All Mixed Up

Aditya Birla Science & Technology Co. Pvt. Ltd. studied and developed an improved impeller for the mixing tank used in fiber manufacturing. The proposed design provides five times better mixing for solid suspensions using 12 percent less power. Simulation helped the engineering team make design decisions that balance mixing performance and power draw.

Improved impeller design

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Viscose staple fiber (VSF) is a man-made biodegradable fiber with characteristics similar to cotton that is used to produce fabric (often called rayon) for clothing and other purposes. VSF is produced by dissolving a solid-phase wood pulp slurry in caustic soda and forcing the solution through tiny holes in a metal cap. It emerges as filaments that unite to form a continuous strand that is solidified by passage through a liquid or heated air. Mixing the pulp slurry and caustic soda solution consumes time and electrical power, so manufacturers of this fiber can save costs and production time with more efficient mixing. Aditya Birla Group is the world's largest producer of VSF. The engineering team at Aditya Birla Science & Technology Co. Pvt. Ltd. used computational fluid dynamics (CFD) to study and develop an impeller that would increase mixing efficiency and reduce power consumption.

SIMULATION OF VSF PRODUCTION PROCESS

With revenues of about $41 billion in 2014, Aditya Birla Group is also the world's largest producer of carbon black (in addition to VSF) and a leader in aluminum and copper production, branded clothing, mobile communication, life insurance and grocery stores. The group's research arm, Aditya Birla Science & Technology

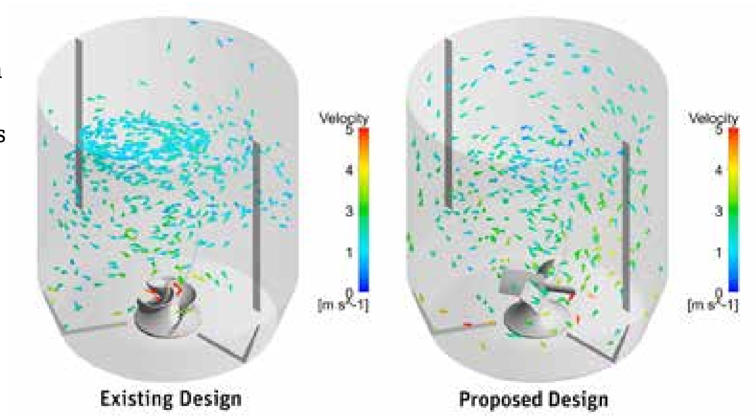
“Aditya Birla Group used CFD to study and develop an impeller that increased mixing efficiency by a factor of more than five and reduced power consumption by 7 kW.”

Co. Pvt. Ltd., works with the various business units to improve process performance.

The first step in VSF production is mixing of caustic soda and wood pulp, generally in a three-to-one ratio, in a mixing tank. The mixing tank is cylindrical with a height-to-diameter ratio of approximately 1. A pyramid-shaped impeller is located at the bottom of the tank.

The team began by performing steady-state multiphase simulation of the existing mixer configuration with ANSYS CFX CFD software. The tank was divided into about 1.7 million unstructured tetrahedral elements. A fine mesh was generated near the impeller and a coarse mesh was used in the rest of the tank. The team employed the frozen rotor mixing model to accommodate impeller motion, and utilized the Euler–Euler inhomogeneous multiphase model to simulate the multiphase liquid–solid mixing nature of the system. The standard k-ε turbulence model accounted for the turbulent nature of the mixing process. The reactions taking place inside the tank were not modeled.

For the simulation, engineers assumed that the tank was initially filled with a solid slurry and liquid solution with a 0.42 density ratio. Because the liquid solution is the heavier component, it occupies the bottom of the tank at the beginning of the simulation. The mixing value was defined as the percentage of tank volume having a liquid volume fraction of 0.65 to 0.85. Engineers integrated pressure on impeller blades as determined by CFD calculation to obtain the torque, which in turn was used to calculate power consumption.



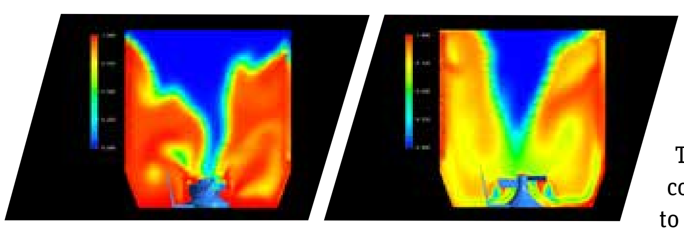
^ Mixing was improved with a reduction in power consumption.

SIMULATION OF EXISTING MIXER

Case I used the existing pyramid-shaped impeller rotating at 500 rpm with a diameter-to-tank-diameter (D/T) ratio of 0.258 and a centerline-to-tank-height (C/T) ratio of 0.17. C/T is significant because the liquid level in the tank must be kept above the impeller level to avoid splashing of solid slurry against the tank walls. Any increase in impeller height reduces the amount of slurry that can be drained from each batch. The normalized velocity vector plot shows that this impeller creates a good deal of circulation in the bottom of the tank, but there is very little suction in the top half of the tank. The simulation generated a liquid volume fraction profile showing a mixing value of only 11.26 percent, and predicted 60 kilowatts (kW) of power consumption.

ITERATING TO AN IMPROVED DESIGN

The team further evaluated other possible impeller designs in an effort to improve the mixing operation performance. To iterate to an optimal mixer design, they needed to trade mixing performance for power consumption. The final design, Case VI, used a curved-blade impeller placed near the bottom of the tank while reducing the rotational speed from 500 rpm (Case 1) to 350 rpm. The mixing value for this configuration was increased to 63 percent, which is 5.6 times better than Case I, while the power consumption decreased to 52.6 kW, even better than Case I. The impeller modeled in Case VI was found to



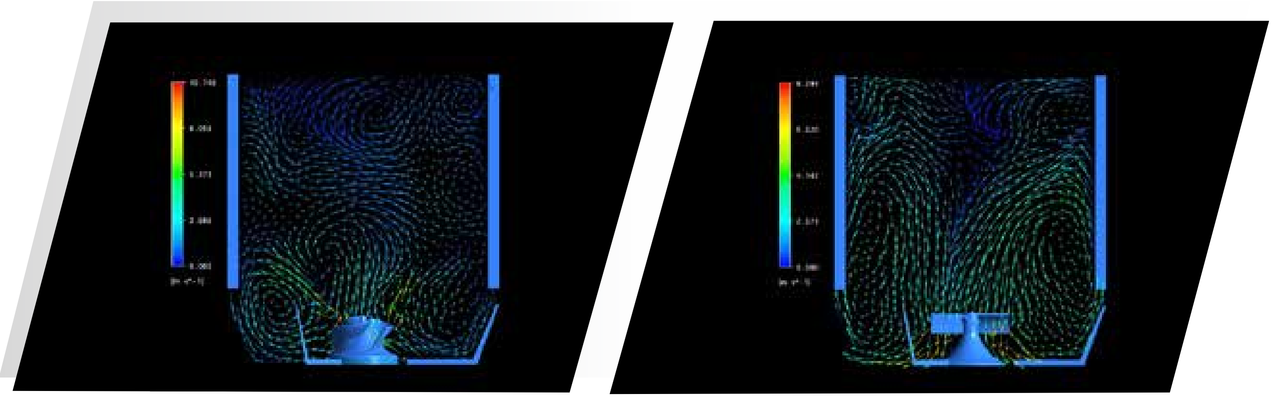
^ Liquid volume fraction profile throughout tank for initial (left) and final design (right). In the initial design, the top zone is rich in particles; there is poor mixing of the particles with the liquid and insufficient suction from the impeller to pull particles to the bottom. The improvement for the entire domain is greater than is shown in this single 2-D plane.

	Case I (initial configuration)	Case II	Case III	Case IV	Case V	Case VI (final)
Changes Made	Pyramid-shaped impeller	Pyramid-shaped impeller. Pitched-blade down-flow turbine.	Curved-blade down-flow turbine. Higher blade angle.	Curved-blade impeller along with cone.	Curved-blade impeller placed closer to bottom of tank.	Curved-blade impeller with smooth cone profile for better mixing. Reduced dead zones.
Effect of Change Over Previous Case		More suction in the top half of the tank. Better circulation near the tank bottom.	Stronger suction and even larger recirculation loops. High power consumption.	High power consumption.	Amount of slurry that can be drained from every batch equal to Case I. Improved flow profile and reduced dead zones. High power consumption.	Better mixing than Case 1. Reduced power consumption over Case 1.
Mixing Value (%)	11.26	30.71	77.6	68.28	67.1	63.0
Power Consumption (kW)	60	74.3	118.5	150	157	52.6

be the most efficient design that provides maximum benefits in terms of mixing efficiency and power consumption.

The changed design is expected to reduce batch time, improve throughput and reduce process costs. When compared to previous impeller design, the proposed design has better suction, good mixing value, a reduced amount of unmixed solids and lower power consumption. This is just one of studies conducted in the past decade in which simulation has helped Aditya Birla Group to identify and improve productivity and reduce costs across its manufacturing businesses.

Mixing
ansys.com/mixing



Velocity vectors for initial (left) and final design showing improved mixing performance. In the improved design, the curved cone and the impeller rotate as a single body, achieving better mixing. The proposed impeller generates stronger downflow than the existing design.