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Scientific Computing

Nature's Aerodynamic Blueprints Inspire New Engineering Designs

Researchers from STFC's Scientific Computing Department (SCD) and the University of Manchester are using the surface patterns found in Nature to find ways to reduce fuel consumption and increase aerodynamic efficiency for aircraft, ships and cars.

Challenge

When air passes over an aircraft wing the flow is disturbed by surface friction, separating the flow and leaving a gap above the surface, which creates a drag on the wing.

This surface friction drag and flow separation, which are common phenomenon in air, road and water vehicles, have a large impact on fuel consumption, cruising range, endurance and aerodynamic performance.

To reduce the impact, fin-like structures called vortex generators are attached to the leading edge of the wing to create a swirling mass of air that can reduce the separation gap. These are widely used for aerodynamic applications but are relatively large and can disrupt the entire field of flow if not used properly.

Approach

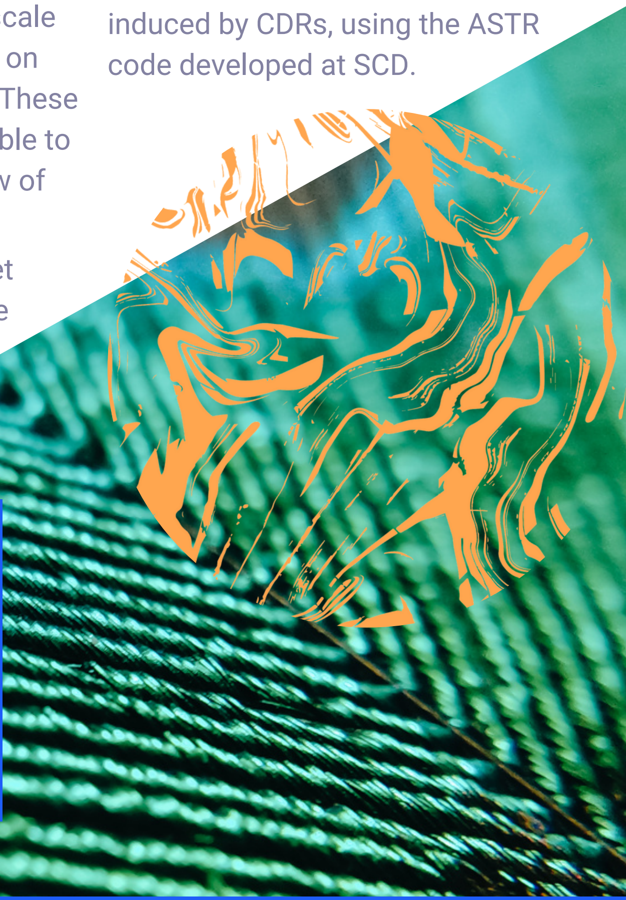
The research team, led by SCD's Dr Jian Fang, used high-fidelity computational simulations to study the airflow process and explore innovative ways to improve aerodynamic efficiency and reduce fuel consumption.

Inspired by the natural streamlined efficiency of birds and fish as they move through air and water, the team investigated the micro-scale pattern of ridges and grooves on bird feathers and shark skin. These tiny directional grooves, invisible to the naked eye, control the flow of fluids over their surface.

Dr Fang and his colleagues set about mimicking these groove patterns by implementing a technique which they called 'convergent divergent riblets' (or CDRs) as an alternative to the usual vortex generators.

Using the Hawk supercomputer at the High-Performance Computing Centre in Stuttgart, Germany, the team tested how the riblets would perform when air flows over them.

To do this, they adopted the direct numerical simulation approach to explore the details of the vortices induced by CDRs, using the ASTR code developed at SCD.



"Sharks and birds are both well adapted to moving efficiently through fluid, be it water or air. If you examine shark skin or bird feathers under a microscope, they both share a common feature: small directional grooves invisible to the naked eye that are used to control the flow of fluid over the surface."

Dr Jian Fang, STFC Scientific Computing Department

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The researchers observed how the CDRs direct the airflow into the grooves and how the turbulent air moves along them. They looked at the influence of spacing between riblets, demonstrating that wider spacing encouraged resistance to flow separation by generating large-scale ‘streamwise’ vortices.

By adjusting the parameters of the CDRs they can control the scale and strength of the vortices – narrower converging and diverging strips produce small vortices, while wider strips produce larger, stronger vortices.

There is currently a trade-off, however, as reducing the flow separation can increase the overall drag on the vehicle surface. Dr Fang is confident that, with further studies, it will be possible to find ways to address that issue and achieve reductions in both.

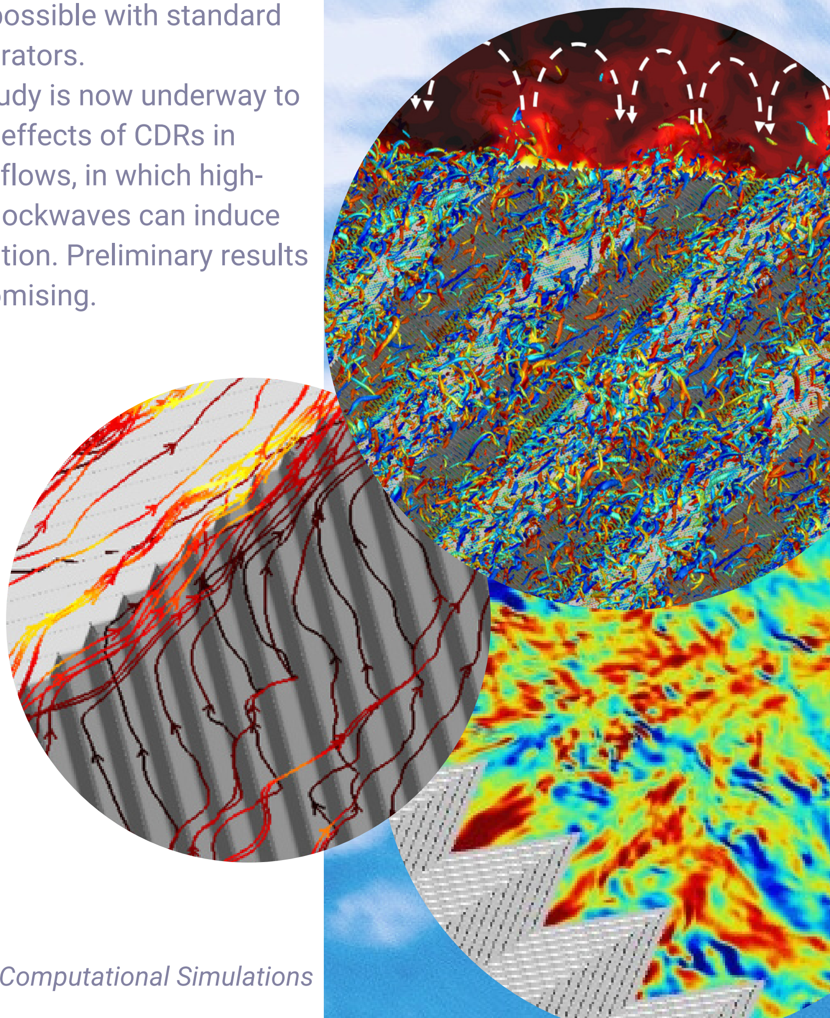
> “As we increased the spaces between the riblets, the vortices became stronger, and through our simulations we were able to find the point at which the spacing produced the largest effect.”
>
> **Dr Jian Fang, STFC Scientific Computing Department**

Benefits

- This work lays the foundations for optimising the aerodynamics of vehicles that have the potential for more efficient performance and lower fuel consumption.
- The ability to ‘fine-tune’ the size of the vortices by changing the riblet parameters provides the potential for engineers to refine the CDRs for specific applications – something that is not possible with standard vortex generators.
- A further study is now underway to explore the effects of CDRs in supersonic flows, in which high-pressure shockwaves can induce flow separation. Preliminary results are very promising.

This project received support and resources from PRACE (Partnership for Advanced Computing in Europe) which enabled computational performance testing of the ASTR code on a large scale, using over 100,000 cores. This furnished the researchers with confidence that the code would run at scale in an optimal way. It has since enabled Dr Fang to improve the Input/Output performance and a new version of the ASTR code is soon to be released.

PRACE



Computational Simulations