Shape-memory alloys might help airplanes land without a peep

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Having a home near a busy airport certainly has its perks. It is close to many establishments and alleviates the problem of wading through endless traffic to catch flights. But it does come at a cost—tolerating the jarring sounds of commercial airplanes during landing and takeoff.

Researchers at Texas A&M University have conducted a computational study that validates using a shape-memory alloy to reduce the unpleasant plane noise produced during landing. They noted that these materials could be inserted as passive, seamless fillers within airplane wings that automatically deploy themselves into the perfect position during descent.

"When landing, aircraft engines are throttled way back, and so they are very quiet. Any other source of noise, like that from the wings, becomes quite noticeable to the people on the ground," said Dr. Darren Hartl, assistant professor in the Department of Aerospace Engineering. "We want to create structures that will not change anything about the flight characteristics of the plane and yet dramatically reduce the noise problem."

The researchers have described their findings in the *Journal of Aircraft.*

Aircraft noise has been an ongoing public health issue. Airplanes can generate up to 75-80 decibels during landing, which can be damaging to hearing over the long term. For example, studies have shown that people exposed to sustained aircraft noise can experience disturbed sleep and an increased risk of stroke and heart disease compared to those who do not live near airports.

The source of aircraft noise is different during ascent and descent. During takeoff, the engines are the primary source of noise. On the other hand, when airplanes slow down to land, the engines do not need to generate power and are mostly idling. At this time, the wings begin to reconfigure themselves to slow down the airplane and prepare for touchdown. Similar to the opening of Venetian blinds, the front edge of the wing separates from the main body. This change causes air to rush into the space created, circle around quite violently and produce noise.

"The idea is similar to how a sound is generated in a flute," said Hartl. "When a flute is played, air blown over a hole begins to swirl around the hole, and the size, the length and how I cover the holes, produces a resonant sound of a certain frequency. Similarly, the circulating air in the cove created between the front edge of the wing and the main wing resonates and creates a sharp, unpleasant noise."

Earlier work from Hartl's collaborators at NASA showed that fillers used as a membrane in the shape of an elongated "S" within this cove could circumvent the noise-causing air circulation and thereby lessen the jarring sound. However, a systematic analysis of candidate materials that can assume the desired S-shaped geometry during descent and then recess back into the front edge of the wing after landing was lacking.

To address this gap, the researchers performed comprehensive simulations to investigate if a membrane made of a shape-memory alloy could go back and forth, changing shape for every landing. Their analysis considered the geometry, the elastic properties of the shape-memory alloy and the aerodynamic flow of air around the material during descent. As a comparison, the researchers also modeled the motion of a membrane made of a carbon-fiber-reinforced polymer composite under the same airflow conditions.

Hartl said these types of simulations are computationally expensive since the flow of air around the conformal material has to be modeled while analyzing the air-induced motion of the material.

"Every time the air applies some pressure to the material, the material moves. And every time the material moves, the air moves differently around it," he said. "So, the behavior of the airflow changes the structure, and the motion of the structural changes the airflow."

Consequently, the team had to perform calculations hundreds to thousands of times before the motion of the materials was correctly simulated. When they analyzed the outcomes of their simulations, they found that both the shape-memory alloy and the composite could change their shape to reduce air circulation and thereby reduce noise. However, the researchers also found that the composite had a very narrow window of designs that would enable noise canceling.

As a next step, Hartl and his team plan to validate the results of their simulations with experiments. In these tests, the researchers will place scaled-down models of aircraft wings with the shape-memory alloy fillers into wind tunnels. The goal is to check if the fillers can deploy into the correct shape and reduce noise in near real-world situations.

"We would also like to do better," said Hartl. "We might be able to create smaller structures that can reduce noise and do not require the S-shape, which are actually quite large and potentially heavy."

More information: Gaetano Arena et al, Design of Shape-Adaptive Deployable Slat-Cove Filler for Airframe Noise Reduction, *Journal of Aircraft* (2021). DOI: 10.2514/1.C036070

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