Minisymposium: GLOBAL FLOW INSTABILITY

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Summary

Linear stability theory is concerned with the evolution of small-amplitude disturbances superimposed upon a steady- or time-periodic so-called *basic* flow. The vast majority of investigations during the second half of the last century has dealt with the analysis of one-dimensional (*"parallel"*) basic flows. On the other hand, *Global flow instability* deals with essentially non-parallel (as well as with weakly non-parallel) flows [1] and is an emerging and highly-active area of research, to which a Minisymposium has been dedicated. Four invited contributions from three countries were presented, one summarizing experimental work and the rest presenting alternative numerical methodologies to solve the large eigenvalue problem resulting in the context of BiGlobal instability analysis. Applications addressed ranged from laminar and turbulent separation control (Avi Seifert, Tel-Aviv University), vortex instabilities (Michael Broadhurst, Imperial College London), and cavity flow hydrodynamic (Leo González, School of Naval Engineering, UP Madrid) and aeroacoustic (Javier de Vicente, School of Aeronautics, UP Madrid) instabilities. With the exception of the first author, whose contribution is outlined below, papers were submitted describing in detail the contents of the talks delivered.

Dr. Avi Seifert explored the *Relationship of global flow instability and flow control*, based on experimental results in a wide variety of external aerodynamics configurations. He discussed possible relationships between global instability modes and control of separated regions. It was repeatedly found that the effective frequencies for control of separated flow on numerous configuration results in a Strouhal number of order unity. This Strouhal number is based on the length of the baseline separated flow region. Regardless of the turbulence level upstream of separation, the curvature and the history of the boundary layer, the effective frequency for reattaching a separated flow remains of order unity. It was hypothesized that a feed-back loop exists between the reattaching flow, sending upstream an acoustic wave that when coincides with the frequency of the actuator causes enhanced effectiveness and receptivity of the excitation introduced by the actuator. It is hoped that global flow instability analysis of a properly measured or computed baseline flow will enable to reproduce, explain and eventually predict this type of resonance.

Mr. Michael Broadhurst, in collaboration with Prof. Spencer J. Sherwin, used BiGlobal linear theory and Direct Numerical Simulation to discuss *Helical instability and breakdown of a Batchelor trailing vortex*. The new perspective offered concerned the relaxation of the restrictive assumption of azimuthal homogeneity, invariably used in earlier analyses of the same phenomenon. Their main conclusions were that (a) helical instability is responsible for the onset of spiral-type vortex breakdown and (b) pressure gradients were shown to exert a strong influence on the evolution of vortex breakdown. In the latter respect, they presented an extension of the Parabolized Stability Equations technique, which is capable of addressing the issue of pressure-gradients in the axial flow direction.

Dr. Leo González discussed *A finite-element alternative for BiGlobal instability analysis*, as an alternative to well-established spectral methods for the spatial discretization of the BiGlobal eigenvalue problem. Motivation for this approach is provided by the desire to address instability in flows over or within complex geometries. Low-order elements have been used (by contrast to the high-order spectral-element used by the previous authors) and several validation cases in closed and open flows have established the ability of the methodology presented to address the problem at hand. The flexibility of the method was exploited by analyzing, for the first time, a lid-driven cavity of triangular shape. From a numerical point of view, the key conclusion has been the need for a high-order extension of the finite-element method, that is presently unavailable for this class of stability problems.

Finally, Mr. Javier de Vicente, in collaboration with Profs. E. Valero and V. Theofilis, presented *Numerical considerations in spectral multi-domain methods for BiGlobal instability analysis of open cavity configurations*. They mainly focused on results of their parallelization efforts associated with the solution of the sparse-matrix based BiGlobal eigenvalue problem. Both incompressible and compressible flows can be addressed by the algorithms developed, respectively corresponding to hydrodynamic and aeroacoustic instabilities. Target application in this work has been the open cavity configuration, in the presence of model stores placed inside the cavity. The authors presented some distributed-memory solutions to the eigenvalue problem; on the basis of the associated convergence rates and CPU timings they concluded that shared-memory solutions were an alternative worthy of exploration.

Discussion of key issues presented during the Minisymposium followed, with a good degree of interaction between the speakers and the audience. Flow control was singled out as a promising direction[2], in which the tools presented in the Minisymposium may be applied. In this context, and at the invitation of the organizer, the Minisymposium was concluded by a short exposition by Prof. P. Luchini – a world-leading expert in the subject of global flow instability – of the connection between adjoint-based flow-control methodologies and global flow instability. Readers interested in further information on recent developments on the topic of Global Flow Instability, may also visit: *http://www.aero.upm.es/es/departamentos/crete05/Home.html*

References

1. Theofilis, V., "Advances in global linear instability analysis of nonparallel and three-dimensional flows," *Prog. Aero. Sci.*, Vol. 39, 2003, pp. 249–315.
2. S. S. Collis, R. D. Joslin, A. S. and Theofilis, V., "Issues in active flow control: theory, control, simulation and experiment," *Prog. Aero. Sciences*, Vol. 40, 2004, pp. 237–289.