ANSYS CASE STUDY

CFX Simulation Improves Ventilation at Grand Central Terminal

HATCH MOTT MCDONALD

EXECUTIVE SUMMARY

Challenge:

To understand the current ventilation conditions of Grand Central Terminal's trainshed region.

Solution:

Implement CFX software from ANSYS as the CFD modeling tool to predict the benefits of various design options, making it possible to improve the trainshed ventilation system in a cost-effective manner.

Benefits:

- CFX results correlated well with existing conditions and confirmed the effects of recent ventilation system changes.
- CFX analysis enabled engineers to evaluate the cost and benefits of a wide range of potential design improvements, making it possible to obtain the most benefits for the funds available to improve ventilation.
- The excellent correlation of the model generated confidence in CFD analysis and led to the award of a $2.3 million contract to a new ventilation system.

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Introduction

Grand Central Terminal (GCT) serves as the principal hub of the MTA Metro-North Railroad, the second largest commuter railroad in the U.S., with approximately 240,000 customer trips each weekday and some 70 million trips per year. When GCT opened for business in 1913, its Beaux-Arts terminal was one of two major stations in New York City for long distance rail travel. But as American's began to forsake rail travel in the 1950s, the private railroad that owned the terminal neglected upkeep and its condition deteriorated rapidly.

In 1997, a $175 million restoration project was completed. As part of the restoration, the GCT concourses now lead to the "trainshed," one of the largest underground structures in Manhattan, consisting of 30 platforms on two levels.

Grand Central Terminal

Ventilating the trainshed has become difficult over the years as widespread use of air-conditioned equipment added waste heat into a facility designed long before the age of air-conditioning. Improving ventilation is a difficult challenge because of the 2.5 million square feet occupied by the trainshed and the fact that outside air can only be reached in limited areas because of the dense construction above ground.

Because of the unique design challenges, several changes that had been made in the past at considerable expense ended up having no major positive impact. To avoid repeating that experience, Hatch Mott McDonald (HMM), a full-service engineering firm based in New York, was contracted to conduct a preliminary study using computational fluid dynamics (CFD) to explain the fluid and thermodynamic processes that drive environmental conditions in the trainshed. The company selected CFX software as the CFD modeling tool for this project.

Challenge

HMM began its preliminary study, during which global lumped-parameter and 3-D CFD models of the trainshed were developed to understand the current ventilation conditions and the impact of changes that have been made in recent years.

The team determined that the trainshed experiences high air temperatures during the summer months—at ground level, temperatures are typically 15 degrees Fahrenheit above ambient. Ventilation, which is currently provided by sidewalk grilles and a few small vent shafts, is insufficient to support the exceptionally large area of the trainshed.

There are several key reasons why efforts are being made to improve ventilation in the trainshed:

- Improve passenger comfort, as commuters move through the platform before entering the air-conditioned trains.
- Increase comfort for MTA employees, who spend a considerable amount of time on the trainshed.
- Increase the service life of the trains, which function daily under high ambient temperatures.

"CFX made it possible to base our design decisions on facts rather than opinions. With CFX, we're confident that we'll deliver a solution that not only works, but also gives our client the biggest bang for the buck."

—Norman Rhodes, Project Manager, HMM

"The initial study with CFX correlated well with existing conditions and confirmed the effects of recent ventilation system changes," said Rhodes. "As a result, we won a much larger contract to design a new ventilation system."

HMM analysts determined that a lumped parameter model using coefficients that are assumed to apply over the entire trainshed region was the best approach in predicting the benefits of a wide range of proposed changes to the ventilation system—making it possible to improve conditions in a cost-effective manner.

"CFX accuracy, robustness, and scalability are ideally suited to the large, complex modeling problems we address on a daily basis," said Norman Rhodes, project manager for HMM. "CFX provides an extremely comprehensive user subroutine capability that allows us to create fully programmable user functions. We used this capability extensively on the project to improve the accuracy of our model in simulating flow through the grilles and similar features."

Solution

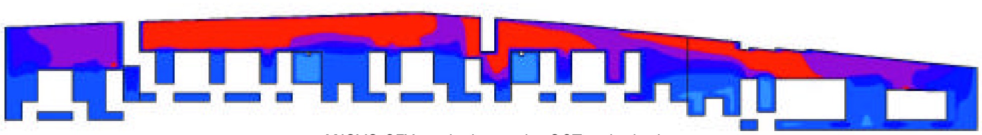
To reduce the computational requirements, HMM created two separate models for the upper and lower levels of the trainshed and treated the results of each as a boundary condition for the other.

HMM greatly increased the detail of the model in order to provide the accurate predictions required for making decisions. One of the most critical areas was found to be the sidewalk grilles, which present a challenge because at a width of about three feet they are on a very small scale in relation to the rest of the model. Yet their impact is great because they represent such a large proportion of the available venting. Analysts at HMM refined the heat sources in the model, which consist of the trains themselves, the air conditioners on the trains, and the thermal inertia of the buildings above the trainshed.

Once the model was completed, the next step was to validate it by comparing its predictions to temperature and humidity measurements along the platform. "We compared the air currents predicted by the model to observations of the smoke flow when small trash fires occur in the train shed," explained Rhodes. "The model correlated very well to the actual physical results so we are now in the process of using it to assess the impact of a wide range of design changes."

Rhodes further explained that the critical challenge was optimizing the design by providing the most ventilation efficiency per dollar expended.

"While we're still in the midst of our design study, it's already clear that the most effective approach will be one that combines more grille space with active ventilation. The main trade-off is adding additional sidewalk grilles versus putting in more ventilation. The sidewalk grilles have a very positive impact—temperatures are lower to the north of the grille. We also looked at the impact of increasing air supply, which generally has a smaller impact but affects a larger area. We determined that we need to move air from the south end to the north end, so it can flow out of the sidewalk grilles."



ANSYS CFX analysis results GCT trainshed

The combined effects of these changes are so subtle and complex that many different model iterations will be required in order to obtain an optimized design. "During the preliminary analysis, we were able to explain to our client various observations that had been made but were difficult to understand," Rhodes said. "The excellent correlation of the phase one model helped to generate confidence in computer simulation and led to the award of a $2.3 million contract for HMM to design a new ventilation system."

Benefits

Because there was no easy—or inexpensive—solution to the trainshed ventilation problem, HMM engineers needed to take advantage of every possible tool at their disposal.

"The initial study with CFX correlated well with existing conditions and confirmed the effects of recent ventilation system changes," said Rhodes. "As a result, we won a much larger contract to design a new ventilation system. We're currently evaluating the cost and benefits of a wide range of potential design improvements, which will make it possible to obtain the most benefits for the funds that are available to improve the ventilation system."

The biggest challenge, according to Rhodes, will be determining which combination of changes will have the greatest impact on environmental conditions at the lowest possible cost. With conventional engineering calculations and physical experiments alone, HMM would have had to essentially guess at the answer. But thanks to CFX, the project engineers were able to turn guesswork into fact.

"CFX made it possible to base our design decisions on facts rather than opinions," Rhodes concluded. "We're in the process of evaluating every reasonable configuration, estimating cost and determining the impact on trainshed conditions. With CFX, we're confident that we'll deliver a solution that not only works, but also gives our client the biggest bang for the buck."

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