Development, validation and application of the code complex DYN3D - ATHLET

For the validation of the coupled 3D neutron kinetics/thermohydraulic code complex DYN3D-ATHLET, two international benchmark exercises comprising the analysis of main steam line break scenarios for a VVER-440 type reactor and a Western PWR have been solved. In both exercises, an asymmetrical overcooling in the different coolant loops was initiated. Therefore, the occurrence of possible re-criticality of the shut down reactor due to the overcooling connected with positive reactivity insertion significantly depends on the adequate description of coolant mixing inside the reactor pressure vessel.

In the framework of an EU PHARE project under the leadership of FZR with participants from 8 EU and East European countries, measurement data on transients in nuclear power plants with VVER type reactors have been collected and documented. Two transients, the power drop of one generator down to house load level at NPP Loviisa (VVER-440) and turning off one from two working feedwater pumps at NPP Balakovo (VVER-1000), were selected for the analysis using different coupled code systems. For the key parameters, a good agreement between measurements and calculations was achieved. Remaining differences could partially be explained by uncertainties in the input information, like the control rod positions or pressuriser heater set points. It was found, that the correct modelling of the heat transfer in the gas gap between fuel and cladding is significant for the estimation of the fuel temperature Doppler feedback, which influences the change of power level during the transient. As a result of the project, the confidence of the results of the different codes has been improved.

A new nodal expansion method (HEXNEM) was developed and implemented into the code DYN3D. The significantly enhanced accuracy of the neutron flux calculation was shown in benchmark exercises. In co-operation with IPPE Obninsk (Russia), DYN3D was coupled to the internationally widely used thermohydraulic system code RELAP. Accident analysis calculations were performed for the small power, integral reactor concept ABV-67 designed in Obninsk.

Validation of thermohydraulic system codes

In the framework of a concerted action on the validation of the thermodynamic code ATHLET (developed by Gesellschaft für Anlagen- und Reaktorsicherheit), an experiment performed at the Japanese test facility CCTF simulating a large break loss-of-coolant accident with combined cold and hot leg ECC injection was analysed. In this experiment, large counter current flows of water and steam with condensation occur. The analysis aimed at the validation of a new condensation model in ATHLET. In general, the course of the transient was calculated in good agreement with the experiment. However, in the case of high condensation rates in some thermo-fluid dynamics objects,
large oscillations of the vapour volume fraction occur, which lead to high computation times. It was concluded, that the numerical implementation of the new condensation model in ATHLET has to be improved.

Within the co-operation with HEW and TÜV Hannover, ATHLET input decks for German PWRs and BWRs have been modified and extended. The implementation of a cross flow model into the downcomer description of a BWR enables the user to estimate the asymmetrical distribution of the coolant mass flow rate and temperatures in total loss of feedwater scenarios.

Computational fluid dynamics simulations of one and two-phase flow

The experiments on coolant mixing in PWRs in the ROCOM test facility have been accompanied with CFD simulations. Experiments with the injection of plugs of a tracer fluid (salt water) into a steady state flow field or during the start-up of circulation have been analysed. These experiments simulate a temperature or boron concentration perturbation in one of the loops. Even the transport of the tracer in the complex instationary flow field during the start-up of the circulation was well reproduced in the calculations. The agreement between experiment and calculation was significantly improved, if the measurement data are averaged from experiments repeated under the same conditions. This is due to the fact, that fluctuations of the flow field observed in the experiments are partially damped in the calculations.

Using the CFD code CFX-4.2, experiments carried out at the Rossendorf two-phase flow test loop were numerically simulated. Velocity and void fraction profiles of water and air flows were measured with different gas and liquid superficial velocities in a vertical tube using high resolution two-phase instrumentation (wire mesh sensor). Taking into account different forces acting on the bubbles, radial velocity and void fraction profiles were calculated. Flow regimes showing a maximum of the void profile near the wall of the tube were well simulated with CFD. For flows with a higher part of larger bubbles, a maximum of the void distribution in the centre of the tube is observed. This was not reproduced in the calculations using the Euler/Euler approach. It was shown by a detailed simulation of one single large bubble, that it oscillates around the centre of the tube. This must be reflected in the description of the forces acting on the bubbles also in the Euler/Euler approach.

CFD simulations of a loss-of-vacuum accident in a fusion reactor were performed. Velocity, pressure and temperature distributions after air penetration into the vacuum were calculated. It was a special challenge to simulate the super-sonic air flow after opening of the leak.
Coolant mixing in pressurised water reactors

The work aims at the determination of temperature and boron concentration distributions at the core entrance during main steam-line breaks and deboration transients. Experiments were carried out at the mixing test facility ROCOM modelling the German KONVOI type pressurised water reactor in the scale of 1:5. The disturbance is modelled by injecting salt water as a tracer into the affected loop. A new quality of tests is achieved by using mesh-sensors with numerous measuring positions in the downcomer and at the core entrance, the high measuring frequency (up to 200 Hz), the variability of the four-loop test facility and the direct comparison to CFD calculations. The mixing in the pressure vessel is incomplete. In case of running coolant pumps, the tracer arrives almost completely in the sector of the core that belongs to the disturbed inlet nozzle, the most affected fuel element receives about 90 % of the initial disturbance. Strong fluctuations of the tracer concentration are observed at the slopes of the tracer distribution. The mixing of short plugs is promoted by the non-uniform distribution of the travelling time in the downcomer, caused by large-scale vortices. The maximum observed concentration decreases with decreasing plug length. The injection of the tracer during the start-up of the coolant circulation leads to a maximum opposite to the angular position of the disturbed inlet nozzle.

Development and calibration of two-phase flow measurement techniques

The qualification of the diversified level indication system for boiling water reactors developed by FZR was started according to the German reactor safety regulations. The qualification procedure and the series production will be accomplished by an industrial supplier of measurement instrumentation. FZR contributes as a scientific consultant.

A new generation of signal acquisition units for the wire-mesh sensors for high-speed visualisation of two-phase flows was developed. The measuring frequency was increased from previously 1,200 to 10,000 frames per second. This results in a significant improvement of the resolution. The wire-mesh sensor is now capable of resolving individual bubbles in several successive frames at higher flow velocities (≈ 10 m/s). This is important for the investigation of the transition from slug to annular flow.

In co-operation with the Technical University of Nishny Novgorod (Russia) a new ultrasonic mesh sensor was developed. The sensor is based on a system of crossing ultrasonic wave-guides. It is complementary to the electrical wire-mesh sensors of FZR, because it can be applied to non-conducting fluids. The dimensions of the wave guides were decreased to minimise the disturbance of the flow.
For the investigation of transport processes in bubble columns and foam layers, a PET detector is under construction. The scanner will allow to measure the distribution of a tracer marked by a positron emitting nuclide with a time resolution of better than 1 s. It consists of 8 axial layers with 16 BGO detectors each. The spatial resolution will be in the range of a centimetre. The mechanical construction of the detector arrays and the development of the signal acquisition circuitry was finished. The licence for operating the scanner with open radioactive sources was obtained. First tests are expected for the near future.

In co-operation with the Technical University Dresden, the development of a stroboscopic gamma-tomograph for an axial turbo pump was started. The work aims at the measurement of the gas fraction field inside the rotating impeller, when the pump is working in two-phase flow mode.

Basic studies of two-phase flows with foam production

Needle probes were used to characterise the axial gas fraction distribution in foams. A method was developed to measure bubble sizes and the number of bubbles per unit volume in experiments with wet unstable foams of aqueous solutions of different alcohols. It is based on the analysis of the time derivate of the probe signal. The main goal is the development of coalescence models for wet unstable foams. Furthermore, a 10 l reactor of the Technical University Hamburg/Harburg was equipped with needle probes to measure the transient axial gas fraction distribution during depressurisation tests with foaming liquids.

Thermoconvection and instabilities at the boundary layer of two non-miscible liquid reacting components

Flow instability at the inter-phase surface between two non-miscible liquids were investigated for the cases of non-reactive mass transfer (extraction) and exothermal reactions at the phase boundary. Experiments were carried out in a capillary gap equipped with a shadowgraph set-up. A numerical model for the two-dimensional flow in the gap was developed, which considers the chemical reaction, the thermal and concentration effects on the fluid density and the surface tension. The model is capable of predicting all types of experimentally observed instabilities (density driven circulation cells, double-diffusive fingering regimes, Marangony type instabilities). The quantitative agreement concerning wave lengths and growth rates must be further increased.

Transient two-phase flows in pipelines

The wire-mesh sensor was used to study the transient flow pattern in an air-water flow in a vertical pipe. The superficial velocities of both phases were varied in a wide range, so that bubble, slug and annular flow regimes were covered. The evolution of the flow pattern along the vertical pipeline was studied by increasing the axial distance between air injection and sensor. Bubble size distributions were obtained from the
sensor data. The development of these distributions along the tube length allow to quantify the effects of both bubble coalescence and fragmentation. Furthermore, a new data evaluation method was developed to obtain gas fraction profiles for distinct classes of the bubble size. In a realistic turbulent two-phase flow, it was shown that the direction of the lateral motion of bubbles depend on the bubble size. The lift force acting on bubbles in the boundary layer changes its sign when the bubble diameter exceeds about 5-6 mm. This confirms theoretical findings for the motion of a single bubble known from literature.

On the basis of the experimental results, the development of a one-dimensional theoretical model of the behaviour of a large number of bubble classes was started. It describes the flow along the vertical pipe for a given bubble size distribution at the inlet. The model contains constitutive equations for bubble coalescence and fragmentation. For the calculation of the radial profiles of velocity and gas fraction, a second 1D model was elaborated, which considers all important fluid forces acting on the gas bubbles in dependence on the bubble size. The profiles are calculated under the assumption of quasi-stationary conditions, i.e. it is assumed that each bubble is in equilibrium concerning the acting forces.

**Materials and Components Safety**

*J. Böhmert, A. Ulbricht, M. Grosse*

**Microstructural analyses of irradiated model Fe alloys**

The effect of copper, phosphorus and nickel on the radiation embrittlement was investigated using an irradiation experiment at surveillance positions in two Russian VVER-type reactors with 8 iron based alloys. As well Charpy-V impact and tensile tests as small angle neutron scattering experiments were performed with specimens from these alloys. The specimens were tested in the as-received state, in the irradiated state (fluence $1 \times 10^{19}$ and $8 \times 10^{19}$ n/cm$^2$ [E $>$ 0.5 MeV]) and in the post-irradiation annealed state.

Irradiation produces strong hardening and embrittlement. The effect increases with Cu and P content. Ni causes an additional embrittlement, which is superimposed to the effect due to Cu and P. The effect can be eliminated by annealing at 475°C/100h but not totally in the case of high Cu or P content.

Small angle neutron scattering measurements show that not only the volume fraction but also the type of the radiation defects varies in dependence on the composition of alloys. Independent on the Ni content, the volume fraction of irradiation defects increases with increasing Cu content. P has no influence. The fluence dependence of the irradiation defects differs for Cu-containing and Cu-free defects.
Evaluation of the irradiation behaviour of Russian pressure vessel steels from the irradiation programme Rheinsberg

Different charges from VVER-type reactor pressure vessel steels were irradiated in the VVER-2 Rheinsberg. Four charges from 15Kh2MFA, two charges from 15Kh2NMFAA and one charge from 10KhGNMAA weld metal were tested by FZR. Testing comprises Charpy-V impact tests and quasi-static 3-point bending tests. In this way ductile-brittle transition temperatures and J-integral related fracture toughness according to the Master curve concept were determined. All charges show a good toughness in the initial state and meet the Russian standards. Irradiation shifts both the transition temperature determined by Charpy tests and the $T_o$ reference temperature determined by the Master curve concept. The shift of the reference temperature $T_o$ is higher than the shift of the Charpy transition temperature. The results permit to estimate the irradiation embrittlement coefficient. Based on that, shifts of the transition temperature were predicted in the range of $20^\circ\text{C}$ to $>220^\circ\text{C}$ for a 25-years reactor life. Whereas a shift of $20^\circ\text{C}$ proves a very low irradiation sensitivity, values of more than $200^\circ\text{C}$ cannot be accepted. The embrittlement can be, however, remedied by thermal annealing at $475^\circ\text{C}/100\text{h}$ as shown by annealing experiments. The differences of the irradiation sensitivity for the different charges are not only due to composition effects, but also due to different textures.

Reconstitution techniques qualification & evaluation to study ageing phenomena of nuclear pressure vessel materials

The assessment of the ageing behaviour of structural components especially of the nuclear reactor pressure vessel (RPV) requires material parameters. In some situations only small quantities of the material of interest are available. The technique of constructing specimens from small quantities of material is commonly called 'reconstitution'. The construction of compound specimens is achieved by attaching additional material (studs) around a material of interest - the insert material - to prepare a test specimen of standard dimensions.

An EU project was performed to stepwise qualify, verify and compare two different reconstitution techniques: stud-welding and electron-beam welding. The project aimed at identifying the limits of applicability of technical reconstitution parameters that have the potential to affect the experimental values measured with reconstituted specimens: i.e. the material and the insert length, the welding procedure, the heat input, the weld seam quality and strength. Two types of specimens that are most frequently used in RPV assessment were considered: Charpy V-notch impact and precracked Charpy size specimens for fracture toughness. The initial emphasis was put on un-irradiated material. Afterwards the optimum reconstitution procedure was verified with irradiated RPV steels.

The overall analysis of the data gathered from all project partners was summarised in a document that could serve as a European Code of Practice for the reconstitution of irradiated Charpy V-notch impact and Charpy size fracture toughness specimens.
In-vessel retention of core melt

H.-G. Willschütz, E. Altstadt

To get an improved understanding of the processes occurring during the late phase of a core melt down accident the FOREVER-experiments at the Royal Institute of Technology (Stockholm) are currently underway. These experiments are simulating the behaviour of the RPV lower head under the thermal loads of a convecting melt pool with decay heating and simultaneous pressure loads. The geometrical scale of the experiments is 1:10 compared to a common Light Water Reactor. Due to the multi axial creep deformation of the vessel with a non-uniform temperature field these experiments are on the one hand an excellent source of data to validate creep models for different pressure vessel steels. On the other hand the results of pre-test calculations can be used to optimize the experimental procedure. At FZR a finite element model is developed. Using the computational fluid dynamics module the temperature field within the melt pool and within the vessel wall is estimated. Transient structural mechanical calculations are performed applying an advanced creep model which takes into account large temperature, stress and strain variations. Post test calculations of the FOREVER-C2 experiment were performed. If the temperature field in the vessel wall is fixed along the creeping process, the calculated creep curves disagree with the measurement. Considering the variation of the temperature field, the calculated results show a good agreement with the measurements.

Waterhammers in pipelines

T. Repp

The pressure waves induced by a sudden slow down of the fluid flow in a pipe line are modelled using the finite element method. Special attention is put on the influence of fluid-structure interaction if the pipe diameter is relatively large in comparison with the wall thickness. The transient velocity and pressure distribution are calculated for a straight pipe and a 90° elbow assuming a slightly compressible fluid. The coupling between the elastic pipe wall and the fluid is realized by boundary elements. It is shown that there are local stresses in the elbow which are higher than those calculated with conventional uncoupled calculations. It was found that also pressure waves in radial direction occur. The radial waves are induced by the elastic deformation of the pipe (change of diameter). A test facility for waterhammer experiments has been built up (pipe diameter 200 mm), thus in 2000 a validation of the finite element simulation will be possible.

Simulation of Particle and Radiation Fields

B. Böhmer, J. Konheiser

Neutron and gamma dosimetry of reactor pressure vessels

The BMWi project „Influence of the gamma irradiation on the deterioration of reactor pressure vessel materials and on reactor dosimetry measurements“ was started. Input data for neutron-gamma transport calculations for two Russian and two German reactor types have been collected. First calculations of neutron and gamma fluences and damage parameters for VVER-type reactors were performed in cooperation with Russian scientists.
As contribution to the EU TACIS project “Embrittlement Studies of the Reactor Pressure Vessel of the Greifswald-440 Reactors” neutron fluence and dpa-values for the inner and outer reactor pressure vessel walls, 10 angular and 10 height intervals were obtained for the whole lifetime of the Greifswald units 1 to 4 and for the operation time since vessel annealing (unit 1). Based on these data suitable positions for taking trepans during the planned Greifswald trepan investigation project could be proposed.

**B. Böhmer, J. Konheiser**

**Increasing the accuracy of neutron and gamma fluence calculation**

The Rossendorf Monte Carlo code TRAMO is being upgraded. The geometrical module now allows to define oblique cylinders and permits different geometrical structures in different horizontal layers. A new procedure for the treatment of elastic scattering using equiprobable angular intervals was included. In contrast to the formerly used Legendre Polynomial expansion, the new procedure allows to use any number of energy groups without loss of accuracy or significant increase of calculation time.

Fluence calculations for two irradiation positions in the KORBUS irradiation facility were performed with TRAMO using different versions of reactor models and numbers of energy groups. Comparing the results obtained with different versions the uncertainties of fluences caused by model deficiencies and group approximations could be evaluated. They were found to be smaller than 10%. A comparison between measured and calculated activation reaction rates and an adjustment of the calculated fluence spectra to the measured reaction rates has been carried out with the code COSA3. The calculations and measurements agreed within the error boundaries.

In cooperation with Russian scientists, space-dependent spectrum covariance matrices including the correlations between group fluences at different spatial locations were calculated for the ex-core region of a VVER-type reactor. Unexpected high positive correlations were found between fluences at different ex-vessel cavity detector positions. The calculated covariance matrices were used to test the new multi-spectrum adjustment code COSA3 developed from the code COSA2.

**K. Noack, A. Rogov**

**Design of the neutron/gamma shields for the experiments PANDA and STRESS-SPEC at the FRM-II**

In addition to the plan the neutron/gamma shields of the PANDA and STRESS-SPEC experiments at the new research reactor FRM-II has been designed on the base of results of neutron/gamma transport calculations performed with the Monte Carlo code MCNP. The PANDA spectrometer and the STRESS-SPEC diffractometer will be equipped and operated by the Technical University Dresden and by the Hahn-Meitner Institute Berlin, respectively. The tasks consisted in finding a technically feasible design of the shields which within the frame of given maximum geometric extensions must meet the demand that on the
outer surface a prescribed maximum value of the total biological dose is not exceeded. Additionally, among the possible solutions of this problem an optimisation had to be performed considering the following conditions:
- to minimise the cost of the shield,
- to minimise the weight of the shield and
- in case of PANDA the maximum possible use of nonmagnetic material in the neighbourhood of the measurement equipment.

The optimum solutions were defined and serve as the base for the engineering design of the shields which is under way.

**R. Küchler, K. Noack**

**Model calibration and verification of radionuclid transport**

A computer code has been developed to simulate the reactive transport of various chemicals in the unsaturated soil. For the calibration and verification of the code and of its mathematical models the following data from a natural field are necessary: chemical concentrations, rate constants of minerals and equilibrium coefficients of the involved chemical reactions. However, field data can be obtained only with great expenses so that they are often replaced by data from column experiments. Therefore, it is planned to perform systematic model experiments with unsaturated columns to verify the modelling of the diverse processes by the code. The construction of the column experiments is running parallel to the development and verification of hydraulic measurement techniques. The following preparatory works for the experiments were carried out:
- determination of hydraulic parameters of beach sand.
- measurement of the water distribution in the unsaturated columns at constant irrigation.
- automatisation of the data acquisition from the columns.

The evaluation of the column test data will be based on the complete one-dimensional mathematical migration model. The elaboration of this model is in progress.

**R. Koch**

**Calculation of effective two-group cross-sections**

The neutron and gamma transport code HELIOS for lattice burnup in general two-dimensional geometry was implemented and tested under the operation system SunOS 5.3. In order to test the implementation and the processing code, the well known benchmark assembly of Babcock and Wilcox was used. The influence of different geometrical models was studied. The code was used to prepare two-group libraries of macroscopic cross sections for different loading pattern of the European Pressurized Reactor. These data can be used with the code DYN3D for the analysis of transient processes in nuclear reactors.
Safety and effectiveness of chemical processes


Supported by BMBF

Environmentally safe process control and state diagnostics in chemical plants using neural networks

The work aims at the development of a neural-network approach to the diagnosis of discontinuous chemical processes in a production plant. To obtain scalable state features, a scaling model based on energy balances is being developed so that this method could also be used in geometrically dissimilar reactor vessels of different volumes. Scaling studies conducted in laboratory reactors and a pilot plant showed that very accurate measurements of process and plant variables are necessary to extract suited features for the state classification. For example, the industrial plant has to be equipped with sensors for the accurate measurement of the cooling power.

Moreover, the kinetic investigation of a complex three-phase hydrogenation has been completed to be able to apply the neural-network approach to monitoring of heterogeneous reactions. A specific procedure for a quantitative High Performance Liquid Chromatography (HPLC) analysis was developed to improve the modelling of the complex hydrogenation process by means of concentration profiles. The HPLC analysis revealed that two intermediates can play a role during the hydrogenation of an aromatic nitro compound.

Experiments and numerical simulations of exothermic chemical reactions

A two-years research program "Grignard reactions" was started in cooperation with the Arzneimittelwerk Dresden (AWD). The molar reaction enthalpy of a Grignard reaction was measured in a closed reaction calorimeter as a function of temperature. The investigation of the spontaneous behaviour has shown that the initiation of the Grignard formation can be detected by a Fourier-Transform Infrared (FTIR)-spectro-meter much earlier than by using the temperature or the pressure signals. Further, by dosing the organic halide with different feed rates, reproducible induction times as a function of the concentrations were obtained, what is very important for a safe initiation (i.e. without runaway) of Grignard reactions.

The institute took part in the international benchmark DAKAPO (data acquisition by calorimetry for polymerisation reactions) and has in this way broadened the scope of activities by including polymerisation reactions. The benchmark aimed at establishing a standard polymerisation reaction and at the assessment of the accuracy of the calorimeters. The evaluation of the benchmark is still pending.

In the framework of an industrial contract, different exothermic polycondensation reactions (production of phenolic resin and epoxy resin) were studied regarding their hazardous potentials. The thermokinetic parameters obtained by calorimetric measurements are needed to design the cooling system for safe operation of poly-
condensation processes in a production plant. Besides thermal stability screening measurements carried out in a Differential Scanning Calorimeter (DSC), calorimetric profiles of these polycondensation reactions were recorded under similar operating conditions like in the production plant.

**Liquid Metal Magnetohydrodynamics**

**Magnetic field applications in crystal growth and metallurgy**

Numerical codes have been developed and used for melt flow and heat transport calculations of crystal growth problems. For the industrial Czochralski growth of silicon commercial codes were used in order to simulate the melt control by means of different magnetic fields. The calculations were compared with model experiments and real growth experiments of silicon single crystals. Parameter regions have been identified where the growth process and the grown crystal show clear improvements. Meanwhile the corresponding magnetic systems are successfully introduced into industrial growth facilities.

For simulations of transport phenomena and magnetic field influences on growth processes in ampulla an own spectral code was developed. These results are compared with InAs growth experiments performed at Bergakademie Freiberg where a rotating magnetic field is installed in order to enhance the convective transport within the melt.

In cooperation with the Fraunhofer institute IFAM-Dresden the stabilization of an inductively stirred melt surface by means of an external magnetic field was studied. The goal of that work is to improve the melt extraction process for the production of thin metallic fibres. The magnetic field leads to a serious stabilization of the melt surface which improved the process significantly. A model experiment has been built up using the lower melting fluid SnPb in order to study the effects at the wheel meniscus in more detail. Measurements with a high-speed camera show that the oscillating meniscus has a strong influence on the diameter distribution of the extracted fibres. The model experiments demonstrated that by means of special magnetic fields in the vicinity of the melt meniscus a significant reduction of the mean diameter and of the diameter distribution width can be obtained.

Model experiments have been performed with a rotating magnetic field of variable frequency. The flow velocity driven by this field shows a significant maximum at some specific field frequency.

**The Riga Dynamo experiment**

The theory of magnetic field generation in cosmic bodies due to the homogeneous dynamo effect has been widely elaborated during the last decades. However, an experimental verification of this effect was missing until recently. At the Riga dynamo facility, self-excitation of a magnetic field in a liquid metal flow has been observed for the first time in November 1999. For increasing rotation rate of the driving propeller,
the amplification of an applied magnetic field has been measured. At the highest rotation rate of 2150 rpm, an exponentially increasing 1.3 Hz signal has been detected on the background of the amplified 1 Hz signal. Additionally, after switching off the excitation current, a slowly decreasing eigenmode was observed at the lower rotation rate of 1980 rpm. The results correspond convincingly with numerical predictions.

Electromagnetic boundary layer control for saltwater

The flow of saltwater around bodies can be controlled by electromagnetic forces localized directly on the surface of the body even though the electromagnetic forces penetrate only slightly into the low-conducting fluid. With suitable arrangements of electrodes and permanent magnets Lorentz forces can be produced which for instance accelerate the fluid motion parallel to the body surface. This results in a stabilized flow, drag reduction of the body, and prevention of flow separation. All these effects have been convincingly demonstrated during experiments performed at the Shipbuilding Test Basin Hamburg in a saltwater flow. For example, the flow around a hydrofoil has been kept separation free at angles of attack where the usual flow shows vortex separation. This is accompanied by a lift increase of about 90%.

Measuring techniques for liquid metals

Liquid metals are non-transparent, typically hot and aggressive. There is almost no commercial measuring technique available for a determination of local velocities or pressure. A mechano-optical velocity probe was developed which is able to measure two components of local velocities. It is calibrated and tested in different melts like InGaSn, SnPb, SnBi or PbBi. The measuring principle consists in the velocity induced elongation of a glass rod which is encapsulated in a glass capillary. This elongation is then measured by optical means using an endoscope and a camera. Due to its measuring principle the probe is independent of any electromagnetic fields. It is now developed and tested up to temperatures of about 700°C.

Several successful tests have been performed applying an ultrasound velocimeter to liquid metal flows. Together with the primary producer of that system and some potential users from industry a European project proposal has been set up in order to further qualify this system for higher temperature applications up to liquid steel.

Levitation of metallic samples

Electromagnetic levitation is a well-known method in order to support and fix metallic samples without any contact to some wall. However, these samples typically show a strong tendency to instabilities resulting in serious rotation or oscillation of the body. The physical reason of such spontaneous instabilities has been identified as being due to the finite skindepth of the levitator field. Frequency dependent threshold for the occurrence of these instabilities have been calculated as main results of the theoretical investigations. Model experiments were performed...
clearly confirming the theoretical results. Based on these investigations a method to stabilize the levitated samples by means of steady magnetic fields is developed. This method shall now be transferred into the existing levitation facilities with DASA-Dornier.