ANSYS®
CASE STUDY

Strive for Greener Environment: HVAC Manufacturer Uses CFX To Improve Energy Efficiency, Reduce Environmental Impact

THE TRANE COMPANY

EXECUTIVE SUMMARY

Challenge:
To improve energy efficiency in the design of refrigerant-cooled hermetic motors for water- and air-cooled chillers.

Solution:
Implement CFX to simulate heat transfer phenomena in high-power induction motors and refrigerant flow through the hermetic motors.

Benefits:

- Enabled engineers to explore large-scale unsteady flow phenomena to obtain the highest energy efficiency in a wide range of applications.
- Minimized environmental impact by improving reliability of the products, increasing service intervals, and reducing the need for disassembly of the units. Also eliminated possible emission of refrigerant associated with these processes.
- Using CFX to analyze the unsteady flow field inside the chiller, track down the response of the unit structure, and predict air motion around the machines, allowed engineers to deliver units with lowest noise radiation.

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Introduction

As living standards rise precision manufacturing proliferates around the world, air-conditioning equipment accounts for more and more energy consumption. Stricter environmental regulations and increasing environmental consciousness of air conditioning equipment users demand more efficient compressors with less impact on the environment.

The Trane Company, a leading worldwide supplier of indoor comfort systems, is using the latest technology —CFX software—to achieve these goals.

Trane centrifugal chillers in the chilled water plant at the University of Arizona, Tucson.

Improving energy efficiency is a key issue in the design of chillers for an air-conditioning system. Efficient chillers not only reduce the operating cost but also reduce green house gas emissions by reducing power consumption. A one-percent increase in efficiency brings substantial savings over the life of a medium size chiller.

The social and environmental benefits are even greater. Trane engineers are using multi-objective optimization to improve chiller efficiency. Different from the traditional trial-and-error technique, Trane engineers analyze multiple variables and effects simultaneously and optimize the design to achieve the maximum benefit.

Challenge

A refrigerant-cooled hermetic motor is an integral part of Trane water- and air-cooled chillers. This technology provides high efficiency and extends the life of high-power induction motors. In these hermetic refrigeration machines, coolant flow is needed to carry away the heat generated by high power motors to improve energy efficiency and motor durability. However, the coolant flow also induces the windage loss to the systems.

Two competing mechanisms need to be quantified simultaneously to achieve the optimized design of these hermetic systems. Trane engineers use latest computational fluid dynamics (CFD) technology to simulate heat transfer phenomena in high-power induction motors and refrigerant flow through these motors concurrently.

These simulations bring many benefits compared to traditional build-and-test techniques: temperature distribution in the motor is evaluated to eliminate hot spots and obtain uniform cooling; through-flow induced torque and loss are determined; the impact of rotor surface geometry and speed are assessed; and the required mass flow rate for effective cooling is predicted. As a result, hermetic refrigerant machines are designed with optimized configuration for the best energy efficiency.

To improve energy efficiency, design and analysis move from the individual component to the entire system. Compressor aerodynamic performance is no longer limited to single parts, but extended to include the interaction of multiple components. This integrated analysis ensures the maximum performance of each component as a part of the compressor system at various working conditions.

CFX allows Trane engineers to explore large-scale unsteady flow phenomena. Removing these instabilities has the benefit of obtaining the highest energy efficiency in a wide range of applications.

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By using CFX to analyze the unsteady flow field inside the chiller, track down the response of the unit structure, and predict air motion around the machines, Trane engineers deliver units with the lowest noise radiation.

Solution

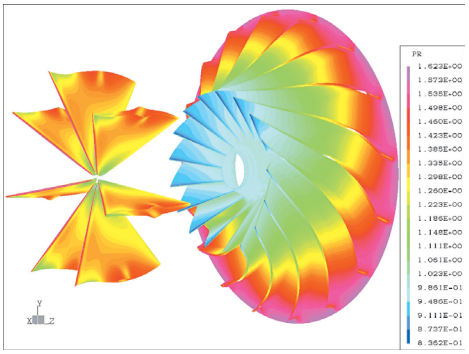
Trane has developed a Virtual Laboratory for the design of refrigerant compressors. It is based on CFX by ANSYS, a CFD software that Trane has found to be ideally suited to modeling indoor comfort systems and which includes a real-gas equation of state for the refrigerant. The result is that engineers can easily obtain overall performance and local flow field details for complete compressor stages without building a prototype.

Different from single-component analysis, the Trane Virtual Laboratory simulates the entire compressor, readily providing information on the interactions between the components. Since it quantifies the impact of design changes of a single part on the performance of the whole compressor, this feature has special value for the overall improvement of machines. This capacity proved very useful when Trane investigated the options to use different diffusers in compressors.

The impact on the overall compressor performance was analyzed in detail, with the simulations indicating that the change would lead to different flow fields inside the upstream and downstream components. The individual performance of these components was altered when the diffuser was changed. The information obtained was of great value to designers, guiding product improvements and avoiding unnecessary design iterations.

Transient simulations in the Trane Virtual Laboratory provide further physical insights into compressor performance and flow field unsteadiness, reduction of which is critical to improve efficiency and reduce vibration and noise levels. Pressure fluctuation distributions inside the impellers and diffusers can be obtained for different compressor designs and loss mechanisms inside the flow field can be studied thoroughly.

CFX allows Trane engineers to explore large-scale unsteady flow phenomena. Removing these instabilities has the benefit of obtaining the highest energy efficiency in a wide range of applications. To minimize the impact on the environment, Trane also develops technology to improve the reliability of our products, increase service intervals, and reduce the need for disassembly of the units. Possible emission of refrigerant associated with these processes is eliminated.



CFX calculates force and torque from pressure and viscous shear stress on the surface of inlet guide vanes and impeller of a Trane centrifugal compressor stage.

For the compressors designed by Trane, the force and torque on components are quantified to ensure safety and reliability. The force and torque are calculated from the pressure and viscous shear stress obtained from flow field simulations on the surface of the components. These force and torque calculations are also used to predict the vibration and noise of the system.

The possibility of failure associated with fatigue of the components is therefore reduced. All this analysis is conducted using a whole system simulation under strict dynamic loading conditions. This cutting-edge technology helps Trane chillers earn a reputation as the world's most reliable refrigeration machines.

In recent years, the sound produced by HVAC equipment has attracted more attention. Since the equipment is typically located near building occupants, noise radiation must be controlled. Reducing acoustic impact is particularly important for hospitals, schools, and music halls.

The machinery sound from HVAC equipment is caused by temporal variation in the flow field. The internal flow field vibrates the machines, setting the air around them in motion. This unsteadiness reaches the human ear in the form of noise.

Benefits

By using ANSYS to analyze the unsteady flow field inside the chiller, track down the response of the unit structure, and predict air motion around the machines, Trane engineers deliver units with the lowest noise radiation. Since Trane developed the industrial first scroll compressor, the Trane 3-D® scroll compressor, in 1987, these devices have dominated the market for small tonnage air-conditioning equipment.

Compared to the reciprocating compressors, where intake, compression, and discharge occur in discrete steps, scroll compressors conduct intake, compression, and discharge phases of operation simultaneously in an on-going sequence. Their smooth operating characteristics reduce force and torque variation inside the compressor, making scroll compressors quiet and reliable.

Lubrication is very critical to improve the durability of scroll compressors since the oil pump is an integral part of the compressor. Trane engineers developed the technology to use the latest particle tracking techniques to predict the oil circulation rate inside the scroll compressors. The oil coming from different regions inside the compressors is tracked through the operating process. Oil circulation features of different designs and oil droplet sizes are obtained at different operating conditions.

CFX helps designers develop compressor designs with adequate lubrication and an ample supply of oil. The fully lubricated moving components extend the durability of the system and reduce the need to replace parts and service the units.

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