MATEMAATIKA-LOODUSTEADUSKOND
MITMEFAASILISTE KESKKONDADE FÜÜSIKA TEADUSLABORATOORIUM
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2014

1. Struktuur

Mitmefaasiliste keskkondade füüsika teaduslaboratoorium, juhataja Ülo Rudi

Research Laboratory of Multiphase Media Physics, Head of laboratory Ulo Rudi

2. Teadus- ja arendustegevuse (edaspidi T&A) iseloomustus.

2.1. **Uurimisgrupi nimetus**:Aerosoolsete kanal-, gradient-ja keerisvooluste teoreetiliste aluste loomine ning rakendused tehnoloogilistes protsessides, uurimisgrupi juht Aleksander Kartušinski, DSc.

Research group: Development of the theory of the particulate channel, shear and vortical flows and its practical application in technologies, leader of the research group Aleksander Kartushinsky, DSc.

2.1.1 Uurimisgrupi teadustöö kirjeldus. The description of the research.

1. The main objective of the research of the flows is to develop 3D complete mathematical model for numerical simulation of the turbulent particulate flows in pipes and channels, jets and shear flow. The model considers 3D tangential motion and 3D rotational motion of a carrier (fluid) and particulate phases together with the four-way coupling which comprises the effect of the particles collisions. The modelling is mainly based on the RANS mathematical method and develops the theory of a free and wall-bounded particulate flows as well as the particles deposition onto various surfaces.

2. The second task of the research group is to develop the analytical and numerical modelling of the vortex ring-like structures. The asymptotic analysis, entrainment diagram method and direct numerical simulation are applied for analysing the structural features of these types of a vortex flow. For investigation of the mixing and transport inside the starting vortex flows the Lagrangian method is applied.

3. In order to validate the results obtained by the theoretical models, the laboratory applies the test rig based on the horizontal channel to generate the turbulent gas and gas-solid particles flows, including the grid-generated turbulent flow, the velocity shear flow, the free jets and the wall-bounded flows, and different measuring equipment, such as Dantec Dynamics Flow Explorer laser Doppler anemometer for the high-precision measuring of velocity and fluctuating velocity of gas and particles, 2D 15Hz particle image velocimeter (PIV) and 10KHz particle tracking velocimeter (PTV), which allow to measure the instantaneous velocities of gas and particles and produce 2D velocity vector fields as well as the particles mass concentration.

2.1.2 Põhilised teadustulemused 2014. aastal. The main scientific results in year 2014

1. The theme “Mathematical modelling of turbulent dense flows and applications”. 3D Reynolds Average Navier-Stokes (RANS) mathematical modelling of turbulent dense particulate flows in horizontal long rectangular channels with considering of particles influence on a carrier gas anisotropy, particle-particle interactions, translational and rotational particles’ motion as well as particles’ deposition. The numerical results showed that the effect of particles creates rapid anisotropy in a channel particulate flow.

It is found that the key force factors that are responsible for formation of 2D flow parameter distribution in CFB freeboard are the particle collisions stemmed both from particles size distribution and variation of particles material density and particle-turbulence interactions. (ETF grant 9343; papers…)

2. EMP230 project “DNS and 3D Reynolds Stress Turbulence Modelling in Particulate Channel Flows with Inter-Particle Collisions and Applications”. 3D RANS modelling of the turbulent particulate channel flow with square/rectangular cross-section. Within this modelling the closure of mass and momentum transport equations of both phases was carried out by means of 3D Reynolds Stress Turbulence Modelling (RSTM) of the carrier flow with implementation of Probability Density Function (PDF) formalism for the particulate phase.

3. Joint research with Eindhoven University (NL). 3D RANS modelling of the vertical pipe turbulent water solid particles-laden flow with implementation of PDF formalism for the particulate phase has been under consideration. The modelling considered particles inertia, flow turbulence and interparticle collision effects. Based on the obtained results a paper is being prepared for the journal of Physics of Fluids.

4. Joint research with Centre for Energy Technology (Adelaide University, Australia).

Main attention has been focused to 3D RANS modelling of the vertical pipe turbulent downward air flow loaded with solid light particles of various Stokes numbers with considering of effect of the Saffman lift and turbophoretic forces on the particles distribution. Based on the obtained results the article is being prepared for the journal of Physics of Fluids.

5. By experimental and theoretical study of dispersion of solid particles in highly diluted particulate turbulent flow in shear and grid-generated flow structures created in horizontal rectangular channel, it was found that a slower rate of particles dispersion occurs in shear flow versus the particles dispersion in grid-generated turbulence flow

6. Calculations of single-phase turbulent flow in the experimental setup including confusor, shear-forming apparatus, test section in the k-epsilon and LES approaches have been carried out. The results obtained are in good agreement with the experimental data. Calculations of particles dispersion from a point source in the previous calculations obtained shear flow were performed. An approach of Discrete Particle Modelling with solver Multiphase Particle-in-Cell (MPPICFoam) was used. We considered several ways of particles injection into the flow. Injection of particles from the cone with the values determined from experiments allows us to simulate the experimentally observed particle dispersion.

7. The model of confined vortex ring has been developed and its predictions have been compared with the results of the numerical simulations. Also the generalization of the vortex ring with elliptical core taking into account effects of the confinement is designed and applied

for prediction of the formation number. Results are presented in research workshop on vortex ring-like structures in sprays in Brighton University (UK). Submitted 2 papers to Journal of Fluid Mechanics.

2.1.3 Uurimisgrupi olulisemad publikatsioonid

1. Kartushinsky, A.; Hussainov, M.; Michaelides, E.E.; Rudi, Y.; Shcheglov, I.;Tisler, S.; Krupenski, I. (2014). Particles deposition at horizontal flat plate in turbulent particulate flow. Canadian Journal of Chemical Engineering, 92(1), 1 - 12.

2. Danaila, I; Kaplanski, F, Sazhin, S. (2014). Modeling of confined vortex rings. Journal of Fluid Mechanics, 1 - 24.

3. Kartushinsky, A.; Rudi, Y.; Shcheglov, I.; Tisler, S.; Krupenski, I. (2014). RANS Numerical Simulation of Turbulent Particulate Pipe Flow for Fixed Reynolds Number. J. Awrejcewicz (Toim.). Computational and Numerical Simulations. Rijeka, Croatia: InTech - Open Access Publisher, 21 – 40.

4. Kartushinsky, A.; Rudi, Y.; Hussainov, M.; Shcheglov, I.; Tisler, S.; Krupenski, I.; Stock, D. (2014). RSTM Numerical Simulation of Channel Particulate Flow with Rough Wall. J. Awrejcewicz (Toim.). Computational and Numerical Simulations. Rijeka, Croatia: InTech - Open Access Publisher, 41 - 63.

5. Kartushinsky, A.; Hussainov, M.; Rudi, Y.; Shcheglov, I.; Tisler, S. (2014). 3D RSTM and PDF modeling for turbulent particulate channel flows. 5th International Conference on Heat Transfer and Fluid Flow in Microscale - COST Action MP1106 Annual Meeting, 22-24 April 2014, Marseille, France. Marseille, France, 2014, O-39.

2.2 Laboratooriumi töötajad, kes on välisakadeemiate või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

Ülo Rudi, ajakirja Oil Shale nõustajate kogu liige; ajakirja Polityka Energetyczna (Energy Policy Journal, Poola Teaduste Akadeemia.) toimetuskolleegiumi liige; International Centre on Energy and Environment Policy liige; kirjastuse Elsevier ajakirja „Energy Policy“ retsensent.

Aleksander Kartušinski, Euroopa Liidu COST programmi projekti 1106 juhtkomitee liige; Euroopa Mehaanikanõukogu EUROMECH liige, ajakirjade Turbulence and Combustion, International Journal of Heat and Mass Transfer, Journal of Fluids Engineering, Physical Review & Research International, ASME Journal of Fluids Engineering, retsensent.

Feliks Kaplanski, Euroopa Mehaanikanõukogu EUROMECH liige, ajakirjade Physics of Fluids, J. Fluid Mechanics, TCFD, Turbulence and Combustion, FDR and reviewer of the European Mathematical Information Service (EMIS)

Sergei Tisler, Euroopa Liidu COST programmi projekti 1106 juhtkomitee liige.