The Dyson Air Multiplier fan has no need for visible fan blades.

Bladeless is More

Fluid flow simulation advances acclaimed new fan design.

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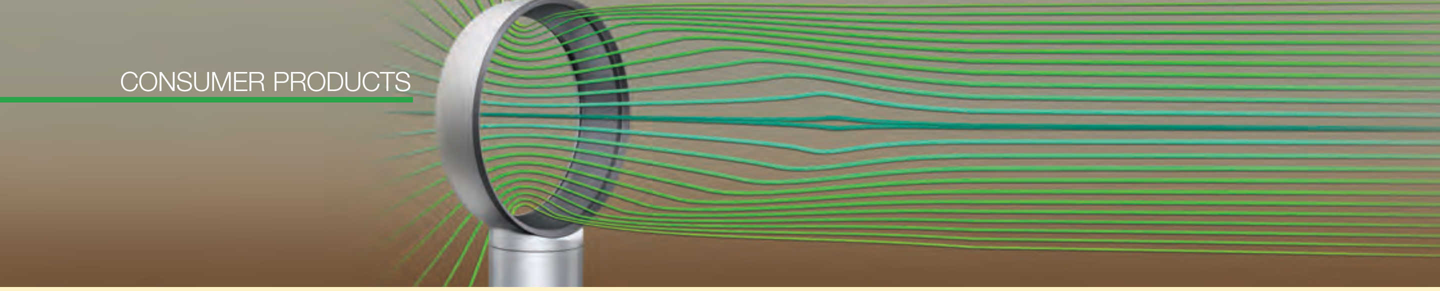
Released to wide international recognition in 2009 — including being named to *Time* magazine's list of best gadgets — the Dyson Air Multiplier™ fan is a both technical and stylistic re-imagining of the household fan. By accelerating air over a ramp, the design eliminates fan blades as well as the buffeting and turbulence associated with these household appliances. From the outset, however, Dyson engineers faced the challenge of developing and optimizing the design of an original new fan without the benefit of previous experience with this type of design. Historically, the company relied on physical prototyping for design development, but resulting cost and time constraints limit the ability to evaluate hundreds of design candidates needed to optimize a new product. To complement experimental testing and reduce development time for this new fan, Dyson's engineers used fluid dynamics software from ANSYS to evaluate up to 10 different designs per day.

The idea for the Dyson Air Multiplier fan originated when the engineering team was testing the Dyson Airblade™ hand dryer. This drying device works by generating a thin sheet of air moving at 400 mph that pushes water off the user's hands. Observing the side effect that the sheet of air was dragging a considerable portion of the surrounding air with it, the team conceived a new idea: to produce a thin, high-speed sheet of air



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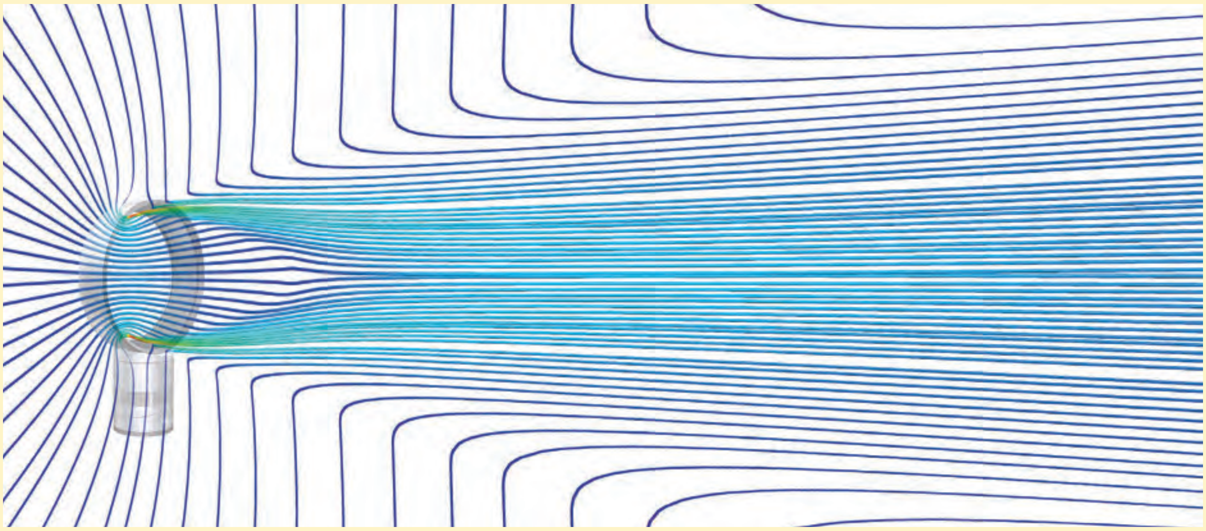
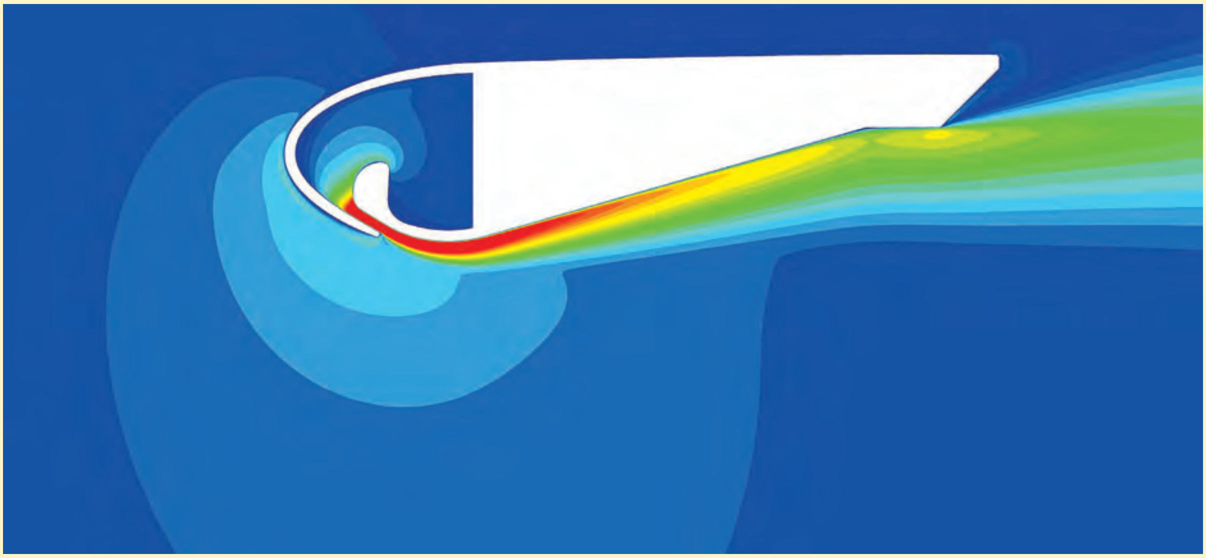
that drags surrounding air — a process known as inducement — through a fan. Airflow leaving the product then drags along more flow — a process known as entrainment — and the Dyson Air Multiplier fan was the result. This unique approach eliminated the need for the external blades of a conventional fan and provided a much smoother movement of air that feels like a natural breeze.

For the new, bladeless fan, Dyson engineers developed a basic design concept in which air is drawn into the base of the unit by an impeller, accelerated through an annular aperture and then passed over an airfoil-shaped ramp that channels its direction. The initial design had an amplification ratio — how much air is dragged along for each unit of primary flow — of six to one, which needed to be improved substantially for the finished product. The conventional approach to evaluating designs was to use rapid physical prototyping for the annular ring. However, with each ring taking several days to build, combined with additional time for measurement and hand finishing and, finally, several days to assemble and test the ring, a total of two weeks would have been required to evaluate each prospective design.

Dyson faced similar fluid flow design challenges in previous development projects, especially with its lines of vacuum cleaners and hand dryers. As before, the company's engineers overcame such problems by using ANSYS FLUENT software to simulate fluid flow without the need for a physical prototype. Being able to visualize fluid flow throughout the solution domain helped engineers to gain an intuitive understanding of the design, leading to rapid improvements. The software's ability to divide the domain into subdomains substantially speeded up the process of making design changes. For example, the subdomains in and around the annular ring contained a very dense mesh to maximize accuracy in this critical area. After making a change, the team had to remesh only the subdomain that contained the change, and thus the time for remeshing was reduced from over an hour to about 10 minutes.



Air is initially drawn in through the base of the fan and is injected through the annular slot, inducing more flow from the surrounding air.



Cross section of the Dyson Air Multiplier fan's ring design showing contours of velocity magnitude. Slower-moving air (dark blue and light blue contours) inside the ring is accelerated by passing over a ramp and out through a narrow opening (green, yellow and red contours).

Dyson engineers first modeled the initial prototype with the goal of validating the accuracy of the fluid flow model. Each case was simulated as a 2-D, steady-state, incompressible, turbulent air flow using the k-epsilon turbulence model. The attractiveness of the 2-D method was the meshing simplicity and relatively short solution time, but the downside was a more simplistic flow field. However, the software from ANSYS was extremely consistent in predicting performance trends that were observed, which gave the engineering team confidence in the simulation results.

The next step was to evaluate a series of design iterations with the primary goal of increasing the amplification ratio to move the maximum amount of air possible for a given size and power consumption. Dyson's engineers quickly homed in on three dimensions as having major impact on performance: the gap in the annular ring, the internal profile of the ring and the profile of the external ramp. The team was able to design and model up to 10 geometric variations of these dimensions in a single day and then to compute the results in a batch overnight. Another major benefit of using fluid dynamics simulation was that the engineers were able to establish relationships between air velocity and delivered flow rate for various designs — a key performance metric.

Over the course of the design process, Dyson's engineers steadily improved the performance of the fan to the point that the final design has an amplification ratio of 15 to one, a 2.5-fold improvement over the six-to-one ratio of the original concept design. The team investigated 200 different design iterations using simulation, which was 10 times the number that would have been possible had physical prototyping been the primary design tool. Physical testing was used to validate the final design, and the results correlated well with the simulation analysis.

With critical acclaim from many reviewers, the Dyson Air Multiplier fan has been a resounding success in the marketplace. By optimizing the design's performance and reducing the number of prototypes, simulation software from ANSYS made a notable contribution to that success.

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