Concepts NREC
EXPERTS IN TURBOMACHINERY

Dyson
CASE STUDY

Concepts NREC Software Blows Holes in Conventional Fan Design

CLIENT TESTIMONIAL: DYSON (April 2011)

You know the feeling when an everyday product lets you down? "I could have designed this better myself," you think. But how many of us turn our thoughts into actions? James Dyson does. He is a man who likes to make things work better, and with his research team, he has developed products that have achieved sales worth over $6 billion in more than 45 countries.

Figure 1: (left to right) Dyson Air Multiplier™ fan range, AM01 Desk Fan, AM02 Tower Fan, AM03 Pedestal Fan

New ideas are the lifeblood of Dyson. Every year, the company reinvests a large amount of its profits into new idea generation at Dyson's impressive Research, Design and Development (RDD) Centre in Wiltshire, England. Located on the edge of Malmesbury, a historic market town some 12 miles west of Swindon, the RDD Centre is home to about 350 engineers, all thinking, testing, breaking, and questioning.

The upshot is a series of everyday products that have been redesigned from the ground up to offer improved performance: the bagless vacuum cleaner, hand dryers using Airblade™ technology, and now, the company's latest creation, the bladeless fan.

If a bladeless fan sounds counter-intuitive, it is. But that's Dyson. This is no ordinary engineering company, but rather one that offers a proactive attitude to design, thinking outside conventional frameworks, and demonstrating a willingness to invest in the latest technologies that can help the company reach its goals in the most effective and efficient manner without any compromise to design creativity. And this is why Dyson is a flagship user of turbomachinery design and development software from Concepts NREC.

Air Multiplier™ Technology

Electric fans haven't really changed since they were invented in 1882. Different materials, new buttons, and the addition of grilles, but still the same problem – the blades chop the air be-fore it hits you. That's why they cause unpleasant buffeting. Take the blades out, and the buffeting stops. But how can a fan work without blades?

Dyson engineers started with pressurised air, forcing it through narrow apertures to create jets. But they needed it to be more powerful to work in a fan. The breakthrough came when they noticed that accelerating air over a ramp amplified it by up to 20 times, drawing in surrounding air through processes known as inducement and entrainment.

That was the concept; now for the design. Today's design process has to be far more efficient than that of yesteryear's. When a young James Dyson became frustrated with his rapidly clogging conventional vacuum cleaner in 1979, he resolved to come up with a better design. However, it took him five years and 5,127 prototypes to perfect his bagless vacuum cleaner technology!

Today, things are different. Time-to-market is vital, and the period from concept to prototype is being squeezed continuously. The trick, of course, is not to hamper creative flair in the process. After all, it's difficult to rush the best ideas.

One of the major challenges with the Dyson Air Multiplier™ bladeless fan was the problem of air intake. The motor had to suck in more than 20 litres of air per second to generate a powerful enough jet. It became clear that a 3D impeller was required, in effect to provide the 'engine' for AM01.

Having enjoyed considerable success using turbomachinery design and development software from Concepts NREC on projects such as a new turbine head to drive the brushes on a small, cylindrical vacuum cleaner for the Japanese market, and the DDM (Dyson Digital Motor) V2 for Dyson's range of hand-held vacuum cleaners, there was no doubting the optimum solution for the 3D impeller.

Software Solution

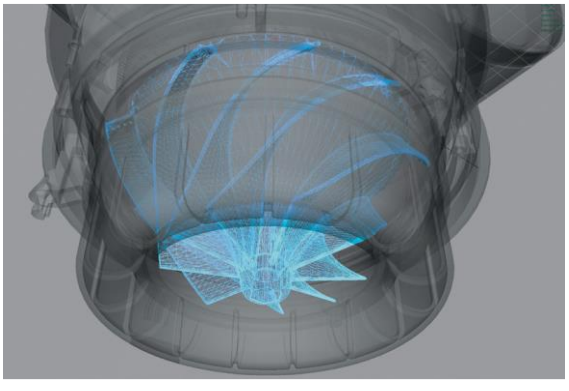
Developed at Concepts NREC, the Agile Engineering Design System® is the only commercially available turbomachinery design system that encompasses and integrates the complete engineering process

through a complementary suite of tools and programs for computer-aided engineering (CAE) and computer-aided manufacturing (CAM).

Integrated elements of the system include preliminary design and detailed design, plus sophisticated analyses such as rapid CFD and FEA. The system also offers best-in-class, specialist five-axis machining software, automated optimisation, and a smooth transfer of data to CAD packages.

Although AM01 was released to the retail market in 2009, design work on the 3D impeller began three years prior, under the tutelage of RDD Manager, Frederic Nicolas. "The challenge was to minimise acoustic emissions and make the quietest fan ever," he explains, "which is why the rotational speeds are low, not high."

So how is a quiet fan achieved? Well, there are two primary considerations: speed and flow rate. The speed is determined by the specification of the motor, but flow rate results from a combination of engineered products.



Impeller integrated in the motor bucket.

"We had to consider carefully the pressure required to overcome the resistance of the main aperture, and then choose the most suitable impeller technology," adds Senior RDD Engineer, Michal Nurzynski. "There are basically three types of impellers: radial (centrifugal), axial, and mixed-flow. However, using Concepts NREC's FANPAL™ application, it was clear that a mixed-flow solution would give us the best performance."

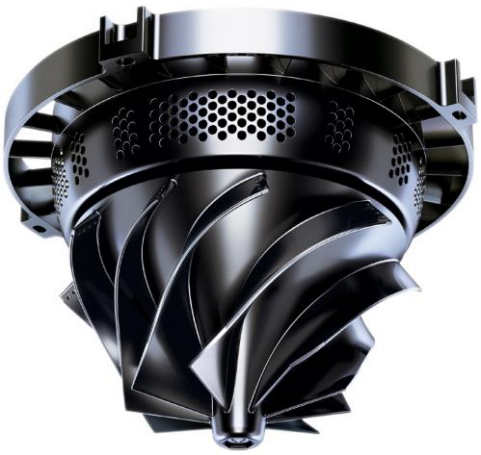
Design Wizard

FANPAL preliminary design CAE software uses a meanline approach to design axial, radial, and mixed-flow fans, both for single and for multiple stages. Users deploy a unique Design Wizard to design the stage, analyse the performance, refine parameters with data reduction, and simulate the machine according to several performance models.

Various fundamental fluid dynamic aspects of fan performance can be modelled using FANPAL, such as disk friction, exit mixing, stator diffusion/losses, volutes, stall and thrust. FANPAL also offers direct integration with Concepts NREC's AxCent® CAE software for detailed blade design and fluid dynamic analysis.

"We used AxCent extensively to undertake iteration after iteration, detailing small changes in blade length and shape before running the software's real-time interactive flow analysis through streamline curvature to assess performance," says Mr. Nurzynski.

AxCent has been developed to handle even the most complex blade geometry. Its many design features include: blade stacking of 2D cross sections; blade restaggering around an arbitrary axis; bowed blades defined by hub-to-shroud bow profiles; bowed or sculpted elements with an arbitrary number of mid-span sections; variable tip clearance on either end of the blade; flow cuts and radial trims; swept leading/trailing edges; multiple, offset, and independent splitter blades; and irregular blade/splitter configurations for noise reduction.



AM01 Partial view of the master bucket showing unshrouded impeller, vaneless diffuser, and vaned diffuser.

"Using AxCent, we spotted that the acoustic performance of the blade was closely linked to blade shape, and we started designing to optimise flow conditions with blades unevenly spaced and blade angles developed to minimise end losses."

The end result is an impeller featuring nine asymmetrically aligned fins with rows of tiny peripheral holes to reduce the friction caused by colliding high and low air pressure (birds of prey balance air pressure around their wings in a similar way).

From Art to Part

The preferred manufacturing method for all of Dyson's plastic parts is injection molding. However, because tools for the injection molding process can take weeks to manufacture and cost thousands of pounds, a suitable rapid prototyping method had to be identified. Dyson has both laser sintering and 3D printing technologies on-site at Malmesbury, but with build times in days and hours rather than minutes, it is not practical or cost-effective to build a physical prototype for each impeller design. To optimise a new product designed for mass consumer markets, engineers require the ability to quickly evaluate hundreds of design candidates. This is where Concepts NREC's CAE software scores heavily.

Simulating air flow using AxCent without the need for a physical prototype is of huge commercial advantage to companies such as Dyson. Being able to visualise flow throughout the impeller helped the RDD team gain an intuitive understanding of the design, leading to rapid improvements. Physical prototyping was only used to validate the final design, and the results correlated well with the simulation analysis.

"We don't just accept that Concepts NREC software is the best tool for the job, it has to compete with other technologies," states Mr. Nicolas. "However, on AM01 and previous projects, we have demonstrated time and time again that we can make the first prototype on specification in terms of performance using *CN* software. The software more than passes the exam in this respect. "

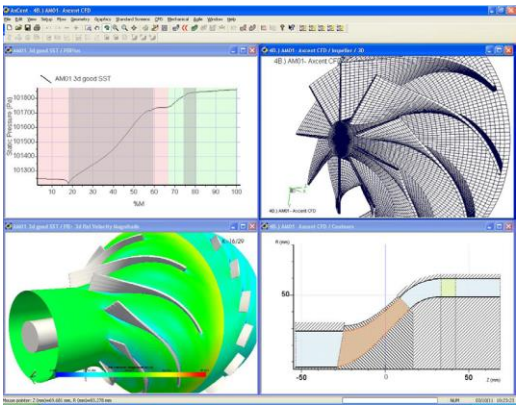
The RDD team at Dyson has in fact tried using alternative software for the same function, but found it more general purpose and less time efficient.

"Concepts NREC is front-end specific for turbomachinery design," says RDD Engineer, Lukasz Kowalczyk. "We can model impeller features and diffuser vanes all parametrically set to a design point. Because of this, changes are straightforward and efficient to implement. For instance, if we need to change flow rate or pressure, the software can output how the whole system will react to these changes – it's a very responsive software package and a perfect niche product."

In the Hot Seat

It's been six years since the first seat of Concepts NREC software was installed at Malmesbury, but its success has been such that Dyson now has three seats of FANPAL and three seats of AxCent. Demonstrating the product's ease of use, Graduate RDD Engineer, Ryan Stimpson has been using the software on and off since joining the company in October 2010.

Engineers like Ryan and technology like Concepts NREC's software represent the future of innovative companies such as Dyson, where there is little respite from new idea generation.



AM01 Impeller designed in AxCent

"Every time we release a product, we are already working on its replacement," says Mr. Nicolas. "For the Dyson Air Multiplier™ fans, the next challenge will be to reduce the acoustic output even further, to little more than a 'breathing' noise."

Whatever ultimatum is set for the Dyson Air Multiplier™ fans, one thing is certain, Concepts NREC's FANPAL and AxCent CAE software will be at the heart of Dyson's endeavor.