

# InSiDE

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**Innovatives Supercomputing  
in Deutschland**



# Editorial

German supercomputing has seen interesting and important changes since the last issue of InSide was published. First, the three German national supercomputing centres joined up to form the Gauss Centre for Supercomputing (GCS) with combined computing power of more than 120 TFLOP/s located in Stuttgart, Garching, and Jülich. You will find a report on the Centre in this issue. Behind these activities is the wish to bundle German HPC resources in an optimum way to provide users with the highest level of performance and service. At the same time the Gauss Centre for Supercomputing is going to represent Germany in the European HPC discussion. So, next, the Gauss Centre for Supercomputing and Partners from 14 European countries founded the consortium PACE – Partnership for Advanced Computing in Europe.

But there have also been big steps in hardware development in Germany. LRZ has installed its second phase upgrade with a peak performance of now 62 TFLOP/s, a description of which can be found in this issue. NIC only recently announced plans for its next phase installation due in autumn this year. More details will be given in the next issue. With these new hardware installations Germany continues its approach of a pyramid of performance at the national level co-ordinating its national supercomputing centres to create the best and most balanced system environment for German and European science.

In a second section a number of application papers are presented. The focus in this issue is on computational fluid dynamics. Three contributions describe problems of turbulence. With the new level of performance provided by the Gauss Centre for Supercomput-

ing users are able to tackle problems that have been beyond their reach only 3 years ago. The contributions nicely show how increase performance and memory size can help to achieve major breakthroughs which can also contribute to the solution of flow problems in industrial environments.

A third section is devoted to projects. The ParMA project (Parallel Programming for Multi-core Architectures) aims at fully exploiting the power of multithreading on multi-core architectures for conventional HPC applications, but also for embedded applications on Multi-Processor System-on-a-Chip (MPSoC) architectures. The EU-funded project CoSpaces is aimed at developing organizational models and distributed technologies for collaborative workspaces for individuals and project teams within distributed virtual manufacturing enterprises enabling effective partnerships, innovation, improved productivity, and reduced design cycles.

Increasingly middleware and tools become important for the HPC community and German HPC centres have very early focused on research in this field. In this issue you will find a description of a Fortran binding for the GNU scientific library, a much more extensive discussion of which will be given in the August 2007 issue of the ACM SIGPLAN Fortran Forum. The UNICORE Grid system provides a seamless, secure and intuitive access to distributed Grid resources such as supercomputers, clusters, and large server farms. The most recent development of UNICORE 6 is presented here.

As usual, this issue includes information about events in supercomputing in Germany over the last months and gives an outlook of workshops in the field. Readers are invited to participate in these workshops.

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## inSiDE

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- Prof. Dr. Dr. Th. Lippert (NIC)
- Prof. Dr.-Ing. M. M. Resch (HLRS)

# Smart Suction - An advanced Concept for laminar Flow Control of three-dimensional Boundary Layers

The list of reasons for a sustained reduction of commercial-aircraft fuel consumption is getting longer every day: significant environmental impacts of the strongly-growing world-wide air traffic, planned taxes on kerosene and emission of greenhouse gases, and the lasting rise in crude-oil prices. As fuel consumption during cruise is mainly determined by viscous drag its reduction offers the greatest potential for fuel savings. One promising candidate to reduce viscous drag of a commercial aircraft is laminar flow control (LFC) by boundary-layer suction on the wings, tailplanes, and nacelles with a fuel saving potential of 16%. (The other candidate is management of turbulent flow, e.g., on the fuselage of the aircraft, by a kind of shark-skin surface

structure that however has a much lower saving potential.) Suction has been known for decades to delay the onset of the drag-increasing turbulent state of the boundary layer by significantly enhancing its laminar stability and thus pushing laminar-turbulent transition downstream. However, in case of swept aerodynamic surfaces, boundary-layer suction is not as straightforward and efficient as desired due to a crosswise flow component inherent in the three-dimensional boundary layer.

Suction aims here primarily at reducing this crossflow, and not, as on unswept wings, at influencing the wall-normal distribution of the streamwise flow component. The crossflow causes a

primary instability of the boundary layer with respect to three-dimensional disturbances. They can grow exponentially in downstream direction, depending on their spanwise wave number, and lead to co-rotating longitudinal vortices, called crossflow vortices (see figure 1), in the front part of, e.g., the wings. Now, on swept wings with their metallic or carbon-fibre-ceramic skins, the discrete suction through groups of micro-holes or -slots with diameters of typically 50 micrometers can excite unwanted, nocent crossflow vortices.

The grown, typically steady vortices deform the laminar boundary layer and can cause its breakdown to the turbulent state by triggering a high-frequency secondary instability, occurring now already in the front part of the wing. The onset of such an instability highly depends on the state of the crossflow vortices. A determinant parameter is the spanwise spacing of the vortices, influencing also their strength. The spacing of naturally grown vortices corresponds to the spanwise wavelength of the most amplified eigenmode disturbance of the base flow. Even in most cases of discrete suction through groups of holes or slots with relatively small spanwise and streamwise spacings such a vortex spacing appears on a suction panel as the strong growth of the most amplified disturbance always prevails. This explains why transition can also set in when "stabilizing" boundary-layer suction is applied. If the suction were perfectly homogeneous over the wall, the suction itself would not excite nocent modes, but any surface imperfections like dirt, insects and so on would.

Recently, a new strategy for laminar flow control has been proposed and experimentally [1] and numerically demonstrated [5]. At a single chordwise location artificial roughness elements are laterally placed and ordered such that they excite relatively closely-spaced, benign crossflow vortices that suppress the nocent ones by a nonlinear mechanism and do not trigger fast secondary instability. If the streamwise variation of flow conditions and stability characteristics is weak this approach has proven to impressively delay transition. A better understanding of the physical background of the effectiveness of this approach has been provided by direct numerical simulations [5], who coined the term Upstream Flow Deformation (UFD).

A major shortcoming of UFD with its single excitation of benign vortices is that it works persistently only for flows with non- or weakly varying stability properties. This typically is not the case on swept wings or tail planes where the boundary-layer flow undergoes a varying acceleration. Hence, an approach combining classical suction with the Upstream-Flow-Deformation method has been proposed by the authors of this article at the Institut für Aerodynamik und Gasdynamik (IAG) at the University of Stuttgart. The research is performed by direct numerical simulations (DNS) of the problem using a computer code developed at IAG that runs on the powerful parallel vector NEC super computers, currently the SX-8, installed at the High Performance Computing Centre Stuttgart (HLRS) (for computational details see [2][3]). Its optimization has been supported by the local NEC group.

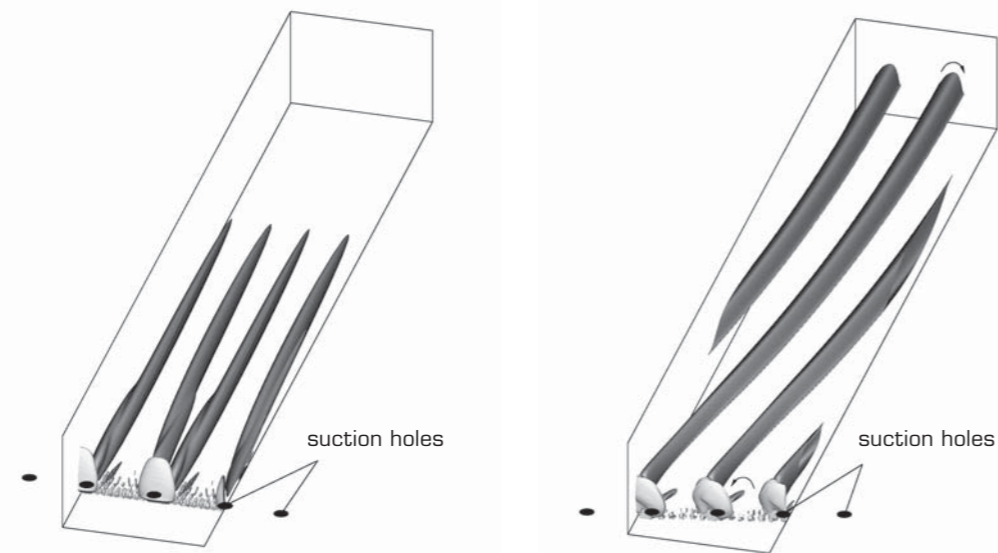


Figure 1: Visualization of vortices emanating from a single suction hole row on an unswept (left) and swept wedge (right). Arrows indicate the sense of vortex rotation. On the unswept wedge vortices are damped downstream, on the swept wedge corotating vortices are amplified due to crossflow instability

The main idea is to excite benign, closely-spaced (UFD-)vortices and to maintain them on a beneficial amplitude level by an appropriate order of suction orifices. The streamwise variation of flow conditions and stability characteristics can be taken into account by adapting the spacing of the suction orifices continuously or in discrete steps. In this way we overcome the shortcomings of the single excitation of UFD-vortices. However we note that this is not at all a trivial task because it is not clear a priori which direction the vortices follow - the flow direction depends on the wall-normal distance - and improper excitation can lead to destructive nonlinear interaction with benign vortices from upstream, or no-cent vortices. For illustration of a case where the adaptation to the chordwise varying flow properties has been done in an improper way see figure 2.

If properly designed (see figure 3) the proposed method unifies the stabilizing effects of boundary-layer suction and UFD. Consequently, the new method strives for (i) securing the working of suction on swept surfaces, and (ii) an additional stabilization of the boundary-layer flow compared to classical suction alone, or, alternatively, it allows to reduce the suction rate for the same degree of stabilization. By the excitation of selected crossflow modes being exponentially amplified and finally forming crossflow vortices not triggering turbulence, the stability of the flow is enhanced as would the suction rate of a conventional suction system have been risen. The reason is that the vortices generate by nonlinear mechanisms a mean-flow distortion not unlike suction, cf. [5], influencing the stability in an equally favourable manner as suction itself. The new method is termed

*smart suction* as the instability of the laminar flow is exploited to enhance stability rather than increasing the suction rate. We hope that it pushes the suction technique that has been prepared by the airliner manufacturers but not yet applied in daily operation to real operational success. Fuel and involved exhaust gas savings of about 16% can be expected using properly working suction on the wings, the tailplanes and the nacelles (see also [4]). As research must not rest on one's laurels simulations of larger parts of the wings and investigations of exciting and maintaining benign vortices by roughness, bumps, dips, or localized suction/blowing actuators are planned. Moreover, the applicability of the technique to LFC on wind turbine rotors is scrutinized.

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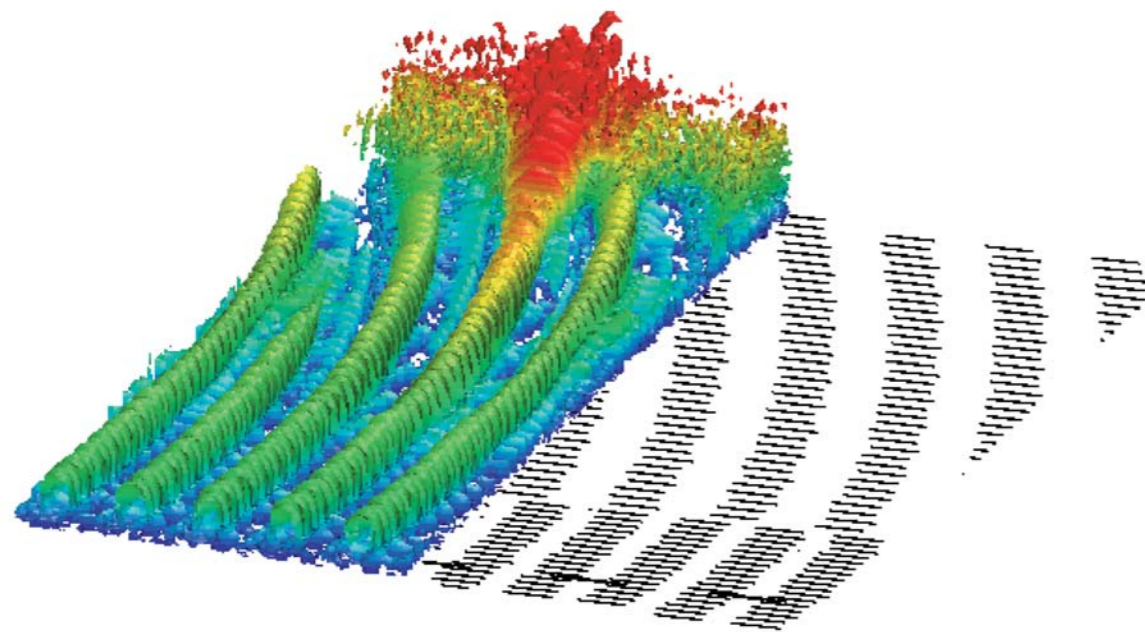


Figure 2: Visualization of vortices (left) and suction orifices/slots at the wall (right) in perspective view of the wing surface for smart suction with improper adaptation of suction orifices. Flow from bottom to top, breakdown to turbulence at the end of domain

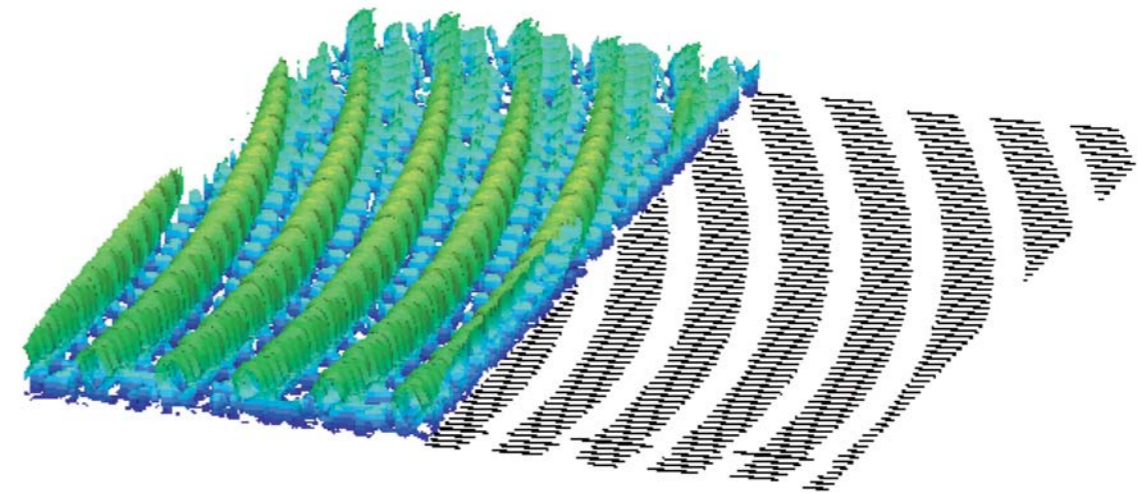


Figure 3: As for figure 2 but with proper adaptation of suction orifices for a simple case

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