Shaping turbulence with smart particles

Project name	Shaping turbulence with smart particles
Subproject	Helical particles in turbulence: experiments
Type	PhD position
Start	2020–2021
Duration	4 years
Location	University of Twente, Enschede, Netherlands
Supervisors	Prof. Dr. Detlef Lohse, Assist. Prof. Dr. Sander Huisman

Can we design turbulence? Turbulence is every-where and yet our fundamental understanding and capabilities to control it remain limited. It is a remarkable property of turbulence that, rather irrespective of the large-scale forcing mechanism, it rapidly tends to restore a universal homogeneous and isotropic- state at smaller scales. This tendency to universality severely hinders our capability to modulate turbulence by acting on few (large-scale) degrees of freedom. This program will enter an unexplored terrain and design non-universal turbulence employing "smart" particles capable of applying appropriate small-scale forcing. The particles will be designed to interact with helicity and small-scale structures, thus touching turbulence at its own core. It will moreover shed light on the physics of complex-shaped particles dispersed in turbulent flows as occurring in nature, take e.g. pollen, plant seeds, fish, bacteria, algae, phytoplankton or sediments. Deeper understanding of these systems will open up the way to technological applications

In this project a systematic investigation of the dynamics of chiral particles in turbulence is planned by means of tracking of chiral particles, produced by 3D printing technology, and by means of flow velocimetry (PTV, LDV) in well controlled turbulent flows in the Twente water channel, the Twente mass and heat transfer water tunnel, the Twente turbulent Taylor-Couette facility, and the Boiling Twente Taylor-Couette facility. The goal of this project is to provide experimental data for the benchmarking of theoretical and numerical models for the dynamics of complex (chiral) particles in turbulent flows. To this end, 3D printed particles with chiral shape (such particles, realized as a proof-of-concept, are shown in Figures 1 and 2) will be produced and accurately tracked (both center of mass and rotational dynamics) under well controlled turbulent flow conditions. The influence of fluid inertia on the angular dynamics of almost neutrally buoyant or light particles is an open theoretical question. In this project the center of mass and rotational dynamics of neutrally buoyant and inertial (heavy) chiral particles will be investigated as a function of the most relevant particle/flow parameters. These include turbulence intensity, particle shape, particle size, and particle density. Typical questions that we want to answer include: how do particles of different sizes influence turbulence? Can the coupling between particle and fluid alter the helicity balance of the turbulent flow? By means of increasing the particle volume fraction we plan to investigate the coupling between particles and flow up to volume fractions of the order of 10%.

We plan to use the Twente water channel, the Twente mass and heat transfer water tunnel, the Twente turbulent Taylor-Couette facility, the Boiling Twente Taylor-Couette facility, and the new homogeneous isotropic turbulence facility to look at the dynamics and kinematics of the particles. These setups all have their advantages and disadvantages. Moreover, the group owns several 3D printer with which we can print small 3D with high accuracy.

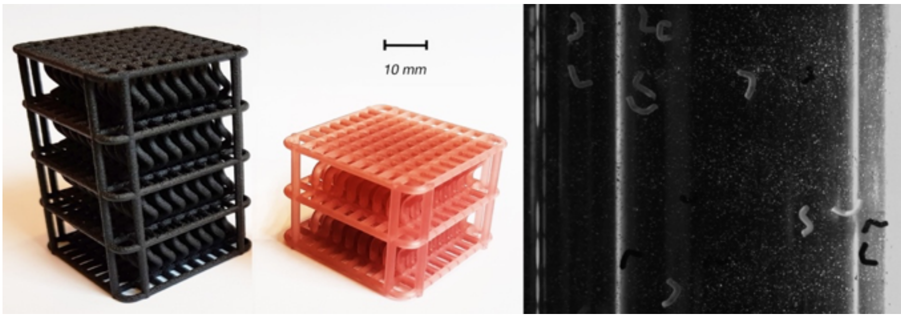

Figure 1: Left: Using 3D-printing the mass production of varying types of chiral, and other, particles was successfully accomplished in the Twente group. Here is show the mass production of small, nearly neutrally buoyant chiral rods (1.02 g/cc). Particles can easily be detached from the structure allowing for higher volume fractions of particles. For Taylor-Couette turbulence it is estimated that a volume fraction of 2% is well within the realm of expectation, thus making global drag measurements also feasible. The scale of the particles can be reduced to approximately 5mm in the largest direction, which is small enough to interact with turbulent structures observed in both the Twente Water Tunnel and Taylor-Couette facilities. On the left the Nylon particles are colored black. This color coding can be used to easily distinguish between the two chiralities. In the center of the figure a different type of semi-transparent Acrylic based plastic is used. These particles have been soaked in a rhodamine dye bath and have thus been made fluorescent for convenient tracking. Both the color coding and fluorescent approaches appear feasible for application. An algorithm has been developed that uses the 3D models also used to produce the particles to obtain the orientation from an image, allowing for full 3D orientation tacking of the rotations of any produced particle, enabling us to study the interaction between the turbulent flow and the chiral particles. This algorithm has been tested for single ellipsoidal and arbitrary patterned particles to extract the orientation and it works well. The neutrally buoyant particles were tested in the Taylor-Couette facility to observe their behavior. Preliminary recordings were made to see the behavior and the interaction with the Taylor-rolls present in the flow. A snapshot of this initial recording is shown on the right figure. Rotations of these particles and their position in the flow can be observed in these experiments. Another interesting topic is that of preferential concentration of chiral particles due to the Taylor-roll structure present in flow.

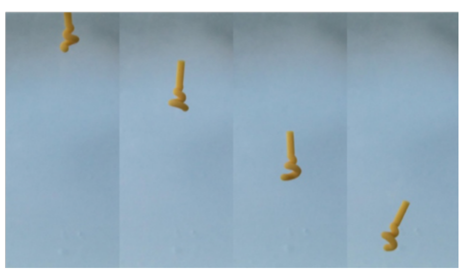

Figure 2: An example of a chiral, “Fusilli”-like, particle printed by the 3D printer of the Twente group. Complex particle shapes, together with external magnetic driving can shape turbulence by changing its behavior in unprecedented way. How do such particles behave in turbulence? How is turbulence influenced?

Your profile:

- You have a background in applied physics, aerospace engineering, or mechanical engineering, or in a closely related discipline. You have strong communication skills, including fluency in written and spoken English. You are enthusiastic and highly motivated to do a PhD. Experimental experience and experience in image and data analysis required. Knowledge of (convolutional) neural networks is a plus.

Our offer:

- We want you to play a key role in an ambitious project in an inspiring and stimulating international work environment.
- We provide excellent mentorship and a stimulating, modern research environment with world-class research facilities.
- You will have an employment contract for the duration of 4 years and can participate in all employee benefits the university offers.
- You will be embedded in a dynamic research group with colleagues working on similar topics.
- Additionally, the University of Twente is a green campus with excellent facilities and resources for professional and personal development, and offers a wide variety of sports facilities.
- You will follow a high-quality personalized educational program.
- The research will result in a PhD thesis at the end of the employment period.
- We strive for diversity and fairness in hiring.

Applicants should be in the possession of a master degree in physics, aerospace engineering, mechanical engineering, or closely related field. Applications should provide:

1. A motivation letter describing why you want to apply for this precise position.
2. Description of your research interests.
3. A detailed CV.
4. Academic transcripts from your Bachelor's and Master's degrees.
5. Name and email addresses of at least two visible references who are willing to send a letter of recommendation on your behalf.
6. An interview with a scientific presentation on your previous work will be part of the interview process.

Potential applicants are encouraged to apply to both Prof. Detlef Lohse and Assist. Prof. Sander Huisman.