How Daikin Applied is achieving multimillion dollar performance gains with new HVAC Compressor Designs developed using 3D Inverse Design

Introduction

Daikin Applied of Minneapolis, Minn., delivers engineered, flexible solutions for commercial, industrial and institutional heating, ventilation and air conditioning (HVAC) requirements. As part of Daikin Industries, a Fortune 1000 company, Daikin Applied is the largest air conditioning, heating, ventilating and refrigeration company in the world.

As any building operations manager knows, the HVAC system represents a large percentage of a building's energy use. Since the 1980s, manufacturers of HVAC equipment like Daikin Applied have worked to make their systems more efficient. This was originally driven by rising energy costs and therefore customer demand. More recently, it was mandated by governmental standards like those set by the U.S. Environmental Protection Agency Engine Testing Regulations and Europe's Ecodesign Directive.

There are several methods for making HVAC systems that meet or exceed new standards, including making individual components such as air conditioning system compressors more efficient. Recently Daikin Applied achieved more than a two-point compressor efficiency improvement within eight weeks by redesigning a compressor unit using a commercially available 3D inverse software system called the TURBOdesign Suite by Advanced Design Technology of London, England.

Image 1. Geometry of the Baseline (Conventional) impeller

Image 2. Secondary flows on the suction surface of the original impeller

Challenge

Daikin Applied needed to redesign an HVAC compressor to achieve at least a 2 point efficiency gain while keeping most of the dimensional constraints similar.

To achieve this new level of efficiency, a new approach was required. Conventional design starts from an assumed blade shape whose performance is evaluated by computational fluid dynamics (CFD) codes. However, since the flow field is highly complex and three dimensional, and there is no direct relationship between the blade geometry and flow field, the design process has to rely on the experience of designers gained through many years of trial and error. Generally speaking, experienced designers can achieve good designs by following closely what has worked in the past. However, such an approach can, inadvertently, result in a reduction of the design space as the designer tends to operate within his comfort zone. Hence, using this approach makes it more difficult to achieve breakthrough designs, and this is one of the main causes of increasing difficulty in achieving further performance improvements.

In the 3D inverse design approach enabled by the TURBOdesign Suite, the blade geometry is computed for a given pressure or loading distribution. It is a well known fact that the 3D pressure distribution controls the viscous behavior of the flow, and hence, by controlling the 3D pressure field, it is possible to directly use the detailed information provided by CFD solutions to arrive at a choice of optimum loading to control particular sources of performance loss in turbomachines.

Image 3. Geometry of Impeller Designed by TURBOdesign Suite

In Daikin Applied's case, the 3D inverse design approach allowed designers to directly use knowledge of detailed fluid dynamics, as provided by CFD and detailed measurements, to arrive at a breakthrough solution that met efficiency goals.

Solution

Daikin Applied remains the largest HVAC manufacturing company in the world by staying competitive. This is in part achieved via vigilant research and development, which means staying in touch with leading technology and keeping up with trends and best design practices and methods. For Guy Phuong, Development Engineer at Daikin Applied, 3D inverse design methodology seemed like a way to effectively and quickly develop viable designs. Based on his research and product demonstrations, Phuong found that turnaround times using 3D inverse design were faster than with traditional methods, especially when training a younger generation of designers. He decided it was the design practice to use.

In the past, Phuong's team used traditional approaches, such as using blade and flow angles, which required in-depth familiarity with both impeller aerodynamics and with the design software programs just to be able to even come close to viable designs. It was a slow, cumbersome practice that needed to change.

"We are always constrained by development time," said Phuong. "So, we were looking for ways to cut development time in addition to achieving the efficiency goals. The TURBOdesign Suite was the only commercially avialable 3D inverse design software. We decided to use it."

Implementing the TURBOdesign Suite did not require very much in terms of time, training or hardware. Phuong had used the software at a previous employer. According to Phuong, becoming an advanced user was easy, taking only a few days working with ADT engineers. It took just three months for Phuong to feel completely comfortable and confident with it. For others at Daikin, training took about two days, and going from beginner to immediate took about three months.

The TURBOdesign Suite software is not hardware intensive. It runs on Windows systems and operates on mid-range workstations with 2.4 Ghz or better processors, 2 GB RAM and 1Gb disk space, so it can be installed on most personal laptops. Therefore, no additional hardware was required to implement it at Daikin Applied.

The main TURBOdesign Suite feature used by Daikin Applied in developing their new HVAC compressor design was the blade loading window. Blade loading has the largest impact on the blade shape and thus blade performance, so this is what was changed the most to come up with the optimum blade design. Phuong found that it was easy to implement design changes without having to worry about blade and flow angles. The TURBOdesign Suite enables quick geometry generation and thus quick optimization as well.

Results

Daikin Applied return on investment was fast.

"We enjoyed a couple of quantifiable returns on our investment," said Phoung.

According to Phuong one return would be the dramatically reduced development time. In the past, many product launches were delayed due to tight scheduling, which had implications across all aspects of the business. Using the TURBOdesign Suite, the new compressor design was completed ahead of schedule in just five months, instead of a previous typical 12 months.

The other important return on investment was of course the performance gains. In general, one point of efficiency gain equates to about $1 million (U.S.) of profit. Daikin Applied's target performance gain for this project using the TURBOdesign Suite software was 2 points of efficiency gain.

"We are still in the process of finalizing the project and at this stage cannot share exact numbers, but are confident our target numbers will be achieved," said Phuong.

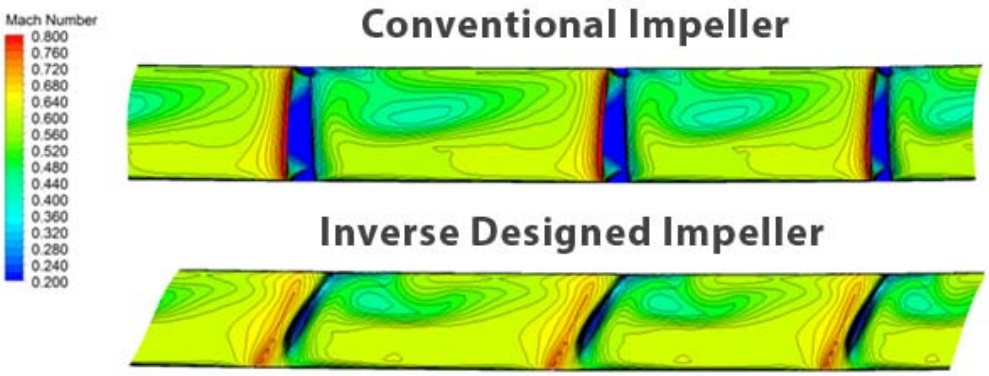

Image 4. Comparison of Exit Relative Mach Number between the Conventional impeller and the Inverse design Impeller showing reduction in exit flow non-uniformity

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