Digital wind tunnels could help develop more fuel efficient airplanes

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Credit: Imperial College London

New research has demonstrated how simulations could produce more detailed and accurate data quicker than physical wind tunnel experiments.

With access to more detailed data, engineers will be able to optimize the design of jet-engine turbine blades and achieve greater weight savings. This would increase the fuel efficiency of aircraft and reduce emissions that contribute to climate change, and comes as airlines are asked to prioritize reducing emissions over offsetting their carbon.

The international team of researchers from UK, U.S., Japan, Canada and Germany, say that their findings, published in *Computers & Fluids*, also opens the door to 'digital' wind tunnels eventually replacing physical wind tunnels, which could reduce costs and lead to improved designs.

Jet engine turbines are currently designed using a combination of Reynolds Averaged Navier Stokes (RANS) simulations, which try to capture the behavior of turbulent flow using approximate models, and wind tunnel testing.

However, RANS simulations have limited accuracy, especially for unsteady flows, and real-world wind tunnel testing can be both costly and time-consuming, and often provides designers with limited data. Consequently, there is an emerging interest in using high-fidelity Direct Numerical Simulations, that capture all aspects of the turbulent flow physics directly, to obtain accurate predictions without resorting to use of wind tunnels.

Lead author Professor Peter Vincent of Imperial's Department of Aeronautics said: "Our simulations are exciting for several reasons. Firstly, they provide us with more accurate and detailed data, so we can learn a lot about the underlying flow physics and potentially use it to train new turbulence models via machine learning-based approaches.

"Secondly, with advances in computer hardware we may soon be able to acquire the data faster and at lower cost than from physical wind tunnel experiments. So although digital wind tunnel testing may not replace physical wind tunnels for some years, our study suggests it's now a real possibility."

While the study specifically focused on testing jet engine turbine blades, there are many others areas where the approach could also play a role, including the design of submarines, cars, high-rise buildings, and wind turbines—all of which currently rely heavily on wind tunnel testing.

Professor Vincent added: "Applications beyond turbo machinery include those in the marine, automotive, and green energy sectors, where we hope the technology will play an important role in coming years."

The simulations were undertaken using the PyFR software on the Titan supercomputer at Oak Ridge National Laboratory. This software is able to run on a range of different hardware platforms, including modern NVIDIA Graphical Processing Units such as those that make up Titan.

"High-order accurate direct numerical simulation of flow over a MTU-T161 low pressure turbine blade" by A. S. Iyer, Y. Abe, B. C. Vermeire, P. Bechlars, R. D. Baier, A. Jameson, F. D. Witherden, P. E. Vincent, published in *Computers & Fluids*.

More information: A.S. Iyer et al, High-order accurate direct numerical simulation of flow over a MTU-T161 low pressure turbine blade, *Computers & Fluids* (2021). DOI: 10.1016/j.compfluid.2021.104989

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