvesting all the residues from the wood (traditionally left in the forest), the syngas could provide a precursor to various chemicals, including ethanol. Presently, after wood pulping, the hemicelluloses and lignin are burned in the Kraft pulping process to recover heat and inorganic cooking chemicals.

Sugars are fermented in a two-stage fermentation process to produce ethanol from hexoses and pentoses. The whole bottom of the distillation column is treated and used in the pulp washing to close the liquor loop. At present, the fuel ethanol price is up to $2.50/gallon or $32.64/MMBtu, which is much higher than the value of hemicelluloses burned to replace wood fuel ($30/dry ton). If ethanol is produced at 50% yield, the value of sugars would be $7.14/MMBtu as steam energy.

Environmental benefits
Pulp and Paper manufacturing is large energy consumer. Biomass provides a large portion of energy for the papermaking process, from "carbon neutral" renewable sources. In fact, the industry has large potential to reduce greenhouse gas emissions through better use of biomass. The AVAP™ process provides value added transportation fuels from the "carbon neutral" source. This enables energy utilization of wood waste currently left to decompose in the woods. Fossil fuel energy inputs for production and delivery of cellulosic energy crops are modest if combined with pulpwood harvesting.

Process Design
Commercial Pulp and Paper process simulation software, apiMAX™, was used for the biorefinery process design.

The unit operations design was based on the results from laboratory testing. The lab trials confirmed the direct fermentability of most hexoses present in the spent liquor. Pilot scale trials were conducted to confirm the viability of the pulping scale-up, and to produce a sufficient quantity of raw materials for further analysis.

The final design was laid out in the process flow diagrams covering the whole process, including the bleach plant and paper machine(s). The design parameters and experimental data were inserted in the simulation model. Empirical process integration was performed to improve the heat and material reuse in the mill. As a final step, Pinch analysis is being performed to minimize the thermal heat requirement.

Upfront process optimization and integration with an existing mill can yield tangible capital cost savings. Examples of such savings are:

1. Reduction of the power boiler size as steam demand decreases.
2. Avoidance of waste treatment, when reuse is feasible.
3. Reuse of chemicals in other processes i.e. CO_2 released from fermentation is used in precipitated calcium carbonate production.