

**ASK THE ENGINEER**

# NOISEPO

## **In Search of Silent Engines**

*What are the causes of engine  
noise and what's being done to  
hush them up?*

*By Dr. Magdy Attia*



*Noise pollution is quickly becoming a billion-dollar problem for the aircraft engine industry. Engine Air contributor, Dr. Magdy Attia, Professor of Aerospace Engineering at Embry Riddle Aeronautical University, examines the issue, as well as current efforts to decrease engine noise.*

# NOISE



"As of November 2006, communities in the United States have spent approximately \$4.5 billion to mitigate the effects of airport generated noise on their communities via residential noise insulation programs as well as land acquisitions. To qualify for this tax money, which is dispersed by the FAA through Airport Improvement Program (AIP) grants, airports must complete a thorough noise impact study. To date, the total number of airports participating in this Program is 268." Source: Federal Aviation Administration (FAA)

## **SOURCES OF ENGINE NOISE**

There are five major sources of noise in a turbofan engine: the fan inlet, fan exhaust, combustion, turbine, and core exhaust. With each component contributing to the noise signature at a different magnitude and

frequency, the resulting chorus can be truly unpleasant.

The fan is responsible for pulling air into the engine. As the blades spin and draw in air, they generate noise by themselves. With modern, large commercial fan blades spinning at around 3,500 rpm, the air immediately downstream of the fan is whirling at fairly high speeds.

This whirling air must be "straightened," before it is exhausted through the fan duct, or the losses in engine performance would be substantial. This is accomplished by passing the air through the stators, which, of course, are a set of stationary blades. As the air comes into contact with the stators, noise is generated and transmitted to the surrounding area via the fan exhaust duct. This particular noise contribution is the high-pitch, piercing sound

commonly attributed to some engines.

A portion of the air intake is redirected to the core of the engine. This air is then further compressed by a series of rotating and stationary blades, or airfoils, within the compressor. Continually spinning and straightening the air, these sets of airfoils, called stages, add to the noise level as well.

The compressed air is then introduced to the combustion chamber of the engine, where jet fuel is added and ignited. This combustion of the air-fuel mixture is another source of noise.

Next, hot air is passed through the turbine component, spinning it to power the engine compression system. The turbine component, with its sets of rotating and stationary blades and their interaction, again contributes to the noise level.

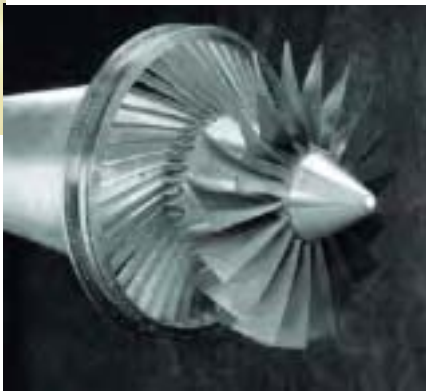
Finally, air is expelled through the exhaust



Fan Stator A



Fan Stator B



Fan Stator C

duct into the freestream airflow around the engine. Often, core exhaust air is mixed with the fan exhaust air before being expelled. The interaction between the two airstreams, as well as the interaction between the engine exhaust and the freestream airflow, is another source of noise, which is often referred to as jet noise.

The noise signature of the same engine also differs depending on the operating mode of the

***Based on research by NASA, which examined and explained the noise-making mechanism in detail, the stators were redesigned to reduce the noise signature.***

engine. For instance, during take-off, the jet exhaust and fan exhaust noises, at roughly 100 dB (decibels) each, far outweigh the noise made by the other components. During landing approach, the fan inlet noise, at roughly 98 dB, is the most noticeable.

**NOISE REDUCTION**

Efforts are underway to better understand how

develop ideas about how to reduce it in a cost-effective manner, without adding too much weight to the engine.

An example of such noise reduction steps is the modification of the fan stator design. Based on research by NASA, which examined and explained the noise-making mechanism in detail, the stators were redesigned to reduce the noise signature.

Scientists liken a large portion of an engine's noise making to waves splashing on the shore. As the whirling air from the fan blades makes contact with (or "slaps") the fan stators, noise is generated. If the stators are perfectly aligned with the rotating fan blades, in a three-dimensional sense, the "slap" is loud and clear. However, if the stator airfoils are swept backwards, air first will make contact with the

engine noise is generated in order to determine how best to reduce such noise. Leading the way are the folks at the National Aeronautics and Space Administration (NASA) Glenn Research Center in Cleveland, Ohio. Their contributions, along with those of many others, industry professionals and academicians alike, have made great strides in the understanding of noise production. Such theoretical understanding of engine noise is helping to

hub (inner radius) and then make contact with the tip (outer radius), reducing the "slapping" noise. Furthermore, if the stators are leaned in the circumferential direction, the airflow, and thus the slapping noise, will be chopped up even further.

An example of passive noise reduction is the modification of the nacelle walls' inner lining so that it is more absorbent of sound waves. This is usually accomplished by installing a layer of porous media on top of the honeycomb; the added layer traps the sound wave, leading to its dissipation as it bounces around inside the lining.

Much also has been accomplished in the area of reducing jet exhaust noise. Jet exhaust consists of the fan (or bypass) stream and the core stream. The core stream, which is smaller in magnitude than the bypass stream, typically is much hotter and moves much faster. As the two streams mix together, and then mix with the outside air, noise is generated. This is a particularly difficult problem to address, since the majority of the jet noise is generated outside of the nozzle.



Mixer nozzle



Hush-kit

To alleviate this source of noise, many engine makers now offer a mixer nozzle as a standard feature on their engines. Mixer nozzles help the two streams mix together more smoothly before they are exhausted into the atmosphere, resulting in an overall cooler, slower airstream, which reduces emissions noise.

Accompanying better technologies for noise

access was to develop hush-kits. A hush-kit is comprised of one or more devices that attach to an existing engine in order to reduce its noise signature. Building on solid scientific understanding of noise and its various sources, many hush-kits tend to focus on the jet exhaust noise component. These kits have been successful in modifying aircraft to be compliant with FAA stage-3 noise regulations.

from the old exhaust nozzle comes in contact with subsonic, or freestream, airflow.) Further noise reduction is achieved by a multi-layered lining, inside the ejector section, that traps the sound waves in honeycomb labyrinths under a perforated, acoustic filter, metal lining. In total, this hush-kit adds 234 pounds to the aircraft weight, promises a 7 dB reduction, and is FAA-certified to stage-3.

reduction have been regulations to enforce the improvements. These regulations came in the form of sound signature guidelines by the FAA. The FAA has instituted categories for noise production, called stages, that are based on the overall weight of the aircraft and the noise it produces during various flight regimes, such as

The figure provided shows an example of a multi-component hush-kit manufactured by Quiet Technology Aerospace, located in Opa-Locka, Florida. This particular hush-kit design, for a Rolls-Royce Spey-powered aircraft, consists of a new twelve-lobe mixer nozzle, an ejector (which looks like another exhaust duct),

**One of the aircraft industry's responses to the new noise regulations and resulting limited access was to develop hush-kits.**

flyover and approach. A stage-3 aircraft, for instance, will produce less noise than a stage-2 aircraft of the same weight.

As a consequence, certain airports started denying access to aircraft with high noise signatures. In addition to being a major inconvenience to owners of certain aircraft, this action by a few, selected airports prompted other airports to follow suit.

One of the aircraft industry's responses to the new noise regulations and resulting limited

and a linkage system that allows for safe deployment of thrust reversers without additional pilot intervention.

The noise reduction mechanism of the Quiet Technology Aerospace hush-kit is multi-layered. First, the twelve-lobe mixer nozzle contributes to noise reduction. Next, further noise reduction is achieved by decelerating the flow in the ejector section to reduce noise from sonic shear. (Sonic shear is a term describing the noise resulting when supersonic airflow



John Wayne Airport noise signatures

With such advancements in noise reduction techniques and mechanisms, life is getting better in many airport neighborhoods. The graph here shows how many fewer homes are affected by airport noise for stage-2 compliant (zone inside red outline) versus stage-3 compliant (zone inside green outline) aircraft.