ANALYTICAL AND NUMERICAL METHODS FOR LINEAR AND NONLINEAR STABILITY ANALYSIS OF SWIRLING FLOWS

Goal of the project

The main objective of the project is to elaborate an improved methodology for investigating swirling flows stability using the mathematical analysis of hydrodynamic instabilities. The proposed methods are based on the application of stability and bifurcation analysis techniques in order to understand the dominant linear/ nonlinear instability of the swirling flows problems with applications in turbomachinery.

Short description of the project

The project approaches the fundamental problem of hydrodynamic stability of swirling flows. A large area of applications in problems of meteorological, aerodynamical or fluid dynamics significance has renewed the interest in the stability analysis of swirling, inviscid flows domain and the relation between the onset of vortex breakdown and hydrodynamic instability of the flow has been put under consideration. The occurrence of the precessing vortex and other instabilities in turbomachinery applications, address the mathematical modeling, the dynamic and stability of swirling flows, as well as the vortex breakdown phenomenon, which are all examples of fundamental problems in fluid dynamics.

We propose spectral methods based methodology that can be used for investigating classical questions addressed for swirling flows. Linear and non-linear stability theory offer a quantitative description of the flow behavior when infinitesimal disturbances are superimposed on the basic flow. Most fluid flows display either a growth in space or a complex spatio-temporal growth of disturbances. The main purpose is to conduct stability investigations based on the analysis of self-induced perturbations propagation in the swirling flow which will allow the recovery of the most relevant information using available computer resources in a very short time for a set of parameters.

Project implemented by

The Department for Mathematics, University "Politehnica" of Timisoara, numerical data and equipement from National Center for Engineering of Systems with Complex Fluids (NCESCF) (at University "Politehnica" of Timisoara).

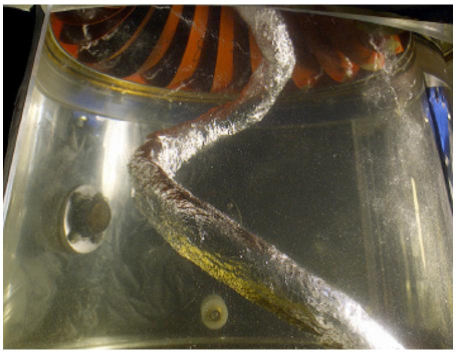
Implementation period

05.10.2011-04.10.2013

Main activities

The main activities are adequate for the proposed objectives:

- Analytical analysis of spectral methods for investigating the stability of the flow with a research on efficient implementations of linear solvers in the area
- Validate the results with data obtained by the experimental programs considered at NCESCF
- Actual application of the methods to problems triggered by swirling fluid dynamics
- Verification under industrially relevant conditions which will help in establishing the validity of the developed models



Fields of interest

The related physics problem is complex with important engineering applications. Solving of the problem using CFD techniques is challenging and time consuming. The approach of the problem using spectral method, which offers an alternative method can reveal important and complex physics and thus to improve engineering design in an efficient way. The researches of the project imply solving present days problems in turbomachinery hydrodynamics in order to understand fundamental aspects of the swirling flow hydrodynamic mechanisms so that one can chose the most efficient flow control method.

Results

- Numerical results on the physical parameters values for the swirling flows problems with application in turbomachinery
- Numerical analysis for the eigenvalue problems governing the linear stability of swirling flows
- Convective/absolute instability analysis of swirling flows
- Extension of the 1D solver for solving columnar swirling flows to the 2D case

The results were presented to international meetings on the subject and/ or published in international journals or proceedings.

1. Dijkstra, H. A., Wubs, F.W., Cliffe, A. K., Doedel, E., Dragomirescu, F.I., Eckhardt, B., Gelfgat , A.Y. , Hazel, A., Lucarini, V., Salinger, A.G., Phipps, E.T., Sanchez-Umbria, J., Schuttelaars, H., Tuckerman, L. S., Thiele, U., Numerical Bifurcation Methods and their Application to Fluid Dynamics: Analysis beyond Simulation, submitted to Communications in Computational Physics (submmitted 24.09.2012)
2. Dragomirescu, F. I., Efficient polynomials based method for a temporal stability investigation in a swirling flow stability problem, Proceedings 9th International Conference on Mathematical Problems in Engineering, Aerospace and Sciences (ICNPAA), Vienna University of Technology, Vienna, Austria, 10-14 Iulie, 2012, AIP Conf. Proc. 1493, pp. 322-329.
3. Dragomirescu, F.I., Susan-Resiga, R., Muntean, S., On the Laguerre functions based Galerkin type method in a swirling flow stability problem with applications in turbomachinery, Proceedings of the conference Mathematical Models in Engineering Science, Paris, Dec. 2012, 228-233.
4. Dragomirescu, F. I., Siddheshwar, P. G. Ene, R. D., Influence of micropolar parameters on the stability domain in a Rayleigh-Benard convection problem - A reliable numerical study, acceptat spre publicare in Italian Journal of Pure and Applied Mathematics, vol. 31, acceptat 16.06.2012.
5. Dragomirescu, F. I., Moisa, I., On Convective/Absolute Instabilities Quantifcation in Swirling Flows in Turbomachinery, Proceedings of the 13th International Conference of Mathematics and its Applications ICMA2012, Timisoara, Noiembrie 2012, 211-216.
6. Dragomirescu, F. I., Nonclassical polynomials based Galerkin formulation in a swirling flow stability problem, Proceedings of APLIMAT 2013, Bratislava, Feb. 5-7, 2013, p.17, 8pages.

The conclusions and a final report will be delivered at the end of the project.

Applicability and transferability of the results

The feasibility of the project is sustained by its significantly important engineering theme, with the results of importance for both applied mathematics and engineering. The main, and most important, goal is to explore the application of our methods modeling techniques to other applications involving simulation of fluid flow. The results are better designs, lower risk and faster time to the market place for these processes. Immediate applications within our research group include numerical stability results for analytical and discrete velocities profiles.

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