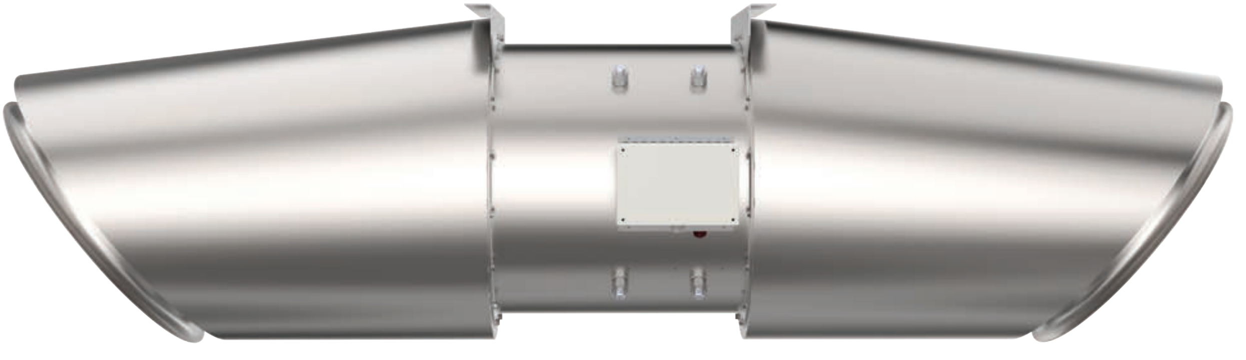
ENERGY-EFFICIENT TUNNEL VENTILATION

A leading ventilation company develops jet fans that are smaller and up to 30 percent more energy efficient.

By Fathi Tarada, Managing Director, Mosen Ltd., U.K.



Improving the efficiency of turbomachinery, including jet fans used in tunnel ventilation systems, is essential in combating the volatile cost of fuel and reducing emissions of greenhouse gases. Energy-efficient equipment is also more attractive to worldwide transportation authorities.

Longitudinal tunnel ventilation systems provide airflow along the length of a tunnel; they are needed to satisfy air quality requirements or to control smoke movement in case of a fire. While there are many different types of ventilation systems available, the most widely used type employs jet fans. In addition to being energy efficient, jet fan ventilation systems should be compact so as not to protrude into traffic space. System designs must also allow for closely spaced fan installation, to reduce cabling costs, and quiet operation that conforms to guidelines.

DESIGNING THE SOLUTION WITH ANSYS

Mosen Ltd., a firm of consulting engineers that develops energy-efficient tunnel ventilation systems, uses ANSYS software to optimize systems design and meet all the other requirements.

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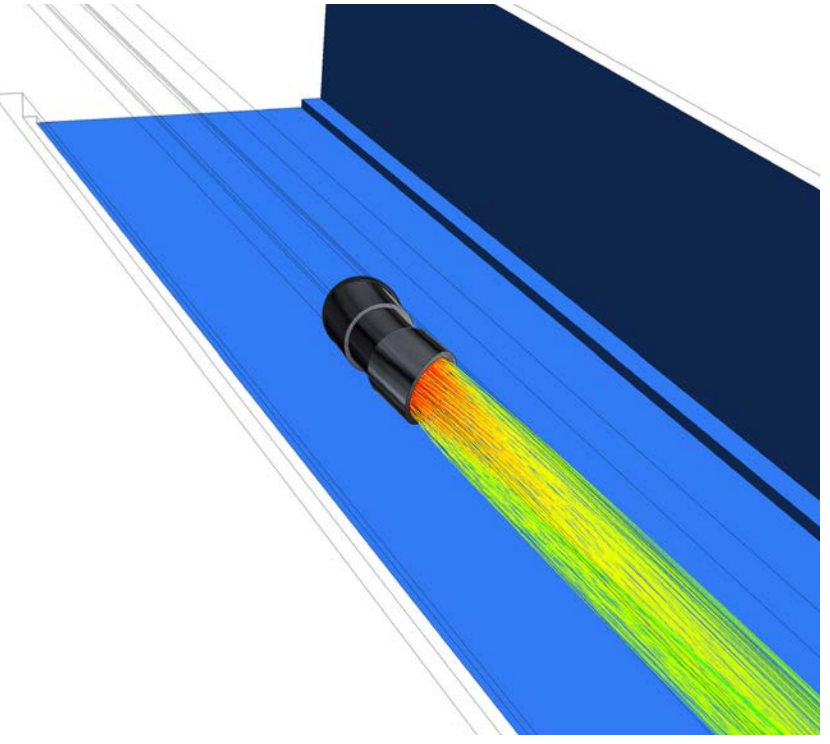
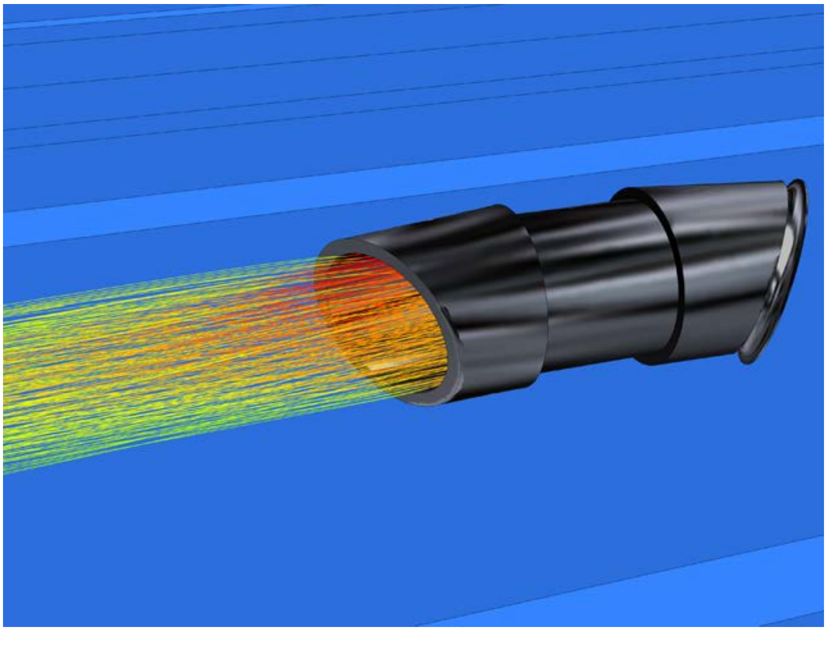


▲ Particle tracks colored by air velocity for airport tunnel project. The jet of air is turned away from tunnel walls and soffit by the MoJet.



▲ Particle tracks colored by air velocity; airport tunnel project

One of the most important factors in improving efficiency of tunnel ventilation systems is minimizing the Coanda effect. "Coanda effect" refers to the tendency of the air steam produced by each jet fan to be drawn to nearby walls, leading to increased friction and significantly increasing the energy required to move the air. This effect occurs because the jet flow close to the wall decelerates, creating a pressure difference across the jet that reinforces its attachment to the wall, even at high velocities. Between 15 percent and 27 percent of the energy used by jet fan ventilation systems is wasted due to this increased aerodynamic friction. Since tunnel ventilation systems consume large amounts of energy, with some installations demanding several megawatts at full load, reducing the Coanda effect goes a long way toward improving energy efficiency.

Engineers at Mosen used ANSYS CFX fluid dynamics software to simulate the airflow, both inside their innovative jet fan — the MoJet® — and within tunnels. To combat the Coanda effect, engineers used ANSYS Workbench to parametrically experiment with different inlet and outlet nozzle designs, all geared toward reducing losses, accelerating flow and diverting it away from tunnel walls to reduce aerodynamic friction.

The top edge of the discharge nozzle on the MoJet is angled to direct flow down from the tunnel ceiling, while the lower edge is undercut to increase the inlet flow area, reducing entry losses. The overall result is that the jet fan has a shape that has been described as a sliced salami. Inlet losses are minimized with a bell-mouth–shaped air intake design. ANSYS Workbench parametric design studies enabled engineers to analyze different inlet bell-mouth shapes and determine the best curvature. This helped to reduce the amount

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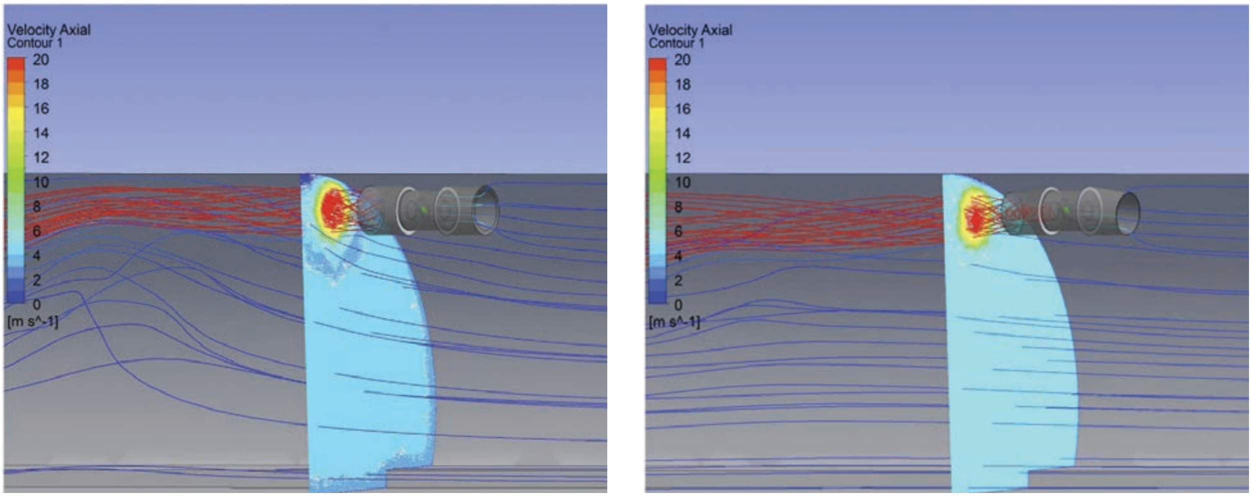

▲ Particle tracking comparison of a conventional jet fan (left) and MoJet (right) reveals reduced downstream Coanda effect with the MoJet.

of flow separation in the intake by 50 percent; it reduced power consumption by approximately 2.5 percent. The final design of the nozzles' sheet metal profiles was complex in comparison with the simple rectangular geometries that conventional jet fans employ, but the design was well within the capabilities of modern machining.

In addition to improving the efficiency of the MoJet, Mosen's engineers reduced its size in comparison with competing designs, which in many applications provided additional clearance to the tunnel ceiling and reduced noise emissions. Once the MoJet was designed, the engineers used ANSYS CFD to model an entire MoJet installation. The resulting model included the tunnel and fan assembly and used a wide range of mesh element sizes to capture flow dynamics.

REAL-WORLD TESTS

Systemair GmbH tested the MoJet in the Galleria Buttoli tunnel near Florence, Italy, in September 2012. Engineers conducted a number of careful tests and reported their results at BHR's International Symposium on Aerodynamics, Ventilation and Fire in Tunnels. The installation factor, which is a measure of the ratio of jet fan thrust to axial thrust imparted to tunnel air, was improved by 11 percent compared to conventional jet fans — a significant enhancement to aerodynamic thrust, and a result that confirmed Mosen's CFD predictions. The test tunnel was horseshoe-shaped. CFD calculations indicated that installation of MoJets in other types of tunnels (rectangular or within niches) would have even better performance; depending upon the shape of the tunnel and the location of the MoJets, the installation factor increase could be as high as 25 percent.

In another case, original specifications for a road tunnel in a major international airport called for 710 mm internal diameter traditional jet fans with two-pole motors. It was anticipated that this installation would be noisy, take up a lot of space, and possibly require increased safety precautions due to high jet velocities required for effective operation. A redesign of the proposed ventilation system used 800 mm internal diameter MoJets with four-pole motors that run at lower speeds. The result was a 30 percent reduction in power consumption and a 7 dB reduction in sound pressure level in the tunnel, along with significantly reduced jet air velocity. In addition, MoJets can be installed much closer to tunnel walls and at reduced distances along the tunnel, reducing construction and cabling costs.

COMPUTATIONAL FLUID DYNAMICS FROM ANSYS
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MoJets have been installed in the Grimstad Port Tunnel in Norway. The fans will ventilate the tunnel to dilute CO and NO_2 emissions as well as control the direction of smoke in case of fire. Some of the pre-existing jet fans had been damaged by vehicle strikes; however, replacement MoJets will provide additional clearance for traffic and reduce future damage. Tests on the new system have indicated reduced sound pressure level as well as increased aerodynamic thrust in the tunnel.

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