Computer Simulation Helps Triple Engineers' Efficiency While Improving Quality of Nonwoven Fabrics

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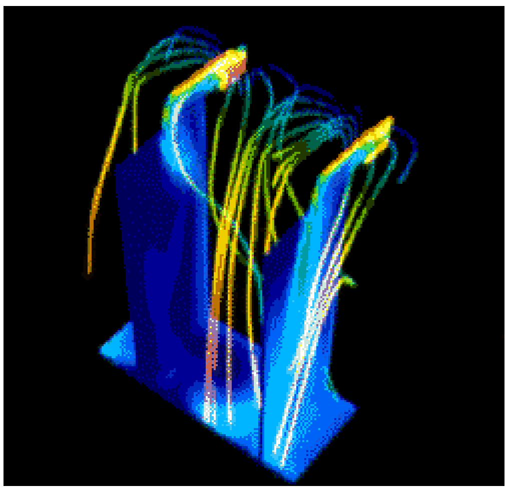

The CFD package in action

Computer simulation of fluid flow made it possible to triple equipment design engineers' efficiency while improving the quality of nonwoven fabrics. DuPont SONTARA(R) spunlace fabrics are produced by a process called hydroentangling that uses high pressure water flows to knot staple fibers. Computational fluid dynamics (CFD) was used to optimize the design of nozzles that supply air for the fiber laydown process, making it possible to increase line speed. Air flows generated by the new nozzle are also less turbulent, which reduces web imperfections.

The technology of DuPont SONTARA is one of three that make up the DuPont Nonwovens business, which generated some $800 million in worldwide revenues for 1995. DuPont is the largest producer of spunlace fabrics in the world, with medical products and absorbents accounting for most uses. Garments of DuPont spunlace fabric have protected doctors and nurses in more than 100 million surgical procedures worldwide. Absorbents, such as industrial and consumer wipes, and newly introduced baby wipes, are the fastest growing category. Other applications include home furnishings, such as mattress pads and window shades, coating substrates for imitation leather and wind barrier fabric for ski gloves and outdoor apparel.

The hydroentangling process begins with using air to lay down short cut length fibers into a random web. Many different fibers including cellulose, cotton, rayon, Kevlarr, Nomexr, and polyester can be used in this process, making it possible to produce products that provide a wide range of properties suitable for nearly any application. This web is conveyed to the hydroentangling portion of the line where hundreds of tiny water jets impact the fibers, knotting them together to provide strength. Hydroentangling eliminates the need for any type of bonding material, making the resulting fabrics very environmentally friendly. Finally, the material is dried and wound onto rolls.

This process relies heavily on aerodynamic and high pressure water flows to achieve both productivity and quality. The airlay nozzle used in the fiber laydown phase of the process is a particularly critical element.

This nozzle is designed to accelerate air to the highest possible velocity without inducing turbulence. Avoiding turbulence is important because the quality of the air coming out of the nozzle has a direct impact on the uniformity of the fabric that is produced. Any imperfection in the airflow will show up in the finished product.

The airlay nozzle's key geometrical feature is a chamber whose cross-sectional area shrinks dramatically from the inlet to the outlet. The reduction in the cross-section achieves the basic goal of the nozzle which is accelerating the air velocity. The hard part is achieving high air velocity while minimizing turbulence. In the early 1970s, DuPont engineers, working with leading fluid flow consultants, developed the airlay nozzle design that served as the industry standard for over 20 years. This design was developed by building a number of prototypes and testing the performance of each one.

A few years ago, DuPont engineers reviewed recent advances in computer simulation and decided that the opportunity existed to improve on that design. They were thinking, in particular, of the emerging technology of CFD which simulates the distribution of fluid flows using a computer. CFD involves the solution of the governing equations for fluid flow, heat transfer and chemistry at many thousands of discrete points on a computational grid in the flow domain. A CFD analysis yields values for fluid velocity, fluid temperature and species concentration throughout the solution domain. CFD also makes it possible to perform detailed parametric studies that allow engineers to optimize a product or process to a far higher level than can usually be achieved by the old build and test approach.

DuPont engineers tested several different leading CFD software packages and compared the results to physical tests. They selected FLUENT CFD software from Fluent, Inc., Lebanon, New Hampshire, because they found that FLUENT results matched experimental values better than the other codes. They also found FLUENT to be ideally suited to parametric studies. Some other codes, for example, required that a new directory structure had to be created for each analytical iteration. With FLUENT, a single directory can be used for as many iterations as desired. Finally, FLUENT was the only code of those examined that offered the ability to simulate curved moving walls, needed to model rolls used in several phases of the hydroentangling process, without the need to write FORTRAN subroutine.

The engineers began by modeling the existing nozzle geometry and comparing the results to physical testing that had been performed when the nozzle was originally designed. The CFD results closely matched the experimental data. This provided the engineers with confidence that CFD could be used to guide the design of a new nozzle. In a matter of a few months, the engineers had modeled a number of different alternatives. The ability to quickly evaluate new designs by viewing and comparing their performance graphically helped engineers improve their understanding of the critical factors in nozzle geometry and helped to guide the design process.

The best of the new designs provided air at a velocity greater than the existing design with turbulence at a considerably lower level. Engineers ordered a full-scale nozzle built and installed on one of the existing hydroentangling lines. The new nozzle worked exactly as predicted by the CFD analysis. Engineers found that the increased air speeds and reduced turbulence of airflow in the new design improved product uniformity. Eliminating the need to build and test prototypes made it possible to develop the new nozzle in a tiny fraction of the time and expense required for development of the earlier nozzle design. This resulted in a reduction of design cycle time by two-thirds.

Based on the success of this project, CFD was used to optimize several other phases of the hydroentangling process. It was used to make incremental improvements in the water nozzles used in hydroentangling itself and also in the drying equipment. These improvements, like the new airlay nozzle, were completed without the need for building expensive prototypes.

Using the experience gained from these improvements, DuPont engineers have recently used CFD to re-engineer the web-forming portion of the hydroentangling process to develop state-of-the-art technology that will be installed in a new $75 million plant that is being built in Oviedo, Spain. This new process will be capable of running a wider range of commodity and specialty fibers at more than twice the production rate of any commercial spunlace facility, worldwide. All in all, CFD has provided DuPont with a major competitive advantage by helping engineers optimize fluid flow throughout the hydroentangling process.