EUROPEAN MECHANICS SOCIETY

Colloquium n. 658 – Coherent structures and instabilities in transitional and turbulent wall-bounded flows

Dates and location

15 September — 17 September 2025, Bari, Italy

Chairperson

Stefania Cherubini

Co-chairperson

Jean-Christophe Robinet

What other funding was obtained?

1000€ from Politecnico di Bari

What were the participants offered?

Morning coffee break and lunch every day. On Monday evening, they were offered a welcome Cocktail with a tour of the Old Town, and a Social Dinner on Tuesday Evening with bus trip to Alberobello (a small city on the South of Bari). Concerning the gadgets, at registration they received a bag with a pen, a schedule and a notebook.

Scientific report

It is still considered a remarkable fact that three-dimensional coherent motion develops in fluid flows at Reynolds numbers much smaller than the critical value for the rise of two-dimensional instabilities. This behaviour is recovered in simple parallel flows, such as pipes, boundary layers and channels, which are prone to subcritical transition, as well as in wall-bounded or open flows around solid objects of complex geometry, such as the flow over a roughness element or a wall cavity, but also in fully turbulent flows, in which three-dimensional coherent structures such as streaks and hairpin vortices are repeatedly observed.

For the case of parallel flows, the arising of three-dimensional coherent structures and the consequent transition to turbulence has been recently interpreted on the basis of a simplified self-sustained cycle relying on simple modal and non-modal energy growth mechanisms, coupled through non-linearity. This self-sustained cycle has proven to be able to explain recurrent exact coherent structures of different type (equilibria, periodic orbit, and chaotic motions) which appear to form the backbone of transition. However, it is still unclear if and how this simplified theory can be extended to the case of fully turbulent flows, where coherent structures develop on top of random, chaotic fluctuations at different (outer and inner) scales, or even to the case of more complex flows in which the laminar solution is far from being parallel, such as three-dimensional flows around solid objects.

In these particular cases, three-dimensional modal or non-modal instability might develop and interact with each other, potentially sharing some features with the self-sustained coherent structures found for the more simple parallel flows.

The purpose of the Euromech Colloquium 658 has been to bring together researchers studying the rise and development of

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instability mechanisms leading to three-dimensional flow structures in different shear flows, with the aim of trying to find some common features between the structures triggering or sustaining turbulence in such different cases. The deep knowledge of exact coherent structures in parallel flows, as well as the recent possibility of performing instability analysis on complex three-dimensional or fully turbulent flows, make now possible the achievement of such an ambitious goal.

These topics have been deeply discussed during the 3-days long Colloquium 658, which brought together 50 participants (excluding the organizers): 17 from France, 4 from Germany, 2 from UK, 12 from Italy, 1 from Netherlands, 2 from Poland, 2 from Spain, 4 from Switzerland, 6 from other countries (Australia, US, Israel).

Among the participant, 39 of them have presented their recent works in 15 minutes long talks. Three key-note lectures have been given, namely by Elena Marensi (UK), Kilian Oberleithner (Germany) and François Gallaire (Switzerland). During the conference, the discussions were grouped in different themes, listed and explained in the following.

One of the objectives of this conference was to bring together the “turbulence / sub-critical transition” community with the “linear instability” community. Many works have been presented on the computation of exact coherent solutions (ECS) of Navier-Stokes equations and the different connections between them, in particular concerning turbulent spot dynamics or the development of turbulent stripes in shear flows such as Couette, channel or Couette-Poiseuille flows. The first results have been shown on the role of optimal trajectories (in the sense of the energy of the system) in the dynamics around the ECS. Sessions “*Invariant coherent structure*”, “*Coherent structures in turbulent flow”* and “*Coherent structures and instabilities in complex flow”* were defined for this purpose. The "Invariant coherent structure" session provided an update on the latest advances in the calculation of ECS for pipe and channel flows.

Session “*Periodic flow”* has addressed the linear stability of periodic flows for mostly three-dimensional configurations. In the community interested in flow stability, this topic is growing rapidly. The set of presentations in this session have shown that the related numerical methods are now sufficiently mature to be applied to highly three-dimensional flow configurations (toroïdal pipe, sudden-expansion pipe, etc...).

*Session “Flow unsteadiness and low-order modeling” has been designed to provide a general framework for n*umerical studies on the modeling of flow unsteadiness and instabilities, often in a close collaboration with experiments whether in cross-comparison or in the use of data in order to improve reduced-order models.

Session "*Transitional flow*" aimed to show recent results on transitional flows and their control. The various presentations focused on both the detailed description of the physical phenomena responsible for the transition and the description of innovative control methods in order to either delay turbulence or suppress a specific characteristic of the dynamics.

Session *"Resolvent and receptivity analyse"* brought together the main presentations on the receptivity of transitional or turbulent flows, most often by using the global resolvent approach. This topic is currently very popular, especially for fully turbulent flows where these methods show remarkable efficiency.

Session "*Compressible flow*" is also representative of the renewed interest in high-speed (super/hypersonic) flows. The methods initially used in the incompressible regime (global stability and resolvent) are transposed to the compressible regime by taking into account shock wave-type discontinuities and the presence of acoustic radiation. These topic are very cutting-edge due to their possible applications to tough aerospace problems.

Sessions *“Coherent structures in turbulent flow”* and *“Coherent structures and instabilities in complex flow”* illustrate the renewed interest in the analysis of coherent structures of turbulent flows from a dynamical rather than a strictly statistical point of view both for academic configurations (pipe, Taylor-Couette, Couette-Poiseuille, boundary layer, wake) and more industrial ones (wind-turbine, rotor-stator, etc.).

The success of this conference encourages us to continue with the aim of bringing together the "instability of turbulent flows’’, “subcritical transition” and “coherent structure of turbulent flows" research communities. It would be interesting to repeat this conference in three or four years to evaluate the scientific evolution of these communities, and their upcoming interactions.

We thank Euromech for making this meeting possible, and for all the financial and organizational support.

Annex:

List names of participants

You will find below the list of people who have paid a Euromech member registration (36)

- Alferez Nicolas
- Alizard Frédéric
- Andriano Gaétan
- Ashtari Omid
- Bergeon Thomas
- Bertoncello Riccardo
- Bongarzone Alessandro
- Burton Thomas
- Ciola Nicola
- Cohen Jacob
- Duguet Yohann
- Gepner Stanisław
- Giannotta Alessandro
- Hao Zengrong
- Kozluk Adrian
- Larcheveque Lionel
- Leclercq colin
- Loiseau Jean-Christophe
- Manganelli Felice
- Mimeau Chloe
- Mongelli Giacomo Luca
- Nichols Joseph
- Palumbo Andrea
- Porpora Gianluca
- Ravaioli Alex
- Rist Ulrich
- Roemer Tristan
- Salamon Timothée

- Schneider Tobias
- Semeraro Onofrio
- Semin Benoît
- Spagnoletta Fabio
- Variale Donato
- Vellala Srinivas
- Wenzel Christoph
- Wesfreid José Eduardo

Below the list of participant we were already members of Euromech (11)

- Bottaro Alessandro
- Fasel Hermann
- Innocenti Giulia
- Jimenez Javier
- Kern Johann Simon
- Klotz Lukasz
- Nastro Gabriele
- Neves Neiva Joao Victor
- Sablon Julien
- Soria Julio
- Volokh Konstatin

Below the list of invited participant (3):

- Oberleithner Killian
- Marensi Elena
- Gallaire François