ANR-DFG AIFIT meeting. Island VWS, Berlin Mitte jointly with TCM 2019
19.-20.12.2019

Thursday 19.12.2019

Participants:
Katsunori Katsunori (Nagoya University)
Julius Reiss (TUB)
Philipp Krah (TUB)
Mario Sroka (TUB)
Hung Truong (TUB)
Thomas Engels (U Rostock)
Kai Schneider (AMU)
Marie Farge (ENS)

Informal discussion started on 9h30. Talks presenting recent results just after.

10h00 Talk Thomas Engels (U Rostock) Adaptive numerical simulations of bristled wings

‘Fransen Flügel’ = bristled wings

Why should this be interesting? Only at low Reynolds number. Kleemeier wing. Robofly video.
Numerical simulation, showing a brief outline of the SISC paper. Time step restrictions.

Low Reynolds number limit (Re=5), here FD2 are used combined with CDF2,0 wavelets.

For time integration RKC (Chebychev) methods are used, 2nd order with s stages.
Stability region is shown, much larger than for RK4 (same number of stages).
If s is increased stability region becomes larger. But stability does not mean increased precision. 8 levels of refinement. Two strokes about 30 000 CPUh with RKC, much cheaper than RK4

Discussion about IMEX schemes. Problem when combining penalization with diffusion (penalized heat equation).

10h40 Talk Katsunori Yoshimatsu: Volume penalization for inhomogeneous Neumann and Robin boundary conditions (JCP 2019 paper).

Motivation, for VP, DNS and CVS. Also crystal growth.
One dimensional problems, error decay. O(h) decay when symmetric BC and O(h^2) when asymmetric.
Free convection in a concentric annulus (2d problem). Penalized equation using Boussinesq approximation.

Robin boundary conditions. 1d Poisson equation first. Exact solution of the penalized equation. O(\eta) penalization error. 1d numerics.
Discretization error. Linear system. Direct solves works, but not iterative methods.

Considering the eigenvalues one is negative.

11h50 Miriam Riebeck (TU Berlin): An active grid for the generation of turbulence: design, construction and first experimental results
Idea of the active grid. 0.2 x 0.2 m cross section. Wind tunnel, different configurations.
First measurements.
PIV, velocity magnitude average, two components. Turbulence intensity.
Question: Prof. Yoshimatsu: size of the insect (fly or BB), 1 cm – 2.5 cm
Decay of turbulence intensity, in 1d. Powerlaw decay. t^-\alpha, alpha= 1 … 1.5
Question of decay regime. Near grid, far grid turbulence.

15h00 Hung Truong (AMU). FSI modeling of flexible wings in revolving and flapping motion.

The complete bumblebee wing model was presented along with the results of FSI simulations in contexts of revolving wing and flapping wing.
The simulations as well as their results from the CaF paper were presented. Firstly, the influence of the number of mass points was studied where a 464 mass-point and 1064 mass-point wings were compared with each other. They showed minor differences in term of lift and drag generated. The wing with 464 mass-points was then chose for next steps due to its cost efficiency. The FSI simulation of a revolving wing was then presented. Flexible wing obtained better lift-to-drag ratio which was inferred as better aerodynamic performance than rigid wings.
Then, preliminary results of flapping flexible bumblebee wing were also presented, cf. ICIAM proceedings. These first results shown that flexible wings produced less lift and thrust than their rigid counterparts (28% and 11% respectively) but required much less aerodynamics power with 36% reduction. Moreover, in flapping motion, inertial forces are much stronger than ones in the revolving motion. They hence strongly deformed the wings and unrealistic shape was observed on wing surface with kinks and wrinkles, especially at the trailing edge. It was pointed out that bending stiffness needed to be added for the membrane part which would make the wing deformation resemble to one of real insect wings.

15h50 End of the session, leaving for Prof. Frank Thiele's workshop and dinner.

Friday, 20.12.2019

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Julius Reiss (TUB)
Philipp Krah (TUB)
Mario Sroka (TUB)
Hung Truong (TUB)
Thomas Engels (U Rostock)
Henja Wehmann (U Rostock)
Kai Schneider (AMU)
Marie Farge (ENS)

9h30 Talk Mario Sroka, Adaptive combustion
Motivation, combustion, turbulence, results

Motivation: pulsed detonation combustor (PDC), 2d numeric

Hydrogen air combustion. Borghi diagram, laminar flame speed versus flame thickness. Karlowitz number.
Flame ball in HIT (3d) and flame fromt in decaying turbulence.
Correlation of flame speed with u_rms is shown, compared with the theory Damkoehler.

Forcing techniques of turbulence: Lundgren, Carroll, Bassenne, Peterson are compared.
Differences in the equations between incompressible and compressible turbulence.
Integral length scale for different forcing types (0.2 L and 0.4 L), also including Rosales, Meneveau, JFM 2015.

10h16 Talk Philipp Krah. Wavelet-adaptive proper orthogonal decomposition.
Daedalus project. Snapshot POD using Delauriers&Dubuc wavelets, which are interpolating.

Old reference Eckart, Young, 1936. Psychometrika. Matrix reduction.

Build up correlation matrix, too big. So use block-based wavelet adaptation.
Preliminary results snapshot wPOD. Distrorted matrix c. Question how to control the error of the singular values.
Example for a flow past a cylinder. Good results for the eigenmodes.
Error estimation. In L infity norm. No uniform convergence of the eigenvalues, when the threshold goes to zero.
Final example for BB using wPOD. Low rank approximation.

11h00 Talk Julius Reiss, The shifted POD: A data based model reduction for configurations with transports of large gradients – and an idea for complex transports
Motivation. Gas turbine example. Assimilation results, 1d reactive Euler equations.
Detonative combustion chamber. Deflagration-to- Detonation-transition.
Moving front have slowly decaying singular values in POD. For one transport just change the frame into a moving one. For two transports use multiple frame decomposition, the so-called shifted POD> Shift and reduce method (SISC paper 2018), residuum based minimization, singular value based objective minimization.
Decomposition as an optimization using a steepest descend.
Schatten 1-norm for optimization, sum of the singular values.
Remarks on boundary treatment (wave in space and time).
Vortex and a flames, pacman example.
Introducting auxiliary fields, e.g signed distance function, can stabilize the POD of movin flames.

12h00 Talk Katsunori Yoshimatsu. Large scale structure . Two point velocity correlation tensor., either in physical space or in spectral space. Batchelor turbulence (k^4 at large scales for the spectrum), or Saffman turbulence (k^2 at large scales for the spectrum).
Decay of TKE as power law. Asymptotic development of the spectral tensor, see Yoshimatsu & Kaneda PRF, 2018. Presentation of the self-similarity form.

E-Z-H decomposition (energy, polarization and helicity, see Sagaut&Cambon's book).
Reflection asymmetry.

Passive scalar theory. Question of large scale anisotropy, role of dissipation is negligible. Freezing of the scalar anisotropy. For isotropic passive scalar turbulence, starting with Corrsin 1951.
Scalar spectral correlation is shown, no scalar source, vanishing mean.
DNS examination of the theory. Low magnetic Reynolds number MHD turbulence, using the quasi-static approximation. Columnar like structures. Anisotropy grows in time. Scalar anisotropy is almost constant at later times.
Spectra of the scalar and the self-similar assumption has been verified.

No question, later: void regions? Clustering?

12h30 Talk Henja Wehmann. Wind tunnel & flying flies.

The species used for free-flight experiments is the sheep-blowfly *Lucilia sericata.* It is planned to have flies fly under different flow conditions inside a closed wind tunnel. The tunnel is closed in order to be able to conduct flow measurements via particle imaging velocimetry (PIV) by seeding the tunnel with particles.
While *Lucilia* can fly upwind for all wind speeds produced by the tunnel (between ca. 0.2 and 1.8 m/s), it is expected that both wind speed and flow disturbances influence the flight trajectories. In order to have the flies fly into a certain direction, blue LEDs are used as a target, as flies tend to be positively phototactic. Only female flies are used, because then sex differences do not have to be accounted for. Female flies tend to be bigger, which is advantageous for the video recordings. Additionally, many previous studies on fly locomotion use female flies exclusively.
Flies are recorded and tracked in backlit conditions (infrared illumination, which they cannot perceive visually). This requires the background to be as light as possible. For the PIV flow measurements, the background should be as dark as possible. This means there is a conflict between the two experiments.
From the setup as it is, only the body position, but no body angles can be extracted. One idea brought into play by Kai Schneider is to calculate curvature and torsion angles on different scales. There was some discussion on the feasibility of automatically tracking the fly in the video recordings.
From the trajectories created so far it becomes apparent that some flies show repeatable behaviour (the trajectories look very similar when the fly is introduced to the tunnel multiple times), but not all of them do. In general, the repeatability of behaviour within a fly seems to be limited. Flies not older than about a week seem a little more likely to start flying when introduced to the tunnel than those older than a week. Younger flies also are less likely to have damaged wings. Flies seem a little more likely to start flying during late morning through afternoon compared to morning and evening. Some wind seems to lead more flies to land on the target compared to no wind and faster wind speeds (maximum target landing rate without flow disturbances around 1.5 m/s). While some starvation might improve flight motivation, the effects were not obvious and starvation of more than 15 hours may even worsen the performance. This means that non-starved flies younger than a week will be used in the experiments.
Flow disturbances may be induced by introducing poles into the tunnel, but these kinds of passive structures might not be the best choice. The active grid developed by Miriam Riebeck might be the solution.

Lunch break

Working session.

17h10 Talk Hung Truong. Optimization of wing parameters.

Principle of optimization, reference solution and equilibrium state.
CMA-ES (covariance matrix adaptation evolution strategy) was used for the optimization. A Matlab code developed by Nikolaus Hassen was coupled with the mass-spring model for the optimization of wing parameters.
An academic test case was shown to demonstrate the optimization process. A wing model with known flexibility was used as a reference data. The objective function for the optimization was defined as the norm 2 of the difference between the equilibrium position of the reference wing versus one of the optimized wing. Then, optimization code was used to retrieve the reference Young modulus with an error smaller than 1%. The objective function as a function the Young modulus was plotted. However, the current code is expensive due to the fact that the solid solver needs to be called hundreds even thousands of times during the optimization process. One-dimensional optimization took more than 10h to obtain the right flexibility parameter. For one-dimensional problem, we use the assumption that all Young modulus are the same, only the vein diameters are different. For higher dimension, the stiffness values of hinges will be taken into account because they can not be estimated from the vein diameters and this was expected to make the code even more costly in term of CPU time.

One solution was proposed to speed up the code by running the solid solver in parallel in Fortran and then giving back the objective function value to the Matlab optimization code.

18h30 Discussion Thomas Idris. Next steps.

End 19h.