Lumley Decomposition of the Turbulent Round Jet Far-field. Part 1 - Kinematics

The current work presents a tensor formulation of the Lumley Decomposition (LD), introduced in its original form by Lumley (1967b), allowing decompositions of turbulent flow fields in curvilinear coordinates. The LD in his form is shown to enable semi-analytical decompositions of self-similar turbulent flows in general coordinate systems. The decomposition is applied to the far-field region of the fully developed turbulent axi-symmetric jet, which is expressed in stretched spherical coordinates in order to exploit the self-similar nature of the flow while ensuring the self-adjointness of the LD integral. From the LD integral it is deduced that the optimal eigenfunctions in the streamwise direction are stretched amplitude-decaying Fourier modes (SADFM). The SADFM are obtained from the LD integral upon the introduction of a streamwise-decaying weight function in the vector space definition. The wavelength of the Fourier modes is linearly increasing in the streamwise direction with an amplitude which decays with the -3/2 power of distance from the virtual origin. The streamwise evolution of the SADFM resembles reversed wave shoaling known from surface waves. The energy- and cross-spectra obtained from these SADFM exhibit a -5/3- and a -7/3-slope region, respectively, as would be expected for regular Fourier modes in homogeneous and constant shear flows. The approach introduced in this work can be extended to other flows which admit to equilibrium similarity, such that a Fourier-based decomposition along inhomogeneous flow directions can be performed.

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Corresponding author: Hodzic, A.
Contributors: Hodzic, A., Meyer, K. E., Velte, C. M., K. George, W.
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Research output: Contribution to journal › Journal article – Annual report year: 2019 › Research › peer-review
Lumley Decomposition of the Turbulent Round Jet Far-field. Part 2 - Dynamics
In the current work the reconstruction of the far-field region of the turbulent axi-symmetric jet is performed in order to investigate the modal turbulence kinetic energy production contributions. The reconstruction of the field statistics is based on a semi-analytical Lumley Decomposition (LD) of the PIV sampled field using stretched amplitude decaying Fourier modes (SADFM), derived in Hodžić et al. 2019, along the streamwise coordinate. It is shown that, a wide range of modes obtain a significant amount of energy directly from the mean flow, and are therefore not exclusively dependent on a Richardson-like energy cascade even in the κ-range in which the energy spectra exhibit the −5/3-slope. It is observed that the −7/3-range in the cross-spectra is fully reconstructed using a single mode in regions of high mean shear, and that shear-stresses are nearly fully reconstructed using the first two modes. These results indicate that most of the energy production related to shear-stresses is related to the first LD mode.

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Measurement of time response of helium-filled soap bubbles
A new method is proposed for measuring the time response of helium-filled soap bubbles (HFSB). A flow of air with bubbles is led through a square flow channel and a two dimensional slit is introduced downstream in the channel. This creates a strong local flow acceleration. Bubble paths are tracked with a camera and the time response is found by comparing bubble speed and acceleration to the local flow speed. The method can be used in a portable setup for monitoring bubble quality during experiments. Bubbles from a new bubble generator design are tested. The generator produces mono-disperse bubbles with a low time response, but data also suggest that the generator needs further optimization. Air-filled soap bubbles (AFSB) are also tested and appear to have a smaller time response than earlier reports on AFSB.

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Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, Technical University of Denmark
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Contributors: Meyer, K. E., Meyer-Johansen, C. O., Finderup, A.
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Design of passive coolers for light-emitting diode lamps using topology optimisation

Topology optimised designs for passive cooling of light-emitting diode (LED) lamps are investigated through extensive numerical parameter studies. The designs are optimised for either horizontal or vertical orientations and are compared to a lattice-fin design as well as a simple parameter optimised commercial pin fin design. The different orientations result in significant differences in topologies. The optimisation favours placing material at outer boundaries of the design domain, leaving a hollow core that allows the buoyancy forces to accelerate the air to higher speeds. Investigations show that increasing design symmetry yields performance with less sensitivity to orientation with a minor loss in mean performance. The topology-optimised designs of heat sinks for natural convection yield a 26% lower package temperature using around 12% less material compared to the lattice-fin design, while maintaining low sensitivity to orientation. Furthermore, they exhibit several defining features and provide insight and general guidelines for the design of passive coolers for LED lamps.

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Corresponding author: Alexandersen, J.
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Research output: Contribution to journal › Journal article – Annual report year: 2018 › Research › peer-review

Experimental comparison and visualization of in-tube continuous and pulsating flow boiling

This experimental study investigated the application of fluid flow pulsations for in-tube flow boiling heat transfer enhancement in an 8mm smooth round tube made of copper. The fluid flow pulsations were introduced by a flow modulating expansion device and were compared with continuous flow generated by a stepper-motor expansion valve in terms of the time-averaged heat transfer coefficient. The cycle time ranged from 1s to 7s for the pulsations, the time-averaged refrigerant mass flux ranged from 50kgm$^{-2}$s$^{-1}$ to 194kgm$^{-2}$s$^{-1}$ and the time-averaged heat flux ranged from 1.1kWm$^{-2}$ to 30.6kWm$^{-2}$. The time-averaged heat transfer coefficients were reduced from transient measurements immediately downstream of the expansion valves with 2K and 20K subcooling upstream, resulting in inlet vapor qualities at 0.05 and 0.18, respectively, and covered the saturated flow boiling range up to the dry-out inception. Averaged results of the considered range of vapor qualities, refrigerant mass flux and heat flux showed that the pulsations at low cycle time (1s) improved the time-averaged heat transfer coefficients by 5.6% and 2.2% for the low and high subcooling, respectively. However, the pulsations at high cycle time (7s) reduced the time-averaged heat transfer coefficients by 1.8% and 2.3% for the low and high subcooling, respectively, due to significant dry-out when the flow-modulating expansion valve was closed. Furthermore, the flow pulsations were visualized by high-speed camera to assist in understanding the time-periodic flow regimes and the effect they had on the heat transfer performance.

General information
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Experimental validation of additively manufactured optimized shapes for passive cooling

This article confirms the superior performance of topology optimized heat sinks compared to lattice designs and suggests simpler manufacturable pin-fin design interpretations. The development is driven by the wide adoption of light-emitting-diode (LED) lamps for industrial and residential lighting. Even for advanced lighting technologies as LEDs, a large fraction of the input power is still converted to heat. Thus, efficient thermal control lowers energy waste, increases lifetime and reduces maintenance costs of this rapidly growing, expectedly soon to be governing, illumination technology. The presented heat sink solutions are generated by topology optimization, a computational morphogenesis approach with ultimate design freedom, relying on high-performance computing and simulation. Optimized devices exhibit complex and organic-looking topologies which are realized with the help of additive manufacturing. To reduce manufacturing cost, a simplified interpretation of the optimized design is produced and validated as well. Numerical and experimental results agree well and indicate that the obtained designs outperform lattice geometries by more than 21%, resulting in a doubling of life expectancy and 50% decrease in operational cost.

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Corresponding author: Lazarov, B. S.
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Pod analysis of flow structures behind cylinders with concave fillets

Surface modifications of cylinders using fillets are investigated with respect to flow structures in a cross flow to a cylinder. Three cylinders are used: a plain cylinder, a cylinder with a helical fillet and a cylinder with a helical staggered pattern of small fillets in tangential direction. The flow field in the wake region is measured with Particle Image Velocimetry (PIV) in both a plane normal to the cylinder and a plane in the wake shear layer perpendicular to the free stream direction. Three different Reynolds numbers in the range from 0000 to 120000 are used. The helical fillet modifies the wake to be more narrow and longer and with less turbulent kinetic energy in the wake. The staggered fillet modifies the shear layers forming at the sides of the cylinder to contain three-dimensional structures. This reduces vortex shedding significantly resulting in even less turbulent kinetic in the wake. Proper Orthogonal Decomposition (POD) is shown to be an effective method for describing three-dimensional time varying flow structures using non-time-resolving planar measurements.

The Effect of Pulsations in Conditions related to Catalytic Converters

The effect of pulsations in a catalyst converter is investigated with the aim of determining if a steady flow captures the same physical phenomena as the pulsating flow. For this specific case, guide vanes are mounted in the sudden expansion to obtain a uniform inlet flow to the catalytic layers. The test rig is successfully validated against other similar measurements, done with a steady flow. The experiments are carried out with a Reynolds number of 105, a Womersley number orders of magnitude larger than 1, but with an ratio between the fluid though time and pulsation period below one. This last part results in a quasi-static boundary condition. For the present setup different amplitudes and pulsation frequencies are investigated. It is thus shown experimentally that they have no influence on the mean flow. A repeatability study has been conducted which shows an overall repeatability of around 2%. An error is observed, where unwanted fractions of the packing block parts of the catalyst dummy. These fractions influence the velocity fields by clogging the hules of the catalyst dummy, but the influence is assumed to be small. Based on the results it is concluded that the mean flow field for this case is independent of the pulsations. When air enters the system a vortex ring appears in front of the catalytic dummy.

Adjoint Optimisation of the Turbulent Flow in an Annular Diffuser

In the present study, a numerical optimisation of guide vanes in an annular diffuser, is performed. The optimisation is preformed for the purpose of improving the following two parameters simultaneously; the first parameter is the uniformity...
perpendicular to the flow direction, a 1/3 diameter downstream of the expansion. The second parameter is the pressure loss introduced by these guide vanes. The optimisation yields an improvement of the uniformity of 1.5% and a 28% reduction in the overall pressure loss.

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Continuous versus pulsating flow boiling. Experimental comparison, visualization, and statistical analysis
This experimental study investigates an active method for flow boiling heat transfer enhancement by means of fluid flow pulsation. The hypothesis is that pulsations increase the flow boiling heat transfer by means of better bulk fluid mixing, increased wall wetting, and flow-regime destabilization. The fluid pulsations are introduced by a flow modulating expansion device and are compared with continuous flow by a stepper-motor expansion valve in terms of time-averaged heat transfer coefficient. The cycle time ranges from 1 to 9 s for the pulsations. The time-averaged heat transfer coefficients are reduced from transient measurements immediately downstream of the expansion valves at low vapor qualities. The results show that the pulsations improve the time-averaged heat transfer coefficient by 3.2% on average at low cycle time (1 to 2 s), whereas the pulsations may reduce the time-averaged heat transfer coefficient by as much as 8% at high heat flux (q 35 kW/m²) and cycle time (8 s). The latter reduction is attributed to a significant dry-out that occurs when the flow modulating expansion valve is closed. Additionally, the effect of fluid flow pulsations is found to be statistically significant, disregarding the lowest heat flux measurements.

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Organisations: Department of Mechanical Engineering, Thermal Energy, Fluid Mechanics, Coastal and Maritime Engineering, Royal Institute of Technology, Danfoss AS
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Contributors: Kærn, M. R., Elmegaard, B., Meyer, K. E., Palm, B., Holst, J.
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Flow in axisymmetric expansion in a catalytic converter
The flow in an axisymmetric expansion (circular diffusor) is used in many different engineering applications, such as heat exchangers, catalytic converter and filters. These applications require a relatively uniform flow at the inlet. To minimise the pressure loss, an ideal solution would be to use a quite long expansion, but this is often not possible due to space restrictions. Therefore a short expansion combined with e.g. guide vanes is often used. The present study will use a Selective Catalytic Reduction (SCR) system for large marine diesel engines as a case. The catalyst is designed for a specific local flow rate and a non-uniform inflow to the catalyst will severely reduce the efficiency of the process. Since each ship will have a unique design the flow system, it is desirable to be able to design the system using Computational Fluid Dynamics (CFD). However, CFD fails to predict flow separation in many cases and cannot be used as the only design tool [1]. Typically CFD has to be validated against experimental data from representative designs under varying conditions to find trustworthy modelling, sufficient grid resolution and suitable boundary conditions. Here Particle Image Velocimetry (PIV) is a unique method that resolve the entire cross flow. This type of flow is expected to have a fluctuating ‘jet’-like structure from the smaller inlet pipe into the larger converter. The fluctuations of the jet are difficult, if not impossible, to capture with standard time averaged models, and more expensive methods like Large Eddy Simulation (LES) could be needed. Here PIV has an advantage compared with other measurement methods, because it captures instantaneous flow fields that are relevant for the catalyst efficiency and thus also for CFD validation. The aim of the present study is to investigate flow phenomena in sudden pipe expansions similar to design used for catalytic converters with different upstream conditions and flow conditioning devices like guide vanes. This is done to provide a set of data that can be used to validate the use of CFD to such flows. For the present study, a down-scaled model of the catalytic converter is constructed, see figure 1. The experiments are performed at laboratory conditions, with lower pressure, temperature and velocity than the full-scale catalytic converter. The Reynolds number based on the velocity in the inlet pipe and the diameter of the converter is Re = 200000. A preliminary study shows that this Reynolds number is high enough to ensure very small dependence of the Reynolds number. The inlet pipe has a diameter of D = 0.1 m. The catalytic container has a diameter of 2.8D and a length of 8D. The diffusor connecting the pipe and the converter container is expanding abruptly within a length of 0.5D. The inlet section has a length of 20D to give almost fully developed flow conditions before the expansion. Several inlet conditions will be investigated, including a straight pipe, one 90° bend and two out-of-plane bends. A catalyst dummy will also be mounted and tested. For the catalyst dummy different model factors will be tested to insure the corrected pressure resistance. The distanced from the expansion to the dummy will also be varied and tested. Then different guide vane configurations will be mounted to investigate the flow uniformity at the catalyst converter. The investigation is done with Stereoscopic Particle Image Velocimetry (PIV). The measuring plane, a cross plane through the converter pipe, will be transverse along the flow direction (z-axis at figure 1). The cross plane is created with a 200 mJ Nd:YAG double cavity laser. Two 16 MPixel cameras are placed in forward and backward scatter, respectively. Glycerine droplets with a diameter of about 2 µm, are used as tracer particles. Example results are shown in Figure 2, where the cross plane is placed 5D downstream of the expansion. Here the mean velocity field of 500 snapshots from the empty converter with a straight inlet shows that the flow consist of a fast ‘jet’ in the middle and negative velocity at the walls. A snapshot been selected to represent a very common flow structure corresponding to the first mode found from a snapshot proper orthogonal decomposition (POD) analysis [2]. The white line indicate the change from positive to negative velocity. In the snapshot, the ‘jet’ has spread along a line through the center and is in contact with two opposite walls. At the rest of the walls, a recirculation zone is seen. As seen in Figure 2, the wall region is well resolved except at the bottom where velocity vectors are missing due to optical reflections.

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Measurement of Turbulent Skin Friction Drag Coefficients Produced by Distributed Surface Roughness of Pristine Marine Coatings
Skin friction drag coefficients are determined for marine antifouling coatings in pristine condition by use of Constant Temperature Anemometry (CTA) with uni-directional hot-wires. Mean flow behaviour for varying surface roughness is analysed by zero pressure gradient, flat plate, turbulent boundary layers for Reynolds numbers from Rex = 1.91x10^5 to Rex = 9.54x10^5. The measurements were conducted at the Technical University of Denmark in a closed-loop wind tunnel redesigned for investigations as this. Ensemble averages of the boundary layer velocity profiles allowed for determination of skin friction drag coefficients as well as roughness Reynolds numbers for the various marine coatings across the range.
of Rex by fitting of the van Driest profile. The results demonstrate sound agreement with the present ITTC method for determining skin friction coefficients for practically smooth surfaces at low Reynolds numbers compared to normal operation mode for the antifouling coatings. Thus, better estimates for skin friction of rough hulls can be realised using the proposed method to optimise preliminary vessel design.

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Contributors: Zafiryadis, F., Meyer, K. E., Gökhan Ergin, F.
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POD Mode Robustness for the Turbulent Jet Sampled with PIV
An important challenge in the description and simulation of turbulence is the large amount of information that is needed to describe even relatively simple flows in detail. The frequent disagreement between Reynolds averaged Navier–Stokes-based simulations and experiments is well known. Albeit, direct numerical simulations and in certain cases large eddy simulations tend to agree fairly well with experiments, their practical implementation introduces the problem of data storage. The experimentalist, however, experiences the same problem, using highspeed particle image velocimetry (PIV) systems and even high speed volumetric PIV systems providing fully three dimensional velocity fields. Another challenge is how do we verify simulations against experiments and ensure that we indeed have simulated the same flow that we have measured?

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Continuous vs. pulsating flow boiling. Part 1: Experimental comparison and visualization
This experimental study investigates an active method for flow boiling heat transfer enhancement by means of fluid flow pulsation. The hypothesis is that pulsations increase the flow boiling heat transfer by means of better bulk fluid mixing, increased wall wetting and flow-regime destabilization. The fluid pulsations are introduced by a flow modulating expansion device and are compared with continuous flow by a stepper-motor expansion valve in terms of time-averaged heat transfer coefficient. The cycle time ranges from 1 s to 9 s for the pulsations. The time-averaged heat transfer coefficients are reduced from transient measurements immediately downstream of the expansion valves at low vapor qualities. The results show that the pulsations improve the time-averaged heat transfer coefficient by 3.2 % on average at low cycle time (1 s to 2) s, whereas the pulsations may reduce the time-averaged heat transfer coefficient by as much as 8 % at high heat flux (q ≥ 35 kW/m²) and cycle time (8 s). The latter reduction is adhered to the significant dry-out when the flow modulating expansion valve is closed.

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Publication status: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Fluid Mechanics, Coastal and Maritime Engineering, KTH - Royal Institute of Technology
Continuous vs. pulsating flow boiling. Part 2: Statistical comparison using response surface methodology

Response surface methodology is used to investigate an active method for flow boiling heat transfer enhancement by means of fluid flow pulsation. The flow pulsations are introduced by a flow modulating expansion device and compared with the baseline continuous flow provided by a stepper-motor expansion valve. Two experimental designs (data point sets) are generated using a modified Central Composite Design for each valve and their response surfaces are compared using the quadratic model. Statistical information on the significant model terms are used to clarify whether the effect of fluid flow pulsations is statistically significant in terms of the time-averaged flow boiling heat transfer coefficient. The cycle time range from 1 s to 9 s for the pulsations. The results show that the effect of fluid flow pulsations is statistically significant, disregarding the lowest heat flux measurements. The response surface comparison reveals that the flow pulsations improves the time-averaged heat transfer coefficient by as much as 10 % at the smallest cycle time compared with continuous flow. On the other hand, at highest cycle time and heat flux, the reduction may be as much as 20 % due to significant dry-out when the valve is closed. These values are higher than reported in part 1 of the paper, but evaluated more consistently at equal heat flux using the response surfaces.

Reconstruction of 3D flow structures in a cylindrical cavity with a rotating lid

The flow in a cylindrical cavity with a rotating lid has been studied for many years, e.g. by Sørensen et al (2006). It contains general flow phenomena like vortex breakdown and in some cases the break down is accompanied by multihelix vortices (Okulov et al, 2010). This type of flow phenomenon is difficult to capture experimentally since the flow is fully three-dimensional and also varies in time. A measurement in a point or in a plane will by itself not give the full picture of the flow. Measurement with Particle Image Velocimetry (PIV) analyzed with Proper Orthogonal Decomposition (POD) is a promising method of reconstructing the full three dimensional, time-varying flow structures. This has been attempted in Meyer et al (2008) and Meyer et al (2009). The analyzed measurements show both that the vortex breakdown in some cases is asymmetrical (rotating around the cylinder axis) and that the presence of helical vortices can be detected.

However, the interpretation of the resulting flow still is done with an element of guessing on whether a specific variation is caused by an actual time variation of a structure or is caused by the rotation of a three-dimensional structure. The present work will also be based on time-resolved stereoscopic PIV measurements in a vertical plane through the cylinder axis as shown in figure 1. Compared to Meyer et al (2008) the measurements will be expanded by adding measurements in several points outside the PIV data plane with a Laser Doppler Anemometer (LDA). LDA has a very good time resolution and the synchronized PIV and LDA measurements will therefore resolve the ambiguity in the interpretation of PIV data.
with respect to whether the flow variations are caused by rotation of a three-dimensional structure or is a real transient phenomenon.

Flow and edge scour in current adjacent to stone covers
This paper presents the results of an experimental investigation on edge scour adjacent to a stone cover laid on a sandy bed. The three-dimensional flow over the edge of the stone layer has been investigated by the use of particle image velocimetry. The flow measurements show a significant amount of turbulence in the primary flow near the junction between the stone layer and the sand bed and the formation of complex secondary-flow structures. The results show that the flow and the edge scour process in a steady current are governed by the size of the roughness elements and to some extent the side slope of the berm. The edge scour is caused by the combined action of the primary flow and the secondary flow. The primary flow stirs up the sediment and puts it into suspension, and the secondary flow carries it away from the junction between the stone layer and the sand bed, resulting in a scour hole forming adjacent to the toe of the stone layer. The measured scour depth attained a constant level of approximately one times the stone size in the live-bed regime; further, the scour depth showed a slight decrease when the side slope of the berm was increased. Design diagrams are presented for the scour depth and the time scale of the scour process.

A numerical and experimental study of the scavenging process in a two-stroke marine diesel engine

A numerical and experimental study of the scavenging process in a two-stroke marine diesel engine
Large eddy simulations of the influence of piston position on the swirling flow in a model two-stroke diesel engine

Purpose – The purpose of this paper is to study the effect of piston position on the in-cylinder swirling flow in a simplified model of a large two-stroke marine diesel engine. Design/methodology/approach – Large eddy simulations with four different models for the turbulent flow are used: a one-equation model, a dynamic one-equation model, a localized dynamic one-equation model and a mixed-scale model. Simulations are carried out for two different geometries corresponding to 100 and 50 percent open scavenge ports. Findings – It is found that the mean tangential profile inside the cylinder changes qualitatively with port closure from a Lamb-Oseen vortex profile to a solid body rotation, while the axial velocity changes from a wake-like profile to a jet-like profile. The numerical results are compared with particle image velocimetry measurements, and in general, the authors find a good agreement. Research limitations/implications – Considering the complexity of the real engine, the authors designed the engine model using the simplest configuration possible. The setup contains no moving parts, the combustion is neglected and the exhaust valve is discarded. Originality/value – Studying the flow in a simplified engine model, the setup allows studies of fundamental aspects of swirling flow in a uniform scavenged engine. Comparing the four turbulence models, the local dynamic one-equation model is found to give the best agreement with the experimental results.

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PIV and LDA measurements of the swirling flow in a low-speed two-stroke diesel engine

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Tomographic PIV measurements behind vortex generators

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Turbulent swirling flow in a dynamic model of a uniflow-scavenged two-stroke engine

It is desirable to use computational fluid dynamics for optimization of the in-cylinder processes in low-speed two-stroke uniflow-scavenged marine diesel engines. However, the complex nature of the turbulent swirling in-cylinder flow necessitates experimental data for validation of the used turbulence models. In the present work, the flow in a dynamic scale model of a uniflow-scavenged cylinder is investigated experimentally. The model has a transparent cylinder and a moving piston driven by a linear motor. The flow is investigated using phase-locked stereoscopic particle image velocimetry (PIV) and time-resolved laser Doppler anemometry (LDA). Radial profiles of the phase-locked mean and rms velocities are computed from the velocity fields recorded with PIV, and the accuracy of the obtained profiles is demonstrated by comparison with reference LDA measurements. Measurements are carried out at five axial positions for 15 different times during the engine cycle and show the temporal and spatial development of the swirling in-cylinder flow. The tangential velocity profiles in the bottom of the cylinder near the end of the scavenge process are characterized by a concentrated swirl resulting in wake-like axial velocity profiles and the occurrence of a vortex breakdown. After scavenge port closing, the axial velocity profiles indicate that large transient swirl-induced structures exist in the cylinder. Comparison with profiles obtained under steady-flow conditions shows that the scavenge flow cannot be assumed to be quasi-steady. The temporal development of the swirl strength is investigated by computing the angular momentum. The swirl strength shows an exponential decay from scavenge port closing to scavenge port opening corresponding to a reduction of 34%, which is in good agreement with theoretical predictions.

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Coupling of theory and practice through inductive learning in experimental fluid mechanics education: A practical study

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Measurement of the rotor wake using PIV on a scaled turbine rotor in a water flume

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Phase-locked stereoscopic PIV measurements of the turbulent swirling flow in a dynamic model of a uniflow-scavenged two-stroke engine cylinder

It is desirable to use computational fluid dynamics for the optimization of in-cylinder processes in large two-stroke low-speed uniflow-scavenged marine diesel engines. However, the complex nature of the turbulent swirling in-cylinder flow necessitates experimental data for validation of the used turbulence models. In the present work, the flow in a dynamic scale model of a uniflow-scavenged cylinder is investigated experimentally. The model has a transparent cylinder and a movable piston driven by a linear motor. The flow is investigated using phase-locked stereoscopic particle image velocimetry (PIV) and time resolved laser Doppler anemometry (LDA). Radial profiles of the phase-averaged mean velocities are computed from the velocity fields recorded with PIV and the validity of the obtained profiles is demonstrated by comparison with reference LDA measurements. Radial profiles are measured at five axial positions for 15 different times during the engine cycle and shows the temporal and spatial development of the swirling in-cylinder flow. The tangential velocity profiles in the bottom of the cylinder near the end of the scavenging process are characterized by a concentrated swirl resulting in wake-like axial velocity profiles and the occurrence of a vortex breakdown. After scavenging port closing the axial velocity profiles indicate that large transient swirl-induced structures exists in the cylinder. Comparison with profiles obtained under steady-flow conditions shows that the steady profiles in general will not be representative for the dynamic conditions. The temporal development of the swirl strength is investigated by computing the angular momentum. The swirl strength shows an exponential decay from scavenge port closing to scavenge port opening corresponding to a reduction of 34%.
PIV in a model wind turbine rotor wake

Stereoscopic particle image velocimetry (PIV) measurements of the flow in the wake of scale model of a horizontal axis wind turbine is presented. Near the rotor, measurements are made in vertical planes intersecting the rotor axis. These planes capture flow effect from the tip and root vortices. The stability of the tip vortices as a function of different tip speed ratios are demonstrated. An instability seems to occur after a time corresponding to four blade passages. The result is vortex pairing and in some cases grouping of three vortices. Further downstream in the wake, measurements in planes perpendicular to the rotor axis is used to investigate the dynamics in the far wake. Here, a precessing core is found and data indicate that the Strouhal number of the precessing is independent of the rotor speed.

PIV study of the effect of piston position on the in-cylinder swirling flow during the scavenging process in large two-stroke marine diesel engines

A simplified model of a low speed large two-stroke marine diesel engine cylinder is developed. The effect of piston position on the in-cylinder swirling flow during the scavenging process is studied using stereoassoscopic particle image velocimetry technique. The measurements are conducted at different cross-sectional planes along the cylinder length and at piston positions covering the air intake port by 0, 25, 50 and 75%. When the intake port is fully open, the tangential velocity profile is similar to a Burgers vortex, whereas the axial velocity has a wake-like profile. Due to internal wall friction, the swirl decays downstream, and the size of the vortex core increases. For increasing port closures, the tangential velocity profile changes from a Burgers vortex to a forced vortex, and the axial velocity changes correspondingly from a wake-like profile to a jet-like profile. For piston position with 75% intake port closure, the jet-like axial velocity profile at the adjacent downstream cross-sectional plane. This is characteristic of a vortex breakdown. The non-dimensional velocity profiles show no significant variation with the variation in Reynolds number.
Turbulent swirling flow in a model of a uniflow-scavenged two-stroke engine

The turbulent and swirling flow of a uniflow-scavenged two-stroke engine cylinder is investigated using a scale model with a static geometry and a transparent cylinder. The swirl is generated by 30 equally spaced ports with angles of 0°, 10°, 20°, and 30°. A detailed characterization of the flow field is performed using stereoscopic particle image velocimetry. Mean fields are calculated using both a fixed coordinate system and a coordinate system based on the instantaneous flow topology. Time-resolved measurements of axial velocity are performed with laser Doppler anemometry, and power spectra are calculated in order to determine vortex core precession frequencies. The results show a very different flow dynamics for cases with weak and strong swirl. In the strongly swirling cases, a vortex breakdown is observed. Downstream of the breakdown, the vortex becomes highly concentrated and the vortex core precesses around the exhaust valve, resulting in an axial suction effect at the vortex center. Mean fields based on the instantaneous flow topology are shown to be more representative than mean fields based on a fixed coordinate system in cases with significant variations in the swirl center location.
Airflow characteristics in the breathing zone of a seated person using desk incorporated pair of confluent jets as personalized ventilation - effect of supply velocities

A workplace with desk, desk incorporated personalized ventilation (PV) and a dressed thermal manikin with realistic body and surface temperature distribution were set in a test room (4.70 m x 1.62 m x 2.6 m). 15 L/s were supplied from a ceiling diffuser to ventilate the room at 26 °C air temperature. The PV consisted of two plane jets placed beside each other (confluent jets) and along the front edge of the desk. The slots had dimensions: 0.06 m x 0.5 m (W x L). The manikin was seated upright with abdomen pressed against the front edge of the desk. The airflow supplied isothermally and upwards from the inner jet (closest to manikin) was the same, twice bigger or twice lower compared to that of the outer jet. The mean velocity field at the breathing zone was measured by Particle Image Velocimetry: a dual cavity laser (λ = 532 nm) and a CCD camera - 35 mm lenses. Glycerol droplets (seeding) were added to the total volume air supply. The maximum absolute mean velocity measured near the manikin’s mouth was 0.25 m/s, when the two confluent jets supplied 8 L/s each. Same velocity was measured when the inner jet was supplying 8 L/s and the outer 4 L/s. The opposite combination, i.e. outer jet 8 L/s and inner 4 L/s, resulted in lower velocity (0.13 m/s) compared to that of the free convection layer alone: 0.20 m/s. The increased velocity at the face allowed more clean air to be inhaled.

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Edge scour in current adjacent to stone covers

The present paper reports some early results of an experimental investigation of edge scour in currents. Two kinds of measurements are made (1) Particle Image Velocimetry (PIV) measurements of secondary currents that take place near a junction between the stone cover and the sand bed in a clear-water experiment; and (2) scour measurements in actual scour experiment in the live-bed regime. The early results indicate that edge scour in a steady current propagating in-line with a stone layer is caused by the combined action of two effects; (1) Primary flow and (2) Secondary flow. The primary flow stirs up the sediment and puts into suspension, and the secondary flow carries it away from the junction between the stone layer and the sand bed, resulting in a scour hole forming adjacent to the toe of the stone layer.

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Flow diagnostics downstream of a tribladed rotor model

This paper presents results of a study of vortex wake structures and measurements of instantaneous 3D velocity fields downstream of a triblade turbine model. Two operation modes of flow around the rotor with different tip speed ratios were tested. Initially the wake structures were visualized and subsequently quantitative data were recorded through velocity field restoration from particle tracks using a stereo PIV system. The study supplied flow diagnostics and recovered the instantaneous 3D velocity fields in the longitudinal cross section behind a triblade rotor at different values of tip speed ratio. This set of data provided a basis for testing and validating assumptions and hypothesis regarding classical theories
Influence of piston displacement on the scavenging and swirling flow in two-stroke diesel engines

We study the effect of piston motion on the in-cylinder swirling flow in a low speed, large two-stroke marine diesel engine. The work involves experimental, and numerical simulation using OpenFOAM platform, Large Eddy Simulation was used with three different models, One equation Eddy, Dynamic One equation Eddy, and Ta Phouc Loc model, to study the transient phenomena of the flow. The results are conducted at six cross sectional planes along the axis of the cylinder and with the piston displaced at four fixed piston positions covering the air intake ports by 0%, 25%, 50%, and 75% respectively, for the fully opened case LES model with 8/12 million mesh points were used. We find that the flow inside the cylinder changes as the ports are closing, from a Rankine/Burger vortex profile to a solid body rotation while the axial velocity profiles change from a wake-like to a jet-like profile.

LES of turbulent jet in cross-flow: Part 1 – A numerical validation study

The paper presents results of a LES based numerical simulation of the turbulent jet-in-cross-flow (JICF) flowfield, with Reynolds number based on cross-flow velocity and jet diameter $Re=2400$ and jet-to-cross-flow velocity ratio of $R=3.3$. The JICF flow case has been investigated in great detail, involving conduction of two independent precursor simulations, prior
to the main JICF simulation, as the considered case has turbulent inflow conditions on both jet and cross-stream side. The LES results are directly compared to pointwise Laser Doppler Anemometry (LDA) measurements, showing a very good agreement on the level of various statistical quantities in all flow regions but the immediate jet-to-cross-flow exhaustion zone. Several LES computations involving grids of up to 15 million grid points have been conducted, showing no improvement in the agreement between numerical results and measurements, possibly indicating a LDA measurement problem in this particular region.
Ontogenetic differentiation of swimming performance and behaviour in relation to habitat availability in the endangered North Sea houting (Coregonus oxyrinchus)

The survival of the highly endangered, anadromous fish species North Sea houting (Coregonus oxyrinchus) depends on the correct timing of downstream dispersal during its early ontogenetic stages. To date, however, no studies have investigated the ontogenetic differentiation of swimming performance and behaviour, including the potential of habitat complexity to influence dispersal rates. By testing larval and juvenile North Sea houting in a laboratory, we examined (1) swimming performance measured as maximum swimming performance (Umax) and routine swimming speed (Uroutine) and (2) the potential of habitat complexity (i.e., cover providing shade) to influence dispersal behaviour in an indoor stream channel. The Umax and the Uroutine were 9.4 and 4.6 cm s\(^{-1}\), respectively, in the larvae [body length (BL) s\(^{-1}\): 7.3 and 3.5, respectively], and 25.2 and 16.3 cm s\(^{-1}\) in the juveniles (BL s\(^{-1}\): 7.0 and 5.2, respectively). We compared laboratory swimming performance data with water speeds in North Sea houting spawning areas in the Danish River Vidaa. Results showed that the water speeds present in 95% and 85% of the water column caused downstream displacement of larvae and juveniles, respectively. However, areas with slow-flowing water near river banks and river beds could function as nursery habitats. Stream channel experiments showed that cover providing shade caused delayed dispersal in both larvae and juveniles, but the larvae dispersed later and spent less time under cover than the juveniles, a finding that implies ontogenetic effects. Finally, the larvae refused to cross an upstream-positioned cover, a behaviour that was not observed in the juveniles. Therefore, habitat complexity may have the potential to influence dispersal behaviour in both larval and juvenile North Sea houting. Overall, we provided the first evidence of ontogenetic differentiation in the North Sea houting. These findings will be valuable for the development and dissemination of science-based conservation strategies.
Swirling flow in model of large two-stroke diesel engine

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Swirling flow in model of large two-stroke diesel engine
A scale model of a simplified cylinder in a uniflow scavenged large two-stroke marine diesel engine is constructed to investigate the scavenging process. Angled ports near the bottom of the cylinder liner are uncovered as the piston reaches the bottom dead center. Fresh air enters through the ports forcing the gas in the cylinder to leave through an exhaust valve located in the cylinder head. The scavenging flow is a transient (opening/closing ports) confined port-generated turbulent swirl flow, with complex phenomena such as central recirculation zones, vortex breakdown and vortex precession. The model has a transparent cylinder five diameters long and is fitted with a static valve with a simplified geometry. The piston motion is controlled by a linear motor. The flow in the experiment has a Reynolds number of 50000 based on cylinder diameter and bulk velocity. Stereoscopic Particle Image Velocimetry (PIV) is used to investigate the scavenging flow for cases with both static and moving piston. Measurements are carried out for several cross-sectional planes covering the majority of the cylinder length. The effect of swirl intensity is investigated using four different port angles going from 0 – 30 degree. Although the flow has a relatively low swirl number of around 0.4, a central recirculation zone is observed indicating a vortex breakdown. The steady flow is also analyzed with Proper Orthogonal Decomposition (POD). The analysis reveals systematic variations in the shape and location of the vortex core. Transient measurements using phase-locked PIV are carried out with moving piston. The transient measurements reveal a violent change in flow topology as a central recirculation zone is rapidly formed, resulting in a change from large positive to negative velocities of the axial component.

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Airflow Characteristics at the Breathing Zone of a Seated Person: Passive Control over the Interaction of the Free Convection Flow and Locally Applied Airflow from Front for Personalized Ventilation Application

A workstation with a desk-mounted Personalized Ventilation (PV) unit, with circular diffuser (d = 0.185 m) supplying air from the front/above towards the face of a thermal manikin with realistic body shape and temperature distribution was set in a climate chamber (4.70 m x 1.62 m x 2.6 m). The distance between manikin's face and the diffuser was 0.4 m. Mixing overhead ventilation at 15 L/s was used to ventilate the chamber. The room air temperature was kept at 20 °C. The PV air was supplied isothermally at 4, 6 or 8 L/s. The thermal manikin was sitting 0.1 m away from the front edge of the table.

Passive method for control over the airflow characteristics at the breathing zone to increase the amount of clean air in inhalation consisted of a rectangular board (0.63 m x 0.36 m) placed below the table and pressed against the abdominal. It acted as a barrier reducing the convection flow upcoming from the lower body. The resultant velocity field at the breathing zone was measured with Particle Image Velocimetry: a dual cavity laser (λ = 532 nm) and two CCD cameras with 35 and 60 mm lenses. Seeding consisting of glycerol droplets (d = 2-3 μm) was added to the total volume supply. The blocking of the convection layer by the board decreased twice the absolute mean velocity at the mouth: from 0.2 m/s to 0.1 m/s. This made it possible for the PV flow already at 4 L/s to penetrate the free convection flow, which without the board was achieved at the PV flow rate of 6 L/s.

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Airflow Characteristics at the Breathing Zone of a Seated Person: Active Control over the Interaction of the Free Convection Flow and Locally Applied Airflow from Front for Personalized Ventilation Application

A method for active control over the interaction between the free convection flow around occupant's body and locally applied airflow from front on the velocity field at the breathing zone of a seated person was studied. A workplace equipped with personalised ventilation (PV) generating flow from front/above against the face of a thermal manikin with realistic body shape and surface temperature distribution (used to resemble a seated human body) was set in a climate chamber (4.70 m x 1.62 m x 2.60 m). The air temperature in the chamber was kept at 20 °C. Ceiling diffuser supplied ventilation air at 15 l/s. The PV air was supplied isothermally at 4, 6 or 8 L/s. The PV diffuser with diameter 0.18 m, was located at distance 0.4 m from the face of the manikin. The distance between the lower chest of the manikin and the front edge of the desk was 0.1 m. Box with 6 small computer fans (suction box) was installed below the table board, above the thighs of the manikin, and was used to exhaust the air of the free convection flow coming from the lower body parts of the manikin. The velocity field at the breathing zone was measured with Particle Image Velocimetry consisting of a dual cavity laser and two CCD cameras. The maximum absolute mean velocity measured in the convective layer at the mouth of the manikin was 0.20 m/s and was reduced to 0.09 m/s when the suction box was used. Thus the weakend boundary layer can be penetrated by the PV flow at the lowered velocity. The use of the suction box and the PV at 4 L/s resulted in the same velocity at the breathing zone as when only PV was used at 6 L/s. The maximum absol
Airflow Characteristics At The Breathing Zone of a Seated Person: Interaction of the Free Convection Flow and an Assisting Locally Supplied Flow From Below for Personalized Ventilation Application

A workstation with Personalized Ventilation (PV) unit and a thermal manikin with realistic body and temperature distribution were set in a test room (4.70 m x 1.62 m x 2.6 m). Airflow at 15 L/s was supplied from a ceiling diffuser to ventilate the room and keep the temperature at 26 oC. The PV consisted of two plenum boxes nested in each other and placed below the desk top, with discharge slots 0.06 m x 0.5 m (W x L). The PV unit was pressed against the abdomen of the thermal manikin. Each box had a separate supply fan. The airflow supplied isothermally and upwards from the inner and outer box was the same: 4, 6, 8 and 10 L/s. The mean velocity field at the breathing zone was obtained by Particle Image Velocimetry: a dual cavity laser (λ = 532 nm) and two CCD cameras with 35 and 60 mm lenses. Seeding, glycerol droplets, was added to the total volume supply. The maximum absolute mean velocity measured near the mouth was 0.1 m/s, when the boxes were installed but not working. When the two slots supplied equal amount of air, the measured absolute mean velocity increased with increasing the supplied air with a maximum of 0.35 m/s at 10 L/s.

Influence of outlet geometry on the swirling flow in a simplified model of a large two-stroke marine diesel engine

We present Stereoscopic particle image velocimetry measurements of the effect of a dummy-valve on the in-cylinder swirling flow in a simplified scale model of a large two-stroke marine diesel engine cylinder using air at room temperature and pressure as the working fluid and Reynolds number 19500. The static model has stroke-to-bore ratio of 4, is rotationally symmetric and the in-cylinder swirling flow is enforced by angled ports at the inlet. We consider a case analogous to engine when the piston is at bottom-dead-center. In absence of an exhaust valve the overall axial velocity profile is wake-like and flow reversal is observed on the cylinder axis, close to the inlet. Downstream, the flow reversal disappears and instead a localized jet develops. The corresponding tangential velocity profiles show a concentrated vortex with decreasing width along the downstream direction. By placing a concentric dummy-valve at the cylinder outlet, the magnitude of reverse flow at the inlet increases, the strong swirl is diminished and the axial jet disappears. We compare these findings with previous measurements in vortex chambers and discuss the relevance of these results with respect to development of marine engines.
Influence of piston position on the scavenging and swirling flow in two-stroke diesel engines

We study the effect of piston position on the in-cylinder swirling flow in a low-speed large two-stroke marine diesel engine model. We are using Large Eddy Simulations in OpenFOAM, with three different models for the turbulent flow: a one equation model (OEM), a dynamic one equation model (DOEM) and Ta Phuoc Loc's model (TPLM). The simulated flows are grid-independent and they are computed in situations analogous to two different piston positions where the air intake ports are uncovered 100% and 50%, respectively. We find that the average flow inside the cylinder changes qualitatively with port closure from a Burgers vortex profile to a solid body rotation while the axial velocity changes from a wake-like profile to a jet-like profile. The numerical results are compared with measurements in a similar geometry [3] and we find a good agreement between simulations and measurements. Furthermore, we consider the unsteady flow and identify a dominant frequency in a power spectrum based on velocity which we show is due to precession of the vortex core, and compare with measurements of the unsteady flow obtained with Laser Doppler Anemometry.

Inside-out electrical capacitance tomography

In this work we demonstrate the construction of an ‘inside-out’ sensor geometry for electrical capacitance tomography (ECT). The inside-out geometry has the electrodes placed around a tube, as usual, but measuring ‘outwards’. The flow between the electrodes and an outer tube is reconstructed; allowing the inside-out sensor to move inside the outer tube. A test sensor was constructed and capacitances were measured using the charge transfer technique. Sensitivity matrices for the inside-out sensor were calculated with a finite element approach and some special issues with the sensitivity matrices are discussed. An adaptation of the Landweber algorithm, which works very well for the inside-out geometry, is presented and a definition of the spatial resolution of an ECT sensor is suggested. Tomograms from a test run of an inside-out sensor are presented and measurements of watercut are compared with images obtained by a camera and a simple direct result based on the capacitance vector.
Investigation of turbulent boundary layer flow over 2D bump using highly resolved large eddy simulation

A large eddy simulation (LES) study of turbulent non-equilibrium boundary layer flow over 2D Bump, at comparatively low Reynolds number $Re_h = U_x h/ν = 1950$, was conducted. A well-known LES issue of obtaining and sustaining turbulent flow inside the computational domain at such low $Re$, is addressed by conducting a precursor calculation of the spatially developing boundary layer flow. Those results were subsequently used as turbulent inflow database for the main non-equilibrium boundary layer flow computation. The Sagaut (Rech. Aero., pp. 51-63, 1996) sub grid scale (SGS) turbulence model, based on a local estimate of the subgrid scale turbulent kinetic energy $k_{sgs}$ and implicit damping of turbulent SGS viscosity $ν_{t(sgs)}$ in the near-wall region, was selected as a suitable basis for the present LES computations due to the fact that block structured MPI parallelized CFD code used in the current computations did not provide a direct possibility for wall-damping of, e.g., the Smagorinsky constant in the near-wall region. The grid utilized in the main calculation consisted of approximately $9.4 \times 10^6$ grid points and the boundary layer flow results obtained, regarding both mean flow profiles and turbulence quantities, showed a good agreement with the available laser Doppler anemometry (LDA) measurements. Analysis of the flow was directly able to identify and confirm the existence of internal layers at positions related to the vicinity of the upstream and downstream discontinuities in the surface curvature and also partially confirm a close interdependency between generation and evolution of internal layers and the abrupt changes in the skin friction, previously reported in the literature. © 2011 American Society of Mechanical Engineers.

Mechanical Engineering Practice – using a simple Stirling engine as case

The first technical course that students in mechanical engineering take at the Technical University of Denmark is called “Mechanical Engineering Practice”. We have used a simple Stirling engine as a design-implement project. Students were asked to design and build a heat engine using materials obtained by their own means and were competing on achieving the highest efficiency. We added an extra dimension to the project by making detailed measurements of the pressure variation to check simple thermodynamic models of the engine. The course had integrated lessons in sketching and technical drawing. The Stirling engine worked well in the drawing assignments. The Stirling engine also served as illustration of coming courses in mechanical engineering. The resulting engines had large variations in their design and most groups succeeded in building a functioning engine. However, achieved efficiencies were quite low.
PIV measurements of flow structures in a spray dryer

Stereoscopic Particle Image Velocimetry (PIV) measurements are made in horizontal planes in a simplified scale model of a spray dryer using water as fluid. The sample rate was sufficient to resolve phenomena at lower frequencies. Data reveal asymmetric velocity fields in both mean fields and dynamics. Data were analysed using Proper Orthogonal Decomposition (POD). An important periodic event is an elongation of the jet core cross section that results in a downstream displacement of the jet towards the chamber wall.

Planar measurements of velocity and concentration of turbulent mixing in a T-junction

Turbulent mixing of two isothermal air streams in a T-junction of square ducts are investigated. Three dimensional velocity fields and turbulent kinetic energy are measured with stereoscopic Particle Image Velocimetry (PIV). The concentration field is obtained with a planar Mie scattering technique using the stereoscopic PIV setup. The concentration measurement method is developed in the present study and the accuracy of the technique is investigated. The resulting data are two dimensional concentration fields taken at 4Hz. The combination of velocity, turbulence and concentration fields give valuable insight into the mixing process, e.g. by showing large scale flow instabilities. The present technique is well suited for easy testing of mixing devices and for validation of computational models.
The exhalant jet of mussels Mytilus edulis

The exhalant jet flow of mussels in conjunction with currents and/or other mussels may strongly influence the mussels’ grazing impact. Literature values of mussel exhalant jet velocity vary considerably and the detailed fluid mechanics of the near-mussel flow generated by the exhalant jet has hitherto been uncertain. Computational modelling of this phenomenon depends on knowledge of the velocity distribution near the exhalant siphon aperture of mussels to provide appropriate boundary conditions for numerical flow models. To be useful such information should be available for a range of mussel shell lengths. Here, we present results of a detailed study of fully open mussels Mytilus edulis in terms of filtration rate, exhalant siphon aperture area, jet velocity, gill area and body dry weight, all as a function of shell length (mean +/- SD) over the range 16.0 +/- 0.4 to 82.6 +/- 2.9 mm, with the corresponding scaling laws also presented. The exhalant jet velocity was determined by 3 methods: (1) measured clearance rate divided by exhalant aperture area, (2) manual particle tracking velocimetry (PTV) using video-microscope recordings, and (3) particle image velocimetry (PIV). The latter provides detailed 2-component velocity distributions near the exhalant siphon in 5 planes parallel to the axis of the jet and the major axis of the oval aperture, and hence estimates of momentum and kinetic energy flows in addition to mean velocity. Data obtained on particles inside the exhalant jet of filtered water was verified by the use of titanium dioxide seeding particles which were de-agglomerated by ultrasound to a size range of 0.7 to 2 μm prior to addition, to avoid retention by the gill filter of the mussels. We found that exhalant jet velocity was essentially constant at similar to 8 cm s(-1), and independent of shell length. Based on geometric similarity and scaling of mussel pump-system characteristics we found that these characteristics coincide approximately for all sizes when expressed as pressure head versus volume flow divided by shell length squared.

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Explanation of visual diagnostics of multihelix vortex breakdown

General information

Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Russian Academy of Sciences
Contributors: Okulov, V., Naumov, I. V., Meyer, K. E.
Pages: 556-560
Publication date: 2010
Peer-reviewed: Yes

Publication information

Journal: Doklady Physics
Volume: 55
LES based POD analysis of Jet in Cross Flow
The paper presents results of a POD investigation of the LES based numerical simulation of the jet-in-crossflow (JICF) flowfield. LES results are firstly compared to the pointwise LDA measurements. 2D POD analysis is then used as a comparison basis for PIV measurements and LES, and finally 3D POD analysis is conducted on the LES datasets, giving some clear depictions of interaction processes between dominant flow structures pertinent to the JICF flowfield.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Technische Universität Darmstadt
Contributors: Cavar, D., Meyer, K. E., Jakirlic, S., Saric, S.
Number of pages: 646
Pages: 253-259
Publication date: 2010

Host publication information
Title of host publication: Direct and Large-Eddy Simulation VII
Publisher: Springer
DOI:
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Source: orbit
Source ID: 275813

PIV Study of the Effect of Piston Motion on the Confined Swirling Flow in the Scavenging Process in 2-Stroke Marine Diesel Engines
The effect of piston motion on the incylinder swirling flow for a low speed, large two-stroke marine diesel engine is studies using the stereoscopic PIV technique. The measurements are conducted at 5 cross sectional planes along the cylinder length and at piston positions covering the air intake ports by 0%, 25%, 50% and 75%. The resulting swirling flow decays downstreams the bulk direction and variation in Reynolds number has only effect in terms of magnitude. When the piston translates towards the top-dwand-centra, it gradually starts closing the intake ports. The tangential velocity profile changes from Rankine/Burges vortex to forced vortex and axial velocity profile changes from wake-like to jet-like and then again to wake-like profile.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, MAN Diesel & Turbo
Contributors: Haider, S., Meyer, K. E., Schramm, J., Mayer, S.
Pages: 270
Publication date: 2010

Host publication information
Title of host publication: CIMAC Congress 2010
Publisher: Conseil International des Machines a Combustion
URLs:
SPIV study of passive flow control on a WT airfoil

Stereoscopic Particle Image Velocimetry (SPIV) measurements investigating the effect of vortex generators (VGs) on the flow near stall have been carried out in the purpose built LM Glasfiber wind tunnel on a DU 91-W2-250 profile. Measurements have been conducted at Re=0.9*10^6, corresponding to free stream velocity U=15 m/s. The objective was to investigate the flow structures induced by and separation controlling behavior of vortex generators on the airfoil. The experimental results show strong separation of the uncontrolled flow whereas an intermittent behavior appears for the controlled flow, where the appearance of vortex structures alternate with a slightly separated turbulent boundary layer. However, the controlled case is yielding less backflow than the uncontrolled one: On average, the controlled flow leaves a nicely attached flow as opposed to the incident one. For the controlled flow, the observed vortex structures generated by the devices are similar to those found in studies at lower Reynolds numbers. Further, mixing close to the wall, transferring high momentum fluid into the near wall region, is seen. The hypothesis of intermittent fluctuations in the boundary layer is further supported by a Snapshot Proper Orthogonal Decomposition (POD) analysis. This analysis also reveals some of the dynamics of the induced vortices, such as pulsations of axial velocity across the vortex cores and oscillations of the vortices primarily in the spanwise direction.

Characterization of Vortex Generator Induced Flow

The aim of this thesis is the characterization and modeling of the longitudinal structures actuated by vortex generators. Results from generic studies performed at low Reynolds numbers have shown that the device induced vortices possess helical structure of the vortex core. Further, their ability to control separation and downstream evolution across the chord of a circular sector have been studied. Similar flow structures to the ones found in the generic experiments have been found in a higher Reynolds number setting, more applicable to realistic cases common to, e.g., aeronautical applications. The helical structure of the vortices can, however, not be confirmed by the results of these experiments due to practical concerns of obtaining a measuring signal with high enough quality and resolution. Furthermore, in order to study the dynamics of the device induced structures, power spectra from LDA time series have been constructed from the burst-mode LDA theory developed mainly by Buchhave and George [19, 46]. In the process of applying this theory to the LDA time series, a technique has been developed correcting for the effect of random noise in spectra and correlations. The power spectra obtained from the flow behind the actuating devices did not display any distinct periodicity of the flow, but rather a random, or at best quasi-periodic, behavior. In addition, commonly employed interpolation and resampling methods for estimating power spectra from LDA data were compared to the corresponding spectra derived from hot-wire data. When the flow was well resolved, these methods showed acceptable results at high LDA data rates at all frequencies except at the highest ones. However, they failed miserably at low data rates, essentially burying the entire spectrum in frequency dependent noise beyond recognition.
Control of the Free Convection Flow within the Breathing Zone by Confluent Jets for Improved Performance of Personalized Ventilation: Part 1 – Thermal Influence

A new method for improvement the performance of personalized ventilation (PV) by control of the free convection flow based on confluent plane jets was studied. The confluent upward plane jets were generated close to the front of human body by openings at the front edge of a desk. The inner jet supplied controlled air while the assisting outer jet supplied room air. The mixing between the two jets was minimized by control of the shear stress between the two flows. Thus the air of the inner jet was transported upward to the face. In this paper, manikin-based equivalent temperatures were analyzed under the condition with this PV method and there was no thermal influence by the flow except for the back of neck.

Dynamic Mode Decomposition and Proper Orthogonal Decomposition of flow in a lid-driven cylindrical cavity

Stereoscopic PIV measurements investigating the effect of Vortex Generators on the lift force near stall and on glide ratio at best aerodynamic performance have been carried out in the LM Glasfiber wind tunnel on a DU 91-W2-250 profile. Measurements at two Reynolds numbers were analyzed; Re=0.9·10^6 and 2.4·10^6. The results show that one can resolve the longitudinal vortex structures generated by the devices and that mixing is created close to the wall, transferring high momentum fluid into the near wall region. It is also seen that the vortex generators successfully can obstruct separation near stall.
PIV Study of In-Cylinder Confined Swirling Flow for Scavenging 2-Stroke Marine Diesel Engines

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Center for Fluid Dynamics, MAN Diesel & Turbo
Contributors: Haider, S., Meyer, K. E., Cavar, D., Schramm, J., Mayer, S.
Publication date: 2009

Host publication information
Title of host publication: Proceedings of the 8th International Symposium on Particle Image Velocimetry: PIV09-0056
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Source ID: 255134

Reconstruction of 3D flow structures in a cylindrical cavity with a rotating lid using time-resolved stereo PIV
Time-resolved Particle Image Velocimetry (PIV) measurements in two perpendicular planes are used to reconstruct a flow in an axisymmetric facility in both time and space. The reconstruction is based on Proper Orthogonal Decomposition (POD) and is used to distinguish between spatial and temporal variations. The flow in a cylindrical cavity with a rotating lid of a height of three radii and a Reynolds number of about 3500 is used as example. The reconstruction identifies a series of flow structures including axisymmetric vortex breakdown and distinct vortex structures along the cylinder wall.

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Russian Academy of Sciences
Contributors: Meyer, K. E., Sørensen, J. N., Naumov, I.
Publication date: 2009

Host publication information
Title of host publication: 8TH INTERNATIONAL SYMPOSIUM ON PARTICLE IMAGE VELOCIMETRY
Source: orbit
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Spatial Spectra of Jet Turbulence Measured by Particle Image Velocimetry
The unique capabilities of particle image velocimetry (PIV) have been utilized together with two-point similarity theory to measure spatial spectra in a 'homogenized' fully-developed turbulence jet at relatively high Reynolds number (20,000). The theory developed by Ewing et al. [1] was found to be in excellent agreement with the data, and in fact key to the present application. Despite relatively poor spatial resolution of the scales of motion (up to 15 times the Kolmogorov microscale) and limited dynamic range due to progressive jet velocity decay, it was possible to produce highly accurate spectra over three decades. Key factors for these results are a very large ensemble of statistically independent realizations (N = 10,841) and a very large, composite field of view (20 relevant integral length scales) which limited the effect of windowing on the spectra.

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Chalmers University of Technology
Contributors: Wänström, M., George, W. K., Meyer, K. E.
Publication date: 2009
Evaluation of the Performance of Vortex Generators on the DU 91-W2-250 Profile using Stereoscopic PIV

Stereoscopic PIV measurements investigating the effect of Vortex Generators on the lift force near stall and on glide ratio at best aerodynamic performance have been carried out in the LM Glasfiber wind tunnel on a DU 91-W2-250 profile. Measurements at two Reynolds numbers were analyzed: Re=0.9·10^6 and 2.4·10^6. The results show that one can resolve the longitudinal vortex structures generated by the devices and that mixing is created close to the wall, transferring high momentum fluid into the near wall region. It is also seen that the vortex generators successfully can obstruct separation near stall.

A turbulent jet in crossflow analysed with proper orthogonal decomposition

Detailed instantaneous velocity fields of a jet in crossflow have been measured with stereoscopic particle image velocimetry (PIV). The jet originated from a fully developed turbulent pipe flow and entered a crossflow with a turbulent boundary layer. The Reynolds number based on crossflow velocity and pipe diameter was 2400 and the jet to crossflow velocity ratios were R = 3.3 and R = 1.3. The experimental data have been analysed by proper orthogonal decomposition (POD). For R = 3.3, the results in several different planes indicate that the wake vortices are the dominant dynamic flow structures and that they interact strongly with the jet core. The analysis identifies jet shear-layer vortices and finds that these vortical structures are more local and thus less dominant. For R = 1.3, on the other hand, jet shear-layer vortices are the most dominant, while the wake vortices are much less important. For both cases, the analysis finds that the shear-layer vortices are not coupled to the dynamics of the wake vortices. Finally, the hanging vortices are identified and their contribution to the counter-rotating vortex pair (CVP) and interaction with the newly created wake vortices are described.
POD as tool for comparison of PIV and LES data
Both Particle Image Velocimetry (PIV) and Large Eddy Simulation (LES) provide instantaneous velocity fields which can contain dynamical flow structures that occur systematically. Turbulent flows also contain random flow structures, and therefore there is a need for tools that can identify the systematic dynamic flow structures. We show how Proper Orthogonal Decomposition (POD) based on snapshots (instantaneous flow realizations) can be used for this purpose. As a test case, we use PIV measurements and LES calculations on the same turbulent jet in cross flow. The Reynolds number based on the crossflow velocity and pipe diameter is 2400 and the jet to crossflow velocity ratio is $R = 3.3$. The POD is able to identify two dynamic flow structures: jet shear-layer vortices and wake vortices. A good agreement for the dynamical content is found between PIV and LES.

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering
Contributors: Meyer, K. E., Cavar, D., Pedersen, J. M.
Publication date: 2007

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Place of publication: Rome
Publisher: Faculty of Engineering, University "La Sapienza"
Electronic versions:
MeyerPODPIVLES.pdf
Source: orbit
Source ID: 209651
Research output: Chapter in Book/Report/Conference proceeding Article in proceedings – Annual report year: 2007 Research peer-review

Stereoscopic PIV and POD applied to the far turbulent axisymmetric jet
Recent experiments on asymptotic high Reynolds number turbulent jet have shown a difference between results from the slice POD applied to the full velocity vector and to the streamwise component of velocity only. In particular, the evolution of the peak in the energy toward azimuthal mode-2 in the streamwise velocity component decomposition noted in earlier experiments, shifted to mode-1 if all three components of velocity were considered. This is in contrast to what appears to be the case for the jet mixing layer and the axisymmetric wake where no such differences were observed. The work reported here applies stereoscopic PIV to the far field of the same jet in which the mode-2 phenomenon was first noticed. Indeed azimuthal mode-1 is maximal if all three velocity components are considered, so the new findings are confirmed. This work also addresses a number of outstanding issues from all the previous measurements, including questions of whether the spatial resolution was adequate and whether the results were influenced by the short-comings of using hot-wire probes in such high intensity turbulent flows.

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Chalmers University of Technology
Contributors: Wähnström, M., George, W. K., Meyer, K. E.
Publication date: 2006

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Place of publication: San Francisco
Publisher: AIAA
Source: orbit
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Research output: Chapter in Book/Report/Conference proceeding Article in proceedings – Annual report year: 2006 Research peer-review

A visual description of the convective flow field around the heat of a human
Mean velocity data obtained by PIV (Particle Image Velocimetry) around the head of a real-life size breathing thermal manikin are presented for two cases of `no breathing' and `continuous exhalation through nose'. Experiments were conducted in a special chamber which provided stationary convective flows around the seated manikin. Results are limited to the plane of symmetry. The paper aims to describe the physical structure of the turbulent flow field by presenting velocity and vorticity data in color graphics.
**Measurement of mean rotation and strain-rate tensors by using stereoscopic PIV**

A technique is described for measuring the mean velocity gradient (rate-of-displacement) tensor by using a conventional stereoscopic particle image velocimetry (SPIV) system. Planar measurement of the mean vorticity vector, rate-of-rotation and rate-of-strain tensors and the production of turbulent kinetic energy can be accomplished. Parameters of the Q criterion and negative $\lambda_2$ techniques used for vortex identification can be evaluated in the mean flow field. Experimental data obtained for a circular turbulent jet issuing normal to a crossflow in a low speed wind tunnel for a jet-to-crossflow velocity ratio of 3.3 are presented to show the applicability of the proposed technique. The results reveal the presence of a secondary counter-rotating vortex pair (SCVP) which is located within the jet core and has a sense of rotation opposite to that of the primary one (PCVP). Consistency of the measurements is verified by the agreement of data obtained in two perpendicular planes. Accuracy of the data is discussed and algebraic relations for some measurement uncertainties are presented.

**POD applied to stereo PIV data of the far turbulent axisymmetric jet**

An experiment was performed to evaluate spatial resolution requirements for multiple and single component POD applications to cross-sections of the far axisymmetric jet. The jet of Gamard et al. was used at an exit Reynolds number of 20,000. Three-component velocity data were obtained at downstream positions of 60, 70 and 100 diameters using stereoscopic PIV. In addition to the standard POD analysis, a novel application of the snapshot POD was used to filter the data in preparation for the classical POD analysis. The two-point Reynolds stress tensor was reconstructed from the dominant snapshot POD-modes, and the convex hull of this data set was extended using symmetry conditions. The results are believed to be relevant to not only understanding previous experiments with hot-wires, but also DNS and LES.
Flow structures in large-angle conical diffusers measured by PIV

Flow in two different conical diffusers with large opening angles (30° and 18°) have been measured with stereoscopic Particle Image Velocimetry (PIV). The measurements were done in a cross section just after the exit of the diffuser. The Reynolds number was 100000 based on upstream diameter and mean velocity. The inlet condition was a straight pipe with a fully developed velocity profile. The diffuser with opening angle of 18° was also investigated with an inlet pipe with a 30° pipe bend shortly upstream of the diffuser. In general the flows show very high turbulence intensities, of the order of 100%. The cases with straight pipe inlet seem to have a high velocity core that moves to different positions in the cross section of the diffuser. Other parts of the cross section have flow separation. The time scale of these motions is an order of magnitude larger than the largest turbulent time scale found in fully developed flow in the downstream pipe, suggesting precession of the high speed core. For the inlet with a bent pipe, the high velocity regions and region with flow separation are found at more fixed positions and the time scale is similar to time scales in fully developed flows.

Measurement of rotation and strain-rate tensors by using stereoscopic PIV

A simple technique is described for measuring the mean rate-of-displacement (velocity gradient) tensor in a plane by using a conventional stereoscopic PIV system. The technique involves taking PIV data in two or three closely-spaced parallel planes at different times. All components of the mean rate-of-displacement tensor are then calculated by using finite difference formulas. Planar measurements of the mean vorticity vector, rate-of-rotation and rate-of-strain tensors and the production of turbulent kinetic energy can be accomplished. Parameters of the Q-criterion and negative-λ2 techniques used for vortex identification can be evaluated in the mean flow field. Dissipation rate of the turbulent kinetic energy in a non-isotropic three-dimensional flow field may also be estimated. Experimental data obtained for a round turbulent jet normal to a crossflow in a low-speed wind tunnel are presented to show the applicability of the proposed technique. The PIV cameras and light sheet optics shown in Fig. 1a are mounted on the same traverse mechanism in order to displace the measurement plane accurately. Data obtained in constant-γ and -z planes are presented. Fig. 1b shows a contour plot of the normalized production rate of turbulent kinetic energy \( P^* = PD/U^3 \) in the z/D=2 plane (D is the jet diameter, U is the crossflow velocity). \( P^* \) is evaluated by using its exact definition, i.e., all nine additive terms in the definition are included. Smoothness of the contour plot indicates the successful implementation of the technique. Measurement uncertainties are discussed and algebraic relations for uncertainties in P and the parameter of the Q-criterion are presented. Consistency of the measurements is verified by showing agreement of two data sets obtained in two perpendicular planes. Accuracy of the data can be improved if optimal spacing between velocity vectors is employed. The feasibility of measuring the truncation error in the rotation- and strain-rate tensors is also demonstrated.


Turbulence studies of negative corona ESP

General information
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Organisations: Department of Mechanical Engineering, Fluid Mechanics
Publication date: 2004

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Place of publication: Kruger Gate, South Africa
Publisher: Tshwane University of Technology
Editor: Hansen, R.
Source: orbit
Source ID: 155849

LDA-PIV Diagnostics and 3D Simulation of Oscillating Swirl Flow in a Closed Cylindrical Container

Results on unsteady vortex breakdown are obtained simultaneously using two diagnostics methods: a) determination of velocity fields by particle tracks (Particle Image Velocimeter - PIV), b) determination of velocity fields by Laser Doppler Anemometry (LDA), are presented. The experiments data are in some regimes supplemented by th 3D computations of the incompressible Navier-Stokes equations in cylindrical coordinates. Perfect agreements between calculation and experiment reveal efficiency of both diagnostics method for pulsating vortex breakdown and numerical method for solution to 3D unsteady Navier-Stokes equations.

General information
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Organisations: Fluid Mechanics, Department of Mechanical Engineering
Contributors: Naumov, I., Okulov, V. L., Meyer, K. E., Sørensen, J. N., Shen, W. Z.
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Original language: English
Source: orbit
Source ID: 25562

Turbulent and stationary convective flow field around the head of a human

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering
Contributors: Özcan, O., Meyer, K. E., Melikov, A. K.
Publication date: 2003

Host publication information
Title of host publication: Proceedings of the Fourth International Symposium on Turbulence, Heat and Mass transfer
Flow Mapping of a Jet in Crossflow with Stereoscopic PIV

Stereoscopic Particle Image Velocimetry (PIV) has been used to make a three-dimensional flow mapping of a jet in crossflow. The Reynolds number based on the free stream velocity and the jet diameter was nominally 2400. A jet-to-crossflow velocity ratio of 3.3 was used. Details of the formation of the counter rotating vortex pair found behind the jet are shown. The vortex pair results in two regions with strong reversed velocities behind the jet trajectory. Regions of high turbulent kinetic energy are identified. The signature of the unsteady shear layer vortices is found in the mean vorticity field.

PIV measurements at the breathing zone with personalized ventilation

Measurements with particle image velocimetry have been carried out in a scale model of the Annex 20 room. Data were taken in a plane near the inlet. The flow consisted of a wall jet (Re=5,000) and a low-velocity region below the jet. POD was used to analyze dominant flow structures. The analysis showed that the flow some of the time has flow structures very different from the mean velocity field. A time-resolved data series was projected onto the orthonormal basis derived from the POD for analysis of the time variation of the POD amplitudes.
Point and planar LIF for velocity-concentration correlations in a jet in cross flow

Simultaneous measurements of velocities and concentration with Planar Laser Induced Fluorescence (PLIF) combined with Particle Image Velocimetry (PIV) are compared to similar measurements with pointwise Laser Induced Fluorescence (LIF) made with a slightly modified standard Laser Doppler Anemometer (LDA). The flow considered is the mixing of a jet in a fully developed cross flow in a square duct with a width of 10 jet diameters. Both a laminar flow case, Re=675, and a turbulent flow case, Re=33750, are presented. For both flows, the ratio jet-to-duct mean velocities was R=3.3. Result of mean velocities, mean concentration and Reynolds fluxes in the symmetry plane of the jet are presented for PIV and PLIF measurements. The LIF measurements performed with the LDA equipment was in general in good agreement with the PIV/PLIF measurements. The cross sections selected for comparison are challenging, since these involve areas with high velocity- and concentration gradients, which in turn amplifies the effect of a finite measurement volume in the two measurement systems. In addition, the concentration measurement was realized by injecting clean water into the dye seeded main flow. This "inverse" configuration resulted in a deeper insight to the concentration measurement process, itself. The comparison of LDA/LIF and PIV/LIF data also resulted in better understanding of the two measurement systems.

Temperature and velocity fields in natural convection by PIV and LIF

Natural convection in a cubical cavity (L = 250 mm) filled with water is created by heating a square plate (0.5 L) centred in the bottom wall and by cooling the sidewalls, while the remaining walls are insulated. The Rayleigh number based on cavity side length and temperature difference between plate and cooled walls is 1.4×10^{10}. The flow is turbulent and is similar to some indoor room flows. Combined Particle Image Velocimetry (PIV) and Planar Light Induced Fluorescence (LIF) are used to measure local velocities and temperatures. Data measured in a symmetry plane parallel to a sidewall are presented in terms of mean velocities and temperature and in terms turbulent quantities including Reynolds fluxes. The flow consists a plume rising above the heated plate into an almost stagnant fluid with a weakly stratified temperature field, as well as thin buoyancy driven boundary layers down the sidewalls. The measured Reynolds fluxes show that the dominating heat transport is in the plume in vertical direction. This transport relates to hot parcels of fluid rising due to buoyancy. A considerable heat transport in horizontal direction from the plume to the surrounding, stagnant fluid maintains the stratified temperature field.
Analysis of flow structures in an Annex 20 room

Flow mapping of a jet in crossflow with stereoscopic PIV

Local heat transfer and flow distribution in a three-pass industrial heat exchanger
Simultaneous measurement of velocity and concentration in a jet in channel-crossflow

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics
Contributors: Özcan, O., Meyer, K. E., Larsen, P. S., Westergaard, C. H.
Publication date: 2001

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Publisher: American Society of Mechanical Engineers
Source: orbit
Source ID: 64185

Stereoscopic PIV measurements in a jet in crossflow

General information
Publication status: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering
Contributors: Meyer, K. E., Özcan, O., Larsen, P. S., Westergaard, C. H.
Publication date: 2001

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Title of host publication: Proceedings of the Second International Symposium on Turbulence and Shear Flow Phenomena
Place of publication: Stockholm
Publisher: KTH
Source: orbit
Source ID: 64155

Advection velocities of flow structures estimated from particle image velocimetry measurements in a pipe

General information
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Organisations: Department of Energy Engineering
Contributors: Meyer, K. E., Westerweel, J.
Pages: S237-S247
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Experiments in Fluids
Volume: 29
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Web of Science (2000): Indexed yes
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Source: orbit
Source ID: 177274
Experimental verification of novel spectral analysis algorithms for Laser Doppler Anemometry data

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Gjelstrup, P., Noback, H., Jørgensen, F. E., Meyer, K. E.
Publication date: 2000

Host publication information
Title of host publication: Proceedings of 10th International Symposium on Applications of Laser Techniques to Fluid Mechanics
Place of publication: Lisbon
Source: orbit
Source ID: 177310

Local heat transfer in an in-line tube bundle with asymmetrical flow

General information
Publication status: Published
Organisations: Department of Energy Engineering
Pages: 399-406
Publication date: 1999

Host publication information
Title of host publication: Progress in Engineering Heat Transfer
Place of publication: Gdansk, Poland
Publisher: Institute of Fluid-flow Machinery Publishers
Source: orbit
Source ID: 174974

Time-series of turbulent flow in a pipe measured with PIV

General information
Publication status: Published
Organisations: Department of Energy Engineering, Delft University of Technology
Contributors: Meyer, K. E., Westerweel, J.
Pages: 83-88
Publication date: 1999

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Place of publication: Santa Barbara
Publisher: The University of California, Santa Barbara
Source: orbit
Source ID: 174972

Lecture notes in Convective Mass Transfer

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Meyer, K. E.
Number of pages: 32
Publication date: 1998
Optical measurement techniques for flow conditions in water

Three-dimensional Effects of Turbulent Flow in an In-Line Tube Bundle

Enhanced heat transfer in flows with longitudinal vortices

Experimental and Numerical Investigation of Turbulent Flow and Transfer in Staggered Tube Bundles
Projects:

**Nano-scale thermal transport and hydrodynamics on heterogeneous surface: a molecular dynamics simulation study**
Situ, W., PhD Student, Department of Mechanical Engineering
Walther, J. H., Main Supervisor
Meyer, K. E., Supervisor
01/03/2019 → 28/02/2022
Project: PhD

**In-Situ undersøgelser af forbrændingsprocesser i store to-takts dieselmotorer**
Poulsen, H. H., PhD Student, Department of Chemical and Biochemical Engineering
Glarborg, P., Main Supervisor
Clausen, S., Supervisor
Mayer, S., Supervisor
Meyer, K. E., Examiner
Rasmussen, N. B. K., Examiner
Spicher, U., Examiner
ErhvervsPhD-ordningen VTU
01/03/2006 → 17/03/2010
Award relations: In-Situ undersøgelser af forbrændingsprocesser i store to-takts dieselmotorer
Project: PhD

**Indsprøjtningsforhold i store dieselmotorer**
Dam, B. S., PhD Student, Department of Mechanical Engineering
Meyer, K. E., Main Supervisor
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Sorenson, S. C., Supervisor
Wachtmeister, G., Examiner
Hjertager, B. H., Examiner
Westergaard, C. H., Examiner
ErhvervsPhD-ordningen VTU
Award relations: Indsprøjtningsforhold i store dieselmotorer
Project: PhD

**LES-beregninger for industrielle strømninger**
Cavar, D., PhD Student, Department of Mechanical Engineering
Meyer, K. E., Main Supervisor
Davidson, L., Examiner
Bingham, H. B., Examiner
Sorenson, N. N., Examiner
DTU stipendium
01/02/2003 → 16/04/2007
Award relations: LES-beregninger for industrielle strømninger
Project: PhD

**Strømning i industrielle procesanlæg**
Ullum, T. U., PhD Student, Department of Mechanical Engineering
Larsen, P. S., Main Supervisor
Lind, L., Supervisor
Meyer, K. E., Supervisor
Finderup Nielsen, N., Supervisor
Sørensen, J. N., Examiner
Jacobsen, C. H., Examiner
Tropea, C., Examiner

DTU stipendium
15/08/2000 → 12/02/2004

Award relations: Strømning i industrielle procesanlæg
Project: PhD

Måling af turbulens og strømningsstrukturer med PIV
Pedersen, J. M., PhD Student, Department of Mechanical Engineering
Meyer, K. E., Main Supervisor
Sørensen, J. N., Supervisor
Sumer, B. M., Examiner
George, W. K., Examiner
Westegaard, C. H., Examiner

DTU stipendium
01/02/2000 → 27/06/2003

Award relations: Måling af turbulens og strømningsstrukturer med PIV
Project: PhD

Simulering og identifikation af strukturer i komplexe fluidstrømninger
Jørgensen, B. H., PhD Student, Department of Mechanical Engineering
Sørensen, J. N., Main Supervisor
Brøns, M., Supervisor
Larsen, R., Supervisor
Meyer, K. E., Examiner
Veldman, A. E. P., Examiner
Mann, J., Examiner

DTU stipendium
01/09/1996 → 26/03/2000

Award relations: Simulering og identifikation af strukturer i komplexe fluidstrømninger
Project: PhD

Numerisk og eksperimental undersøgelse af turbulent strømning og varmeoverførsel i industrielle procesanlæg
Meyer, K. E., PhD Student, Department of Mechanical Engineering
Larsen, P. S., Main Supervisor
Kristensen, H. S., Supervisor

DTU stipendium
01/02/1991 → 30/05/1994

Award relations: Numerisk og eksperimental undersøgelse af turbulent strømning og varmeoverførsel i industrielle procesanlæg
Project: PhD

Experimental and Numerical studies of water flow in choanocytes and choanoflagellates
Asadzadeh, S. S., PhD Student, Department of Mechanical Engineering
Walther, J. H., Main Supervisor
Meyer, K. E., Supervisor
Jensen, K. H., Examiner
Finderup Nielsen, N., Examiner
Wan, K. Y., Examiner

Samfinansieret - Andet
01/08/2016 → 30/09/2019

Award relations: Experimental and Numerical studies of water flow in choanocytes and choanoflagellates
Project: PhD

Heat transfer equipment for utilization of low temperature heat sources
Mancini, R., PhD Student, Department of Mechanical Engineering
Elmegaard, B., Main Supervisor
**Flow in SCR systems**
Gotfredsen, E., PhD Student, Department of Mechanical Engineering  
Meyer, K. E., Main Supervisor  
Velte, C. M., Examiner  
Finderup Nielsen, N., Examiner  
Sundén, B., Examiner  
Samfinansieret - Andet  
01/09/2015 → 04/04/2019  
Award relations: Flow in SCR systems  
Project: PhD

**State-of-the-art laser Doppler systems development for turbulence measurements**
Yaacob, M. R., PhD Student  
Velte, C. M., Main Supervisor  
Buchhave, P., Supervisor  
Meyer, K. E., Supervisor  
Yaacob, M. R. B., PhD Student, Department of Mechanical Engineering  
Mikkelsen, T. K., Examiner  
Hult, J. F., Examiner  
Revstedt, J., Examiner  
Privatist  
15/06/2015 → 30/06/2019  
Award relations: State-of-the-art laser Doppler systems development for turbulence measurements  
Project: PhD

**Experimental and theoretical investigations of turbulent axi-symmetric jets**
Hodzic, A., PhD Student, Department of Mechanical Engineering  
Velte, C. M., Main Supervisor  
George, W. K., Supervisor  
Meyer, K. E., Supervisor  
Bingham, H. B., Examiner  
Podvin, B., Examiner  
Mayer, S., Examiner  
Technical University of Denmark  
01/04/2015 → 20/03/2019  
Award relations: Experimental and theoretical investigations of turbulent axi-symmetric jets  
Project: PhD

**Multiphase Flow Evaluation**
Kjærsgaard-Rasmussen, J., PhD Student, Department of Mechanical Engineering  
Meyer, K. E., Main Supervisor  
Hallundbæk, J., Supervisor  
Knudsen, K., Examiner  
Meyer, S., Examiner  
Vauhkonen, M., Examiner  
EvhervsPhD-ordningen VTU  
01/11/2006 → 30/09/2010  
Award relations: Multiphase Flow Evaluation  
Project: PhD

**Two Stroke Diesel Engines for Large Ship Propulsion**
Haider, S., PhD Student, Department of Mechanical Engineering
Experimental Investigation of Turbulence Structures in Wave Boundary Layers
Carstensen, S., PhD Student, Department of Mechanical Engineering
Sumer, B. M., Main Supervisor
Fredsoe, J., Supervisor
Meyer, K. E., Main Supervisor
Garcia, M. H., Examiner
Soulsby, R. L., Examiner
Forskningsraadfinansiering
01/08/2002 → 30/06/2006
Award relations: Experimental Investigation of Turbulence Structures in Wave Boundary Layers
Project: PhD

Scavenging and swirling flow in two-stroke diesel engines - An experimental study
Ingvorsen, K. M., PhD Student, Department of Mechanical Engineering
Meyer, K. E., Main Supervisor
Walther, J. H., Supervisor
Hansen, M. O. L., Examiner
Alfredsson, H., Examiner
Gervang, B. G., Examiner
1/3 FUU, 1/3 inst 1/3 Andet
01/09/2010 → 24/03/2014
Award relations: Scavenging and swirling flow in two-stroke diesel engines - An experimental study
Project: PhD

Icing Problems of Wind Turbine Blades in Cold Climates
Hudecz, A., PhD Student, Department of Wind Energy
Hansen, M. O. L., Main Supervisor
Battisti, L., Supervisor
Villumsen, A., Supervisor
Meyer, K. E., Examiner
Johansen, J., Examiner
Oleskiiw, M. M., Examiner
Technical University of Denmark
15/11/2010 → 26/05/2014
Award relations: Icing Problems of Wind Turbine Blades in Cold Climates
Project: PhD

Simulation and Control of Wind Turbine Flows using Vortex Generators
Velte, C. M., PhD Student, Department of Mechanical Engineering
Hansen, M. O. L., Main Supervisor
George, W. K., Supervisor
Meyer, K. E., Supervisor
Larsen, P. S., Examiner
Buchhave, P., Examiner
Stanislas, M., Examiner
Forskningsraadfinansiering
01/12/2005 → 04/11/2009
Award relations: Simulation and Control of Wind Turbine Flows using Vortex Generators
Project: PhD

State-of-the-art laser Doppler systems development for turbulence measurements
Testing and development of improved laser Doppler anemometry methods
Experimental and theoretical investigations of turbulent axi-symmetric jets
Fundamental turbulence study for studying the development of the jet for creating an analytical model. The results will be useful for studying the dependence upon initial/upstream condition and the development of turbulence.

Calibration of flow meters by LDA
A technique is developed to calibrate large flow meters used in district heating in site by Laser Doppler Anemometry.

Axial fans and ventilation systems
Over the past few years, the Fluid Mechanics Section has focused on axial fans for ventilation purposes. By improving the rotor designs, a substantial reduction in power consumption can be achieved and the use of fossil fuels can thereby be reduced. A joint EFP programme has been established with the Danish Technological Institute (DTI), (DEFU) and a Danish manufacturer (Exhausto).
At the Department, a cascade wind tunnel has been constructed and CFD techniques have been tuned in order to obtain reliable airfoil data in cascade setups. Furthermore, an analytical model for the aerodynamics of axial fans has been developed as part of a Ph.D. project. Integrating the model with an optimization algorithm enables the design of fans with a low energy consumption. At DTI, a test stand for axial fans has been built for measuring fan performance in order to verify the computed optimum designs. At the Department, an experimental facility has been constructed, enabling measurements using Laser Doppler Anemometry (LDA) in and around the rotor of an axial fan. The ongoing activity has resulted in several master thesis projects at the Department.
With the experimental facilities and the numerical tools, it is possible to design improved rotors and, furthermore, to gain an insight into the physics of the flow and thus the mechanisms responsible for losses.

Improvement of regenerative heat exchanger
Methods for improving heat transfer in heat exchangers used for heat recovery in ventilation systems are investigated. A focus area is to investigate the usage of longitudinal vortices to improve the local heat transfer rate. Project is related to design of axial fans.
Collaborators: Exhausto A/S, Danish Technological Institute
Award relations: Improvement of regenerative heat exchanger
Project: Research

**Design of axial fan (EFP)**
Sørensen, J. N., Project Manager, Department of Energy Engineering
Meyer, K. E., Project Participant, Department of Energy Engineering
Sørensen, D. N., Project Participant, Department of Energy Engineering
01/01/1996 → 31/12/1996
Project: Research

**Centercontract INTERFLOW**
Progress on the three involved projects includes:
OFA-Boiler A The efficiency of mixing of an injected gas into a turbulent flow has been studied by CFD for a range of nozzle configurations at one mass-flow ratio. A 1:60 scale model has been designed and built, and a database has been established for the base flow without OFA-air based on detailed LDA-measurements. Heat exchanger optimization has involved a literature study of available design formulas for in-line tube bundles. The design has been made of a test tube for measuring local heat transfer using an electrically heated gold foil. It will be tested in the laboratory wind tunnel before being installed at various locations in the full scale test facility at DMI. CFD analysis of velocity distributions in manifolds, employing source terms to represent tubes in the bundle, is in progress. Flow-activated reed valve in compressor will involve the development of experimental techniques to in-situ measurement of valve motion and related flow. Various optical techniques are being explored.
Larsen, P. S., Project Manager, Department of Energy Engineering
Nielsen, L. S., Project Participant, Department of Energy Engineering
Meyer, K. E., Project Participant, Department of Energy Engineering
01/01/1996 → 31/12/1998

**PIV målinger i GCT skalamodel**
Meyer, K. E., Project Manager, Department of Mechanical Engineering, Fluid Mechanics
Sørensen, J. N., Project Participant, Department of Mechanical Engineering, Fluid Mechanics
Project ID: 75394
Sam.arb.aftaler, Private danske - Andre virksomheder: DKK50,000.00
15/11/2003 → 31/08/2004
Award relations: PIV målinger i GCT skalamodel
Project: Research

**Activities:**

**A Tensor Formulation of the Lumley Decomposition Applied to the Jet Far-field**
Period: 23 Nov 2019
Clara Marika Velte (Other)
Azur Hodzic (Speaker)
William K George (Other)
Knud Erik Meyer (Other)
Fluid Mechanics, Coastal and Maritime Engineering
Department of Mechanical Engineering
Degree of recognition: International
Links:
http://meetings.aps.org/Meeting/DFD19/Session/B15.2

**Related event**
72nd Annual Meeting of the American Physical Society, Division of Fluid Dynamics
23/11/2019 → 26/11/2019
Seattle, United States
Prizes:

Paper awarded among the best papers from the International Symposium on Energy, Informatics and Cybernetics 2009 and selected for publication in Journal of Systemics, Cybernetics and Informatics
Clara Marika Velte (Recipient), Martin Otto Laver Hansen (Recipient), Knud Erik Meyer (Recipient) & Peter Fuglsang (Recipient)
Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, Fluid Mechanics, Department of Wind Energy

Details
Awarded date: 2009
Degree of recognition: International
Prize: Prizes, scholarships, distinctions