

Preface

This book is most probably the very first book ever on turbulent flows generated and/or influenced by multiscale/fractal structures. It consists of six chapters which demonstrate, each one in its own way, how such structures and objects can be used to design bespoke turbulence for particular applications and also how they can be used for fundamental studies of turbulent flows.

The chapter by S. Sakai sheds a new light on the fractal structure of trees and their effects as fractal sunshades through fractal-enhanced ventilation. The multi-scale compatibility of the fractal structure with the turbulent flow of air for efficient heat exchange is an interesting aspect which this chapter ends with and which is very promising for future research.

The chapter by Y. Sakai, K. Nagata, H. Suzuki and Y. Ito concerns turbulent mixing and diffusion and demonstrates, both experimentally and computationally through the study of various turbulent flows, that fractal grids can greatly enhance mixing and turbulent diffusivities by comparison to regular grids.

It may therefore be natural to expect fractal grids to bring improvements to combustion applications. The chapter of F. Hampp and R.P. Lindstedt demonstrate that this is indeed the case in particular for the very important case of fuel lean combustion. They use multiscale/fractal structures of a different type than the ones in the previous chapters thus helping to shape the concept of bespoke fractal flow design. This point is further strengthened in this chapter by the use of fractal grids optimised for maximum flame acceleration in conditions which are relevant to flame stabilisation in hypersonics.

There are other, very different, practical problems where fractal flow technology can help. F. Nicolleau's chapter applies such technology to the efficient measurement of flow rates in pipes and introduces the idea of a fractal orifice. The experiments and simulations reported in this chapter demonstrate that fractal orifices can be more efficient than classical circular orifices both in terms of pressure drop and in reduced disturbance of the flow.

The negative of a multiscale/fractal orifice, i.e. an orifice with a multiscale/fractal rim, is a multiscale/fractal plate, i.e. a plate with a multiscale/fractal perimeter. The chapter of J.C. Vassilicos shows how such plates can be used for fundamental studies of turbulent flows, for example to show that the shedding frequency is determined by the square root of the area of the plate and by none of all the other lengthscales in the multiscale perimeter, even though these lengthscales do have the effect of greatly reducing the intensity of the shedding. There are also experimental advantages for the very fundamental study of non-equilibrium (i.e. non-Kolmogorov) turbulence.

The final chapter by N. Reinke, A. Fuchs, M. Holling and J. Peinke is a very fundamental study of the turbulence cascade in fractal-generated turbulence as a stochastic process in scale space. Their study is based on multi-point statistics in terms of Kramers–Moyal coefficients. Their experiments and the analysis of their data lead them to the identification of different scaling regimes in the lee of the multiscale/fractal grid and a distinction between a classical saturated energy cascade and disturbed fully developed turbulence.

This book is the result of lectures given at an Advanced School in the International Centre for Mechanical Sciences (CISM) in Udine, Italy, in September 2013. One conclusion from these lectures which also comes out from this book is that there are multiple uses, both for a variety of applications and for fundamental studies, of multiscale/fractal-generated turbulent flows and bespoke fractal flow design. We are very grateful to CISM and ERCOFTAC for their support.

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Turbulence and Why

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