EUROMECH Colloquium 581

"Dynamics of concentrated vortices"

30 May – 1 June 2016, Novosibirsk, Russia

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Concentrated vortices of the vortex filament type are a key element in hydrodynamics. They play a fundamental role in the formation of the flow structure and the mechanisms of transport processes both at the micro- (quantum turbulence) and the meso- (coherent structures in turbulent flows; tornado) scales, and even in astrophysical systems.

The main focus of EUROMECH Colloquium 581 was on the specific features of vortex flows with vorticity concentration and the corresponding physical phenomena. The goal was to allow an effective exchange of ideas on recent developments in the field of concentrated vortex dynamics. Topics discussed included dynamics of vortex filaments, spiral vortices, the effects of instability and waves on vortices, vortex breakdown, vortex reconnection, swirling flames, vortices in two-phase flow, and quantum vortices. The latest methods of theoretical and numerical simulation of concentrated vortices, as well as experimental diagnostics and applications in the energy technologies and aerospace engineering, were presented.

There were 51 participants and about 52 presentations. These included six keynote lectures, delivered by:

1. Thomas Leweke (Marseille, France);
2. Renzo Ricca, (Lombardy, Italy);
3. Natalia Berloff (Cambridge, United Kingdom);
4. William George (London, United Kingdom);
5. Yasuhide Fukumoto (Kyushu, Japan);
6. Vladimir Shtern (Houston, USA).

During the sessions there was time for discussions; most of them were continued during coffee-breaks as well as during a visit to scientific laboratories of the Kutateladze Institute of Thermophysics. The topics considered in the talks and discussed afterwards were:

1. Theoretical and experimental methods for modelling swirl flows with concentrated vortices

Results of experimental observation of the helix-like cavitating vortex were presented. The phenomenon of vortex reconnection between coils of the same helical vortex was experimentally registered for the first time. Two different scenarios of the vortex reconnection were found: reconnection with separation of an isolated vortex ring and formation of a system consisting of the vortex ring, geared with a helical tube. Much attention was paid to development of measurement techniques for swirl flows – PIV and LDA as well as to the methods of velocity field analysis such as Proper Orthogonal Decomposition, and vortex recognition methods.

2. Concentrated vortices (dynamics, waves, helical vortices, vortex breakdown, PVC)

The mechanisms of vortex breakdown (VB) have been discussed over more than a half-century with no consensus achieved. Participants at the colloquium argued that VB occurs via the swirl-decay mechanism. The known diagram by Escudier for VB in a cylindrical container with a rotating lid was essentially extended in terms of parameter ranges and types of VB. Data were presented on the transition from the circular geometry of a container to a polygonal shape, up to square cross-section. The VB existence versus 'Re – aspect ratio' curve shifts to the area of higher Reynolds numbers and lower aspect ratio as the number of polygon angles decreases. Participants also discussed some recent incorrect approaches for analysing helical vortex motion.

3. Swirl flames. Heat transfer in swirl flows. Two-phase swirl flows

The role of vortex structures in different physical processes such as combustion, transfer of light or heavy phases and heat transfer was discussed during the colloquium. Some new effects of non-uniform

physical fields on the behaviour of vortices were revealed. The possibility of an analytical approach for adequate description for buoyancy vortex ring characterisation was demonstrated.

4. Dynamics of quantized vortices in superfluids

Among new findings in the area of superfluid vortices was the effect of mutual deformation of co-axial helical and rectilinear vortices. The effect is similar to the leapfrogging of vortex rings, but here the helical vortex transforms to rectilinear and back again, and the process repeats. Participants at the colloquium provided new knowledge about fundamental aspects, statistical data on superfluid turbulence and the possibility of modelling classical turbulence by quantized vortices in superfluids.

5. Concentrated vortices in technical applications

One of the sections of the colloquium that attracted particular interest was devoted to observation and description of concentrated vortices in real technical devices. A primary application is to vortex systems in wind turbines and hydroturbines. Recent achievements in this area became possible through fruitful cooperation of Danish, Russian, Canadian, Japan, French, Dutch, Swiss and Romanian researchers. At the same time, the vortex community recognised important historical studies on concentrated vortices (including Joukowski in Russia, Da Rios in Italy, Betz in Germany and Kawada in Japan).

During final discussion, participants agreed that in spite of considerable achievements in research on concentrated vortices there exist too many “white spots“. In order to colour them in, it would be appropriate to organise a similar meeting at some time between 2019 and 2021. Many participants said how much they had enjoyed the colloquium. Some commented that they had not expected such high levels of experimental, numerical and analytical study in such a remote Siberian region. Some of them talked about their aim to visit Russia, Siberia and well known Academgorodok. The organisers thank EUROMECH for making Colloquium 581 possible, and for all the financial and organisational support. They are also grateful for financial support from the Russian Foundation for Basic Research.