Blowing against the tide

Professor Grigorios Dimitriadis, Head of the Wind Tunnel Laboratory at Belgiums's University of Liège, details how the decomissioning of technology is affecting progress…

Wind tunnels are experimental installations that create an airflow going past a test object. In a controlled and safe environment, they can recreate real-life situations, like an aircraft flying at 30,000ft and 950km/h or a storm blasting a bridge deck. In this way the aerodynamic forces acting on structures can be measured, the flow-field around them can be visualised and fundamental research on aerodynamics can be carried out. Wind tunnels have been invaluable tools to aircraft, automobile and civil engineering designers for over 100 years. However, a significant number of wind tunnels have been decommissioned over the last 20 years, both in Europe and in the United States. Some of these closures have made the news, for instance the decommissioning of the NASA Ames facilities. There are many reasons for this phenomenon and a significant number of possible implications.

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The end of the Cold War

The drive for wind tunnel decommissioning began after the end of the Cold War. The aerospace industry is funded to a large extent by national defence budgets. As these budgets started to decrease, funding for wind tunnel operations also diminished. The number of new aircraft in development is lower than ever and the few new designs are increasingly international efforts, thus removing the need for extensive national wind tunnel test facilities. Other industries, like the construction and wind energy industries, have significantly increased their wind tunnel usage but not to an extent sufficient to counter the decline of aeronautical wind tunnel testing. Furthermore, transonic, supersonic and hypersonic wind tunnels are only of interest to aerospace projects – without such projects, they cannot survive. Europe has reacted to this situation by grouping national wind tunnel facilities into international entities, such as the German-Dutch Wind Tunnels foundation. European Commission projects like ESWIRP (European Strategic Wind tunnels Improved Research Potential) and EWA (European Windtunnel Association) aim to enhance the complementary capabilities of individual national installations and make them more available to joint research and development activities.

The rise and rise of CFD

Over the last 20 years there has been tremendous progress in the processing power of computers, making it possible to solve increasingly complex fluid dynamics problems. Computational Fluid Dynamics (CFD) has some significant advantages over wind tunnel testing, for example: perfect control over the flow parameters, ease of specimen geometry modification, and relatively small space and personnel requirements. The cost of CFD is not negligible; a medium-sized parallel computing facility can cost as much as a medium-sized low speed wind tunnel to build and run. However, experiments that require use of the largest and astronomically expensive supersonic wind tunnels can still be simulated on a medium-sized parallel computing facility.

On the other hand, CFD can have serious shortcomings in terms of simulation time and trustworthiness. It is generally accepted that attached flows on simple, clean geometries can be simulated quickly and accurately using CFD. However, most real-life applications feature significant areas of aerodynamic interference and unsteady separated flow that are much more difficult to simulate. Some calculations of full aircraft geometries or flows around complex buildings can last for weeks or even months and their predictions can be inaccurate. Ironically, the only way to instill confidence in such simulations is to validate them through comparison against the results of wind tunnel experiments. Nevertheless, some engineering companies that design products featuring mostly attached flow have altogether stopped their wind tunnel activities and rely entirely on CFD.

The case for more wind tunnel testing

The developments mentioned above can be viewed as generally positive. Needing to spend less on defence can only be a good thing, while the emergence of a new technology that can complement and even enhance our aerodynamic expertise is welcome. Having said that, there are some negative aspects to these developments. The cuts in defence spending have coincided with a loss of interest in revolutionary civilian aerospace projects – the

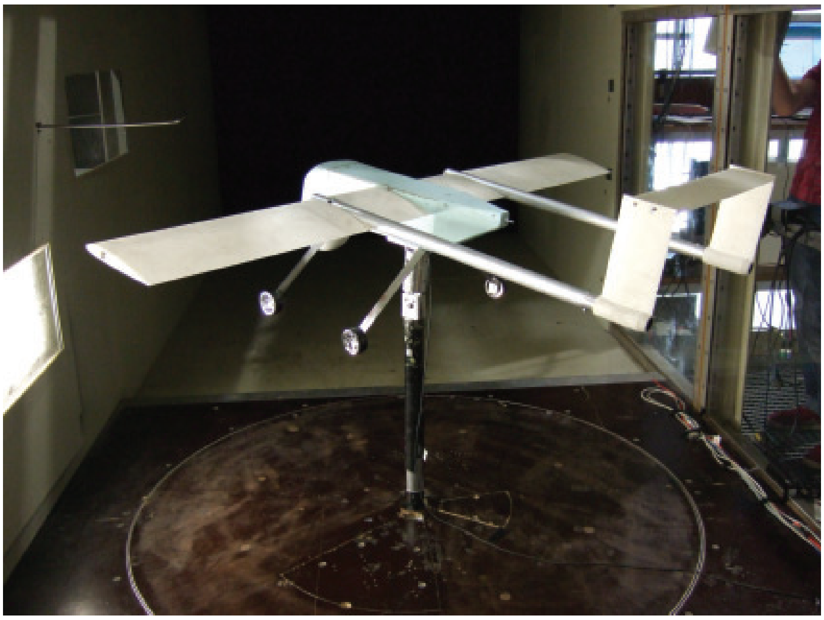

Fig. 1: UAV prototype tested in wind tunnel; more combined experimental and simulation research on these vehicles could vastly improve their designs

spaceplane, the Sonic Cruiser and the European space shuttle are but distant memories. The number of civil aircraft designs in development is lower than ever and development times are longer than ever. Concerning CFD, an over-reliance on simulation results that have not been properly calibrated and validated can be catastrophic. Experimentation is the basis of the scientific method – every theory and every simulation method must be verified through observation.

A 2010 report by the Fraunhofer Institute on wind tunnel activity notes that over the last two decades there have been up to 4,000 scientific publications per year on CFD. In contrast, a maximum of 190 articles per year were written on wind tunnel experiments over the same period. Not only do more researchers work on CFD but they also write more papers. Simulation requires cheaper infrastructure (in some cases a single desktop computer will suffice) and every new numerical technique can become the subject of a publication. Nevertheless, I believe that there is an increasing need for wind tunnel testing.

The increased activity in CFD is one of the reasons giving rise to the need for more experimental data. Many of the simulations being carried out concern complex, separated and unsteady flows and give uncertain results. Small changes in the simulation parameters can result in significant changes in the predictions. In order to validate these simulations and develop robust methods for choosing the parameters, wind tunnel experiments must be carried out and their data must be compared to CFD predictions. The applications of such collaborative work between experimentalists and simulation experts are numerous. For example, one aeronautical application that has seen significant activity over the last couple of decades is the design of Unmanned Aerial Vehicles (UAVs). Many of these aircraft have unconventional geometries and some even use novel propulsion methods, such as flapping wing propulsion. More combined experimental and simulation research on these vehicles could vastly improve their designs.

Another area of recent activity is the field of aeroelasticity, ie the study of the interaction between aerodynamic forces and the elastic and inertial forces internal to the structure. Basic aeroelastic design has been carried out for many years but current activities deal with more advanced phenomena, such as small amplitude vibrations induced by oscillating shock waves on wings flying at transonic airspeeds, or larger amplitude oscillations caused by the periodic separation and reattachment of the flow on wings, rotorcraft blades and wind turbine blades. Simulation alone cannot resolve these problems. Careful aeroelastic experiments must be carried out in the wind tunnel in order to characterise the phenomena and calibrate the simulations. Furthermore, there are new initiatives aimed at developing flexible aeroelastic structures. Aircraft structures featuring this technology will be able to deform actively or passively so that their aerodynamic characteristics will be optimal at all flight conditions. Such an approach to aircraft design could bring about significant efficiency gains but would need to be demonstrated in the wind tunnel and in flight.

Non-aeronautical applications of aerodynamics would also benefit from more wind tunnel testing. Civil engineering structures are very rarely streamlined, so that the flow around them is mostly separated. Some skyscrapers vibrate so much under strong winds that their occupants can get motion sickness. Aeroelastic wind tunnel testing of structures such as towers, bridges and wind turbines can improve safety, efficiency and comfort. Wind tunnels have also started to contribute in other multidisciplinary research activities, such as investigating the aerodynamics of the flapping flight of birds, bats and other animals.

In conclusion, I believe that there is a significant call for increased wind tunnel activity. By extension, the decommissioning of wind tunnel facilities must stop, or at least any decommissioned laboratories should be replaced by new, more modern wind tunnels.

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