Årsrapport 2005

SKC

Svenskt
Kärntekniskt
Centrum

Allmänt

Statens Kärnkraftinspektion, Westinghouse Electric Sweden AB, Forsmark Kraft AB, Ringhals AB, OKG AB och Barsebäck Kraft AB har beslutat att samarbeta i syfte att stödja kärnteknisk verksamhet vid svenska högskolor. Dessa parter har slutit avtal om att fr o m 2002 bilda ett fristående samarbetsorgan, Svenskt Kärntekniskt Centrum (SKC). Styrelseledamöterna presenteras i *bilaga 1*.

Stödet ges dels i form av basfinansiering till professorer och lektorer i grundläggande kärntekniska ämnen vid KTH, Chalmers och Uppsala universitet och dels, liksom tidigare, i form av finansiering av doktorandprojekt med deltagande från svenska högskolor. Basfinansieringen regleras av särskilda avtal med respektive högskola.

Fr o m 2002 finns också kärntekniska kompetenscentra vid KTH (CEKERT) och Chalmers (CKTC). Dessa skall lokalt samordna högskolans grundutbildning och forskning i kärntekniska ämnen. SKC arbetar i nära kontakt med dessa centra, bl a genom att SKC:s föreståndare är medlem i styrelsen för respektive centrum.

Verksamheten i SKC har under 2005 i huvudsak omfattat initiering, finansiering och uppföljning av forskningsprojekt samt åtgärder för rekrytering av teknologer och civilingenjörer. SKC har också givit ekonomiskt stöd till teknologers och doktoranders studieresor. Under året har en ny administratör börjat.

Forskningsprojekt

En förteckning över de forskningsprojekt som fick SKC stöd under 2005 återfinns i *bilaga 2* och presenteras närmare i *bilaga 3*. Under året har stöd till forskningsprojekt beviljats av SKC styrelse enligt följande:

- ”Tomografisk verifiering av kärnbränsleelements integritet”, handledare Staffan Jacobsson Svärd, Strålningsvetenskap Uppsala universitet (kostnad ca 440 ksek/år i fyra år).
- ”Measurements and Analysis of Dryout and film Thickness in a Tube with Various Axial Power Distributions”, handledare Doc Henryk Anglart, Reaktorteknologi, KTH. Förlängning från licentiat- till doktorsexamen (kostnad ca 380 ksek/år i 2 ½ år).
- ”Development of a Multi-Scale Simulation Methodology for Nuclear Reactor Thermal Hydraulic and Safety Analysis”, handledare Prof Nam Dinh, Reaktorsäkerhet, KTH (kostnad ca 740 ksek/år i fyra år).

Övrigt stöd

Övrigt stöd från SKC har beviljats av SKC styrelse enligt följande:

- Post-doc till Kärnkraftsäkerhet, KTH (CEKERT 250 ksek 2005, SKC 450 ksek 2006)
- Stöd till tjänst på Chalmers (500 ksek/år i tre år)

Grundutbildning

Följande kurser gavs under året (siffrorna inom parentes anger antalet deltagare resp. kursens poängvärde):

KTH
Reaktorfysik (14,6)
Reaktorfysik examensarbeten (3,20)
Transportteori och slumpprocesser (som doktorandkurs) (7,5)
Transmutationsfysik (som doktorandkurs) (7,5)
Reaktorteknologi (35,4)
Högre Kurs i Reaktorteknologi (5,4)
Kärnkemi (15,5)
Radikalkemi (15,5)
Kärnbränslecykelns kemi (4,4)
Kärnkemi examensarbete (4,20)

Chalmers
Reaktorfysik (6,5)
Reaktorteknologi (4,5)
Strålskydd (7,3)
Neutronfysik (6,5)
Transportteori och slumpprocesser (5,3)
Kärnkemi (38,4)

Reaktorfysik examensarbete (2,20)
Kärnkemi allmän kurs (18,4)
Kärnkemi tillämpad(16,3)
Vätskeextraktion (7,3)
Kärnkemi examensarbete (7,20)

Uppsala universitet
Energifysik I (25,4)
Kärnkraft - teknik och system (36,5)
Kärnfysik (27,5)
Kärn- och partikelfysik (55,5)
Examensarbeten (6,20)
Joniserande strålning och detektorer (10,5)
Energifysik II (20,4)
Energisystemfysik (25,5)
Risker i tekniska system (15,5)
Kärnkraftteknik (7,8), samarbete med KSU
Non-proliferation and Nuclear Safeguards (*,2), ett samarbete inom ESARDA
(* = 2 studenter från Uppsala)

Sigvard Eklunds pris 2005

Sigvard Eklund var en av pionjärerna inom kärnenergiområdet. Som forskningschef från 1950 vid AB Atomenergi i Studsvik ledde han arbetet med uppförandet av de första svenska kärnreaktorerna. Han ledde IAEA i Wien under 20 år från 1961. Under hans tid vid IAEA infördes provstoppsavtalet och ickespridningsavtalet för kärnvapen samt det sk Safeguard-systemet för internationell kontroll av klyvbart material. Sigvard Eklund avled 89 år gammal den 30 januari 2000.

De välförtjänta pristagarna till Sigvard Eklunds pris 2005 var:

Henric Lindgren för bästa examensarbete:

”POLCA-T code validation against Peach Bottom 2 End of Cycle 2 Turbine Trip Test 2, KTH.

Staffan Jacobsson Svärd för bästa doktorsavhandling:

”A Tomographic Measurement Technique for Irradiated Nuclear Fuel Assemblies”, Uppsala universitet.

Pristagarna firades med en middag på Wallquistska våningen i mitten på December 2005.

Arbetsmarknadsdagar

SKC medverkade vid Charm i februari (Chalmers), Armada i oktober (KTH) och Utnarm i november (Uppsala universitet).

Intresset för SKC och forskning i kärntekniska ämnen på högskolorna tilltar.

Framtid och styrformer

Under 2005 påbörjades arbetet med att undersöka finansiärernas intresse av att fortsätta sitt ekonomiska stöd till SKC efter avtalsperiodens utgång 2007-12-31. SKC:s arbete uppskattas mycket och stödet kommer att fortsätta, förutom från Barsebäck Kraft AB, eftersom verksamheten håller på att avvecklas där.

Parallellt har föreståndaren arbetat på att få till stånd en organisationsform för SKC som bättre tar hänsyn till styrelsens intressen och behov. Arbetet fortgår och styrelsen förväntas ta beslut i frågan under 2006.

WNU Summer Institute 2006

SKC fick under året i uppdrag att tillsammans med KTH och Frankrikes Commissariat à l'Energie Atomique (CEA) att vara värd för WNU Summer Institute som kommer att pågå 8 juli – 18 augusti 2006. WNU Summer Institute hölls första gången sommaren 2005 i Idaho Falls, USA med 77 deltagare från 34 länder. Deltagarna valdes noggrant ut bland de mest framstående forskarstudenterna och yrkesverksamma inom kärnkraftsområdet.

Kursplanen för WNU Summer Institute innehåller bl a:

- Global Setting
- International Regimes
- Technology Innovation
- Nuclear Industry Operations

WNU Summer Institute avslutas med diplomering i en ceremoni som leds av Hans Blix, WNU chancellor och fd generaldirektör för International Atomic Energy Agency (IAEA).

Mer information finns på: www.world-nuclear-university.org

Ekonomi

Resultatrapport och balansrapport per 31 December 2005 är bifogad i *bilaga 4*.

Nettoomsättningen för 2005 uppgick till 15,978 ksek dvs 22 ksek lägre än budgeterat enligt det samarbetsavtal som slutits mellan finansiärerna som uppgår till 16,000 ksek. Skillnaden beror på att de rekvirerade medlen korrigeras utifrån den till föreståndaren, förväntade rekvirerade lönekostnaden. Detta utjämnas mellan åren och för år 2004 översteg nettoomsättningen budgeten med ca 22 ksek.

Kostnaderna för högskolesamarbetet uppgick till 6,465 ksek och var lägre än budgeterat, framför allt beroende på att inget stöd utgick till post-doc KTH, eftersom det redan var utbetalt och fullföljt under 2004.

Totalt sett har kostnaderna för doktorandprojekt minskat, framför allt beroende på att fyra projekt avslutades 2004 samtidigt som endast ett projekt tillkom under 2005. Skillnaden mellan åren för respektive doktorandprojekt beror på olika aktivitet mellan åren. Detta följs upp så att de totala utbetalda medlen inte överstiger den totala beviljade budgeten för projektet.

Beträffande övrig verksamhet har framför allt kostnaderna för administrationen ökat sedan föregående år. Detta beror framför allt på följande: SKC hade en skuld till KTH sedan tidigare år på 133 ksek som utbetalades under 2005. En utredning om SKC:s verksamhet gjordes 2004 av Lars Högberg. Kostnaden för utredningen om drygt 130 ksek utbetalades och belastade 2005 års resultat. Dessutom har kostnader för 2004 års bokslut belastat 2005 års resultat.

Bilaga 1

Styrelseledamöter 2005

Ordinarie

Ordförande	Bertil Dihné	Vattenfall Bränsle AB
	Gustaf Löwenhielm	Statens Kärnkraftinspektion
	Per-Göran Nilsson	Forsmarks Kraftgrupp AB
	Nils-Olov Jonsson	Westinghouse Electric Sweden AB
	Håkan Talts	OKG AB
	Leif Johansson	Ringhals AB
	Agneta Nestenborg	Barsebäck Kraft AB

Suppleanter

	Oddbjörn Sandervåg	Statens Kärnkraftinspektion
	Thord Rooth	Forsmarks Kraftgrupp AB
	Stig Andersson	Westinghouse Electric Sweden AB
	Gunnar Rönnberg	OKG AB
	Eva Telg	Barsebäck Kraft AB

Adjungerade

	Bo Höistad	Uppsala universitet, Institutionen för Strålningsvetenskap
	Waclaw Gudowski	KTH, Reaktorfysik
	Imre Pázsit	Chalmers, Nukleär Teknik

Bilaga 2

Förteckning forskningsprojekt

Kat.	Projekt	Inst/avdeln Projektledare Lic/doktorand	Start mån/år Beräkn avsl med examen	Anmärkning	Projekt Budget 2005 (ksek)
KTH – Kungliga Tekniska Högskolan					
RS-2	Investigation of the heat and mass transfer process during film condensation in presence of noncondensable gases	Reaktorteknologi Univ.lekt Henryk Anglart Krysztof Karkoszka	Apr-02 Mar-06 Tekn.dr	Ref.grpsmöte 050513 Årsrapport 2004 Tekn lic 050519	1,089
HL-3	Detection of Stress-Corrosion Cracks by Means of Nonlinear Scattering of Ultrasonic Waves	Wallenberg laboratory PhD Claudio Pecorari Milan Poznic	Jan-03 Jun-05 Tekn.lic	Årsrapport 2004 Ref.grpsmöte 050526 Licexamen 060203	941
RT-7	Measurements and Analysis of Dryout and Film Thickness in a Tube with Various Axial Power Distributions	Reaktorteknologi Univ.lekt Henryk Anglart Carl Adamsson, Westinghouse	Jul-03 Dec-05 Tekn.lic	Årsrapport 2004 Ref.grpsmöte 050610 Licexamen dec 2005	941
MV-3	Modelling of radiation effects on mechanical properties of ferritic steels	Reaktorfysik Doc Janne Wallenius Christina Lagerstedt	Jul-03 Jun-07 Tekn.dr	Årsrapport 2004 Ref.grpsmöte 050204 Licexamen 051125	800
Summa KTH					**3,771**
CTH- Chalmers Tekniska Högskola					
RF-5	Advanced analysis methods for non-stationary processes in reactor cores	Reaktorfysik Prof. Imre Pázsit Carl Sunde	Jul-02 Jun-07 Tekn.dr	Ref.grpsmöte 041217 Årsrapport 2004 Tekn lic 041217	801
RF-6	Development of the Cf-252 method for reactivity measurements during core loading	Reaktorfysik Prof. Imre Pázsit Johanna Wright	Feb-03 Dec-07 Tekn.dr	Ref.grpsmöte 050530 Årsrapport 2004 Tekn lic 050530	900
RT-6	Use of intelligent computing methods for flow measurements and 2-phase flow diagnostics	Reaktorfysik Doc. Anders Nordlund Håkan Mattsson	Jan-03 Dec-05 Tekn.dr	Årsrapport 2004 Ref.grpsmöte Disputation 051221	400
MV-2	Positron techniques for investigation of radiation damage in materials	Reaktorfysik Doc. Anders Nordlund Elisabeth Tengborn	Nov-03 Tekn.dr	Årsrapport 2004 Ref.grpsmöte 050623	400
RS-3	Studier av jodkemi vid svåra reaktorhaverier	Kärnvetenskap och – teknologi Prof. Lembit Sihver Tekn.lic Henrik Glänneskog	Jan-04 Dec-05 Tekn.dr	Ref.grpsmöte Årsrapport 2004 Disputation 051028	1,000
Summa CTH					**3,501**
Uppsala universitet					
RT-8	Tomographic verification of the integrity of nuclear fuel assemblies	Strålningsvetenskap Doc. Ane Håkansson Tekn.dr Staffan Jacobsson Svärd Tobias Lundqvist	Maj-05 Maj-10 Tekn.dr		**235**
Mälardalelns högskola					
MTO-1	The ORCCA project	Adj.prof. Carl Rollenhag Ulf Kahlbom	Maj-02 Apr-06 Fil.dr	Årsrapport 2004 Ny ”industridoktorand” SKC projektandel 50%	**232**
Total summa					**7,739**

Kategoribeteckningarna har följande innebörd:

RF	*Reaktorfysik*
RT	*Reaktorteknologi*
RS	*Reaktorsäkerhet*
MV	*Materialvetenskap*
HL	*Hållfasthetslära*
MTO	*Människa-Teknik-Organisation*

Bilaga 3

Forskningsprojekt 2005

Investigation of the heat and mass transfer process during film condensation in presence of noncondensable gases

Project leader: Krzysztof Karkoszka, supervisor: doc Henryk Anglart
Division of Nuclear Reactor Technology, Department of Physics, KTH, Stockholm

Background

Condensation is a very important phenomenon in many industrial applications. In the nuclear safety analysis two cases are usually taken into account. The first one is LOCA where pressure level inside the reactor containment must be kept on the safe level. In this situation fast condensation of the huge amount of the released water vapour is required. The second one is the phenomenon of the long term condensation of the water vapour in the non – perfectly insulated non – vented pipes of the power plant pipeline system. Due to such event dangerous amount of the mixture of oxygen and hydrogen (which presence is a natural consequence of the radiolysis process of the water) can be accumulated and can seriously threaten the integrity of the pipeline system. Condensation in the non – vented pipes is a typical example of the film condensation. Due to the transport of the heat through non – perfectly insulated walls its temperature can drop below the saturation one and water droplets can be formed on its surface. Due to the gravity forces such droplets form a liquid condensate. Because of the very small values of the velocity field, film flow can be assumed to be the laminar. Many authors proved theoretically [1] and experimentally [2] that falling liquid films due to gravity forces are always unstable. After some distance from the film entrance, due to the instability, surface waves will be formed. Special place in the wavy film flow pattern is occupied by so called roll (or solitary waves) which transport most of the mass at almost constant velocity and constant shape. Hydrodynamics of this type of waves has been studied for several decades. It is well known fact that due to the thinning of the film, heat transfer through it is much higher than the one predicted by the Nusselt theory [3]. But what is the real influence of the film flow pattern on the heat and mass transfer on the gas side when additionally presence of the noncondensable gas is taken into account is still not clear enough. What is known for sure is that the structure of the liquid film influences both the gas side heat and mass transfer coefficients.

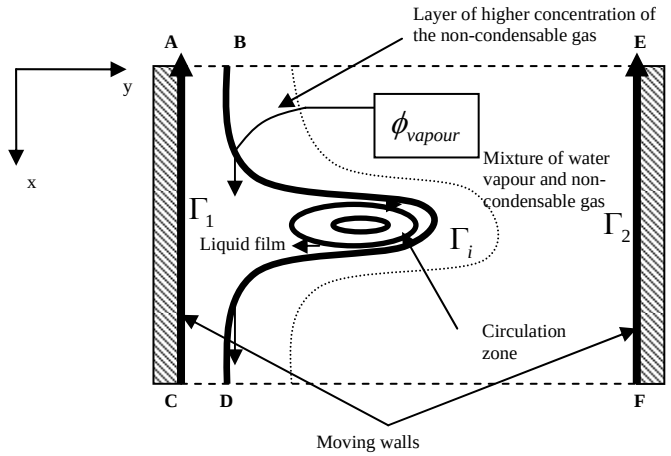

Fig.1 Scheme of the modeled phenomenon

Objectives

The aim of this project is the physical, mathematical and numerical analysis of the influence of the wavy film structure falling down along the vertical surface due to the gravity force on the heat and mass transfer process during condensation from the steam and noncondensable gas mixture.

Results in 2005

Condensation at the wavy liquid film surface has been investigated by a numerical approximation of the 2D Navier – Stokes equations in the general coordinate system (Eq.1):

$$\frac{\partial q^*}{\partial t}+\frac{\partial}{\partial \xi}F^{**}+\frac{\partial}{\partial \eta}G^{**}=\nu D\left[\frac{\partial^2}{\partial \xi^2}\left\{\left(\frac{\alpha}{J}\right)q\right\}+\frac{\partial}{\partial \xi}\frac{\partial}{\partial \eta}\left\{\left(\frac{\beta}{J}\right)q\right\}+\frac{\partial^2}{\partial \eta^2}\left\{\left(\frac{\gamma}{J}\right)q\right\}\right]+\frac{S}{J} \qquad (1)$$

where $q^*, F^{**}, G^{**}, v, D$ are vectors including unknowns variables (*p, u, v, T, ϕ)* and transformation coefficients; α, β, γ are transformation coefficients between Cartesian and general coordinate systems and ξ, η are axes in the general coordinate system, respectively. In order to solve a steady – state problem, artificial compressibility method has been used which allows the continuity equation to be modified into the following form:

$\frac{\partial p}{\partial t}+a^2\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=0$ (2), where *a* is so called artificial compressibility parameter.

Example of the computational results

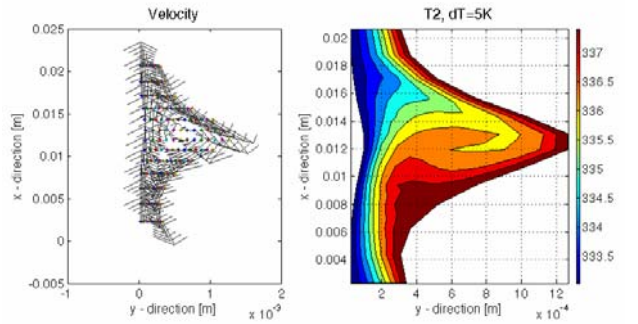

Fig.2 Velocity and temperature fields at the wave side of the computational domain

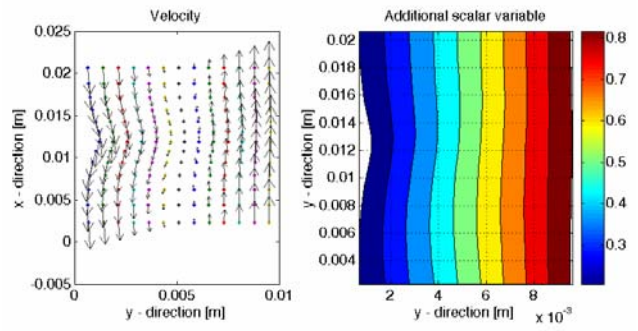

Fig.3 Velocity and additional scalar variable fields at the gas side of the computational domain

Personnel and collaborations

Project leader: Krzysztof Karkoszka, supervisor: Henryk Anglart. Project is also partially a contribution to the SARnet (A Network of Excellence for Research on Severe Accident Phenomenology).

Reference group

Anders Henoch – Ringhals, Farid Alavyoon – Forsmark, Oddbjörn Sandervåg – SKI, Dobromir Panayotov – Westinghouse, Claes Halldin – OKG

References

[1]Lee J., *Kapitza's method of film flow description,* Chemical Engineering Science, Vol.24, 1969

[2]Drosos E., Paras S., Karabelas A., *Characteristic of developing free falling films at intermediate Reynolds and high Kapitza numbers,* I. J. of Multiphase Flow, Vol.30, 2004

[3]Jayanti S., Hewitt G. F., *Hydrodynamics and heat transfer of wavy thin film flow*, Int. J. of Heat and Mass transfer, Vol. 40, 1997

Detection of Stress-Corrosion Cracks by Means of Nonlinear Scattering of Ultrasonic Waves
Third Year Report

Claudio Pecorari, Marcus Wallenberg Laboratory, KTH
E-mail: pecorari@kth.se

During the third year, the project has focused on the development of an ultrasonic method to characterize cracks as being surface-breaking or entirely embedded within the bulk of the material (sub-surface cracks). The growth rate of surface-breaking cracks in pipes carrying pressurized water is higher than that of subsurface cracks because it is favored by the combination of operational tensile stresses and corrosion due to water entrained within the crack. Therefore surface-breaking cracks constitute a considerably higher risk to the structural integrity of a power plant than sub-surface cracks. The motivation for this investigation is provided by the recent failure of conventional methods to discriminate surface-braking cracks from sub-surface cracks when the ligament separating the latter from the closest surface is smaller than the lateral dimension of the inspecting beam [Jenssen et al. 2000].

A theoretical investigation [M. Poznic, C. Pecorari submitted for publication] on the backscattering by surface-breaking and sub-surface cracks has been carried out. In view of the high internal pressure acting on the pipe wall during plant's operation, water is assumed to be entrained within a surface-breaking crack, while sub-surface cracks have been modeled as dry. Recent results [C. Pecorari, and M. Poznic (2006)] obtained during this project have shown the acoustic response of interfaces formed by rough surfaces in contact to be dramatically altered when water in confined by two solid surfaces. The experimental results of Figure 1 illustrate this point, and also show that, on the other hand, the tangential stiffness if not affected at all.

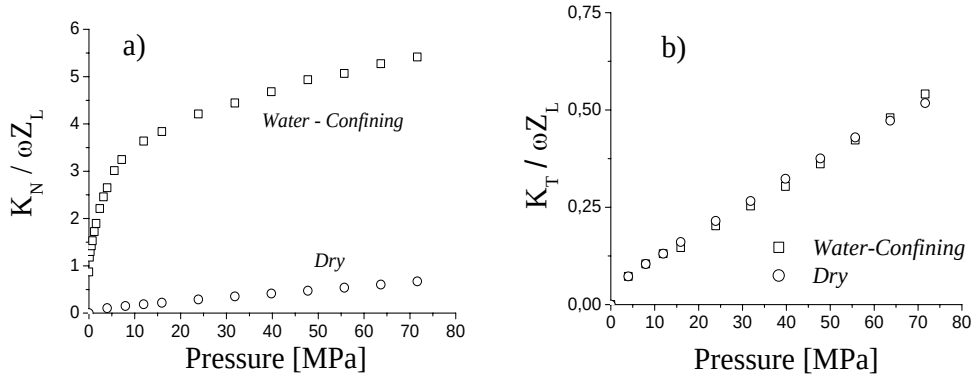

Figure 1. a) Normalized normal, K_N, and b) transverse, K_T, spring stiffness versus pressure applied to a water-confining and dry steel-steel interface. The symbols represent experimental results.

The sudden variation of the normal stiffness with the applied pressure provides the ideal nonlinear behavior necessary for a parametric modulation method to succeed. Figure 2 illustrates the principles of this method. A dynamic, low frequency load $P(t) = \Delta P \sin(\Omega t)$ is superposed to an existing one which partially closes the crack. The effect of the former is to modulate in time the closure of the crack and vary the response of the defect to an inspecting ultrasonic pulse. During a cycle of the low frequency modulation, three signals are recorded, two at the opposite turning points of each cycle, and one at the mid point when P(t) = 0. By using the peak-to-peak amplitude of the back-scattered wave the following ratio $R = \left(B^- - B^+\right) / B_o$ is constructed.

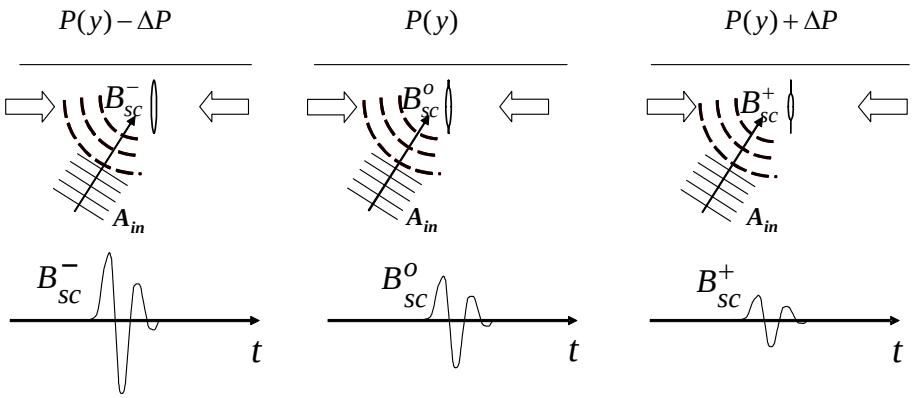

Figure 2. Schematics of the simulated modulation experiment illustrating the relationship between the state of the crack and the signal backscattered by it during a cycle of the modulation. The arrows pointing towards the crack represent the sum of the static pressure and of the modulation.

The numerical simulation carried so far have shown that, for a vertically polarized shear (SV) wave which insonifies a crack at 45 degree incidence, this ratio remains always higher than 0.7 if the defect is a surface-breaking crack, while it does not reach values as large as 0.3 when the crack is subsurface (see Figure 3 for an example). Other configurations, including waves of different polarization and angle of incidence have been considered, but no criterion as clear as that obtained with SV wave could be identified. Furthermore, for this configuration, the model predictions show the criterion to be robust for variations of the angle of incidence up to ± 5 degrees.

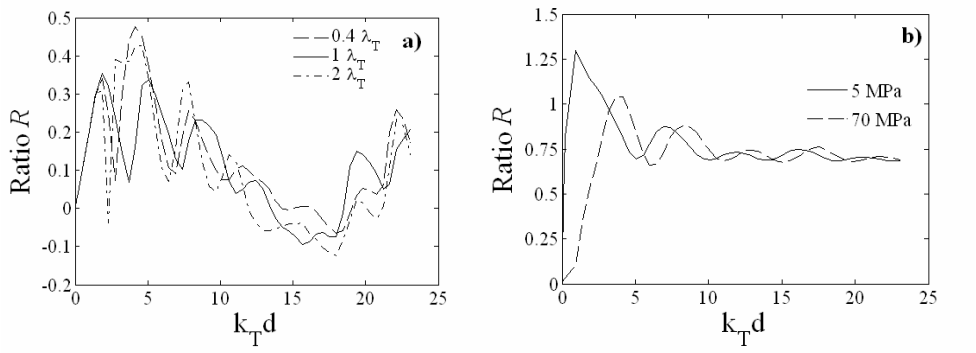

Figure 3. Ratio, R, versus nondimensional crack size $k_T d$ for values of the pressure at the crack tip equal to 5 MPa and 70 MPa. a) dry subsurface crack, b) water-confining surface-breaking crack.

References

A. Jenssen, K. Norrgård, R. Lundström, B. Claesson, and H. Ericsson "Metallographic examination of cracks in nozzle to safe-end weld of alloy 182 in Ringhals 4", Studsvik Report, Studsvik/N(H)-00/099 (2000).

M. Poznic, and C. Pecorari, "So . . . is this a surface-breaking crack?", submitted for publication to the *Journal of Mechanics and Materials*.

C. Pecorari, and M. Poznic, "On the linear and nonlinear acoustic properties of dry and water-confining elasto-plastic interfaces", *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 2006, DOI: 10.1098/rspa.2005.1595.

Measurements and Analysis of Dryout and Film Thickness in a Tube with Various Axial Power Distributions

Project leader: Carl Adamsson, supervisor: doc Henryk Anglart
Division of Nuclear Reactor Technology, Department of Physics, KTH, Stockholm

Background

In high performance heat exchangers, such as nuclear reactors, the critical heat flux gives the most important design boundary. In a BWR nuclear reactor the critical heat flux occurs through the process of dryout, i.e the disappearance of liquid film from the fuel rod surface. At the transition to dryout the heat conduction between the fuel and the coolant is vastly reduced, leading to a sharp increase in fuel temperature and possible fuel damage. It is obvious that accurate methods to predict the dryout limit under various conditions are needed. Today the industry relies on empirical correlations, which require extensive full scale experiments. Moreover, since the correlations used today are not well-founded in physical reasoning they cannot be trusted if used outside the parameter range of the underlying experiment. In some cases this can be a severe limitation; e.g. there has recently been an increasing interest in the influence of the axial power distribution on the dryout power. For practical reasons it is only possible to perform experiments for a very limited set of power distributions. It is thus questionable if empirical correlations can be trusted to predict the quit large effect of the power distribution in an adequate way.

Most models developed are built on the assumption that the annular steam-water flow can be described as a balance between a gas-field, a liquid droplet-field and a liquid film-field. Dryout is then postulated to occur when the liquid film thickness becomes zero. To develop and validate mechanistic models however, experimental data on the film thickness and film flow rate are much more useful than data on only the dryout power itself. Such experiments have been performed by several researchers under various conditions, but most of this data do not focus on the axial power distribution.

Objectives and Methodology

The main objective of the present work is to extend the database of film flow measurements with data that are well suited for validation of phenomenological dryout models with focus on the axial power distribution. For this purpose it was decided to measure the film flow rate at typical BWR conditions for various axial power distributions and at several axial locations.
The method for film flow measurements has been used by several researchers before; the film is sucked of the tube wall and the gas content in the sample is measured through a heat balance calculation.

Results during 2005

The measurements on four axial power distributions (inlet peak, outlet peak, middle peak and uniform) were completed during spring 2005. In June the lab was closed and the equipment dismounted. During fall 2005 the results were thoroughly analyzed and it was concluded that the expected influence of the axial power profile could be seen in the results.

Fig.1 shows the main result; the outlet peaked profiles gives higher drop flow rate and thus smaller film flow rate compared to the inlet peaked profile. This explains why dryout occurs at lower power with outlet peaked profiles.

Two conference papers [1], [2] were published and one article [3] has been submitted for publication. The licentiate seminar is planned at 13th of Mars 2006.

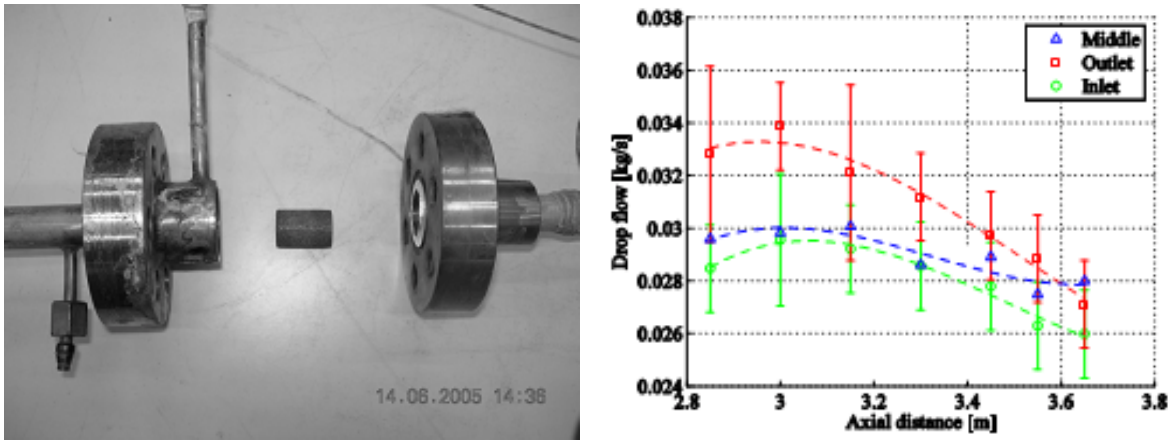

Figure 1. Left: Photograph of dismounted film extraction device. Right: Comparison of drop flow rates for three axial power distributions.

Theoretical Work

The theoretical part of the project will be to investigate the deposition of liquid droplets onto the liquid film by Computational Fluid Dynamics (CFD) methods. To predict the dynamic behavior of the liquid droplets, there are plans to use both Lagrangian particle tracking and the Eulerian description of the droplet field. The work is needed since there are strong indications that the most common correlations used to calculate the deposition rate today cannot be generally valid.

References

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Modelling of radiation effects on mechanical properties of ferritic steels

Research leader: Associate professor Jan Wallenius
Scientist: Christina Lagerstedt, Division of Reactor physics, KTH, Stockholm

Background

Mechanical properties of steels used as components in reactors are degraded due to effects of radiation, thermal ageing and thermo-chemical environment. Often threshold behaviours are observed, meaning that a component may have served without problem for many years, or even decades, before an abrupt change in ductility or volume takes place. These phenomena are further known to be dose rate dependent, meaning that accelerated irradiation tests often will give wrong predictions of limits to service life in a real reactor environment. This is especially trouble-some in light water reactors, where the threshold time for embrittlement or swelling to become significant is of the order of decades. Therefore, it becomes important to obtain a basic understanding of the mechanisms responsible for the irradiation degradation of mechanical properties. Today this can be achieved for pure metals by means of computer modelling, using a multi-scale approach ranging from solutions of the Schrödinger equation to elasticity theory for macroscopic bodies.

Goals of the project

In the present project, existing empirical models for pure elements like Fe are extended to the Fe-Cr-C system, which may serve as an idealised model of ferritic steels actually used for reactor components. By the end of the project, a so called ”Embedded atom method”, or EAM model for this system will have been developed, that is able to correctly reproduce elastic, thermo-physical and point defect properties of this material out of pile, as function of Cr and C content. This model will be used for predicting the change of mechanical properties as function of irradiation dose, dose rate and temperature. Comparison with relevant experimental data will then be made, to check the predictive power of the model. Finally, an evaluation of the applicability of the results with respect to real industrial ferritic steels will be attempted.

Organisation

The work is performed by PhD student Christina Lagerstedt and Associate Professor Janne Wallenius at the department of Reactor Physics. Collaborations with Uppsala University, the institute of Chemical Metallurgy in Paris and the Belgian Nuclear Research Centre in Mol are providing essential input and feedback to the project. The results are presented at international conferences and published in refereed journals. The contact reference group consists of Behnaz Aghili, SKI, Magnus Limbäck, Westinghouse, Mats Molin, Forsmark, Pål Efsing, Ringahls/Barsebäck and Bengt Bengtsson OKG.

Methodology

In 2005, we refined our “two-band” model of the alloy, where we by assigning the change in sign of the mixing enthalpy to interactions between s-electrons of Fe and Cr, could reproduce the formation energy calculated with ab initio methods over the relevant range of Cr concentration. Thus the many-body contribution to the total energy was written as a sum of functionals of d, and s-electron densities, in line with theoretical understanding of transition metals, which state that while s-electrons contribute with minor parts to the cohesive energy, they provide significant parts of pressure and dominate bulk moduli.

This model was applied in molecular dynamics simulation of defect formation energies, and it was shown that the “two-band” set of potentials were capable of reproducing the formation and binding energies of a wide range of interstitial configurations including one or two Cr atoms in bulk Fe. Using the potential in Kinetic Monte Carlo simulations of phase segregation, formation of the alpha-prime phase was observed with cluster characteristics typical for those observed in experiment. Figure X.3 shows the positions of Cr atoms in originally random alloys after simulated ageing at 750 Kelvin.

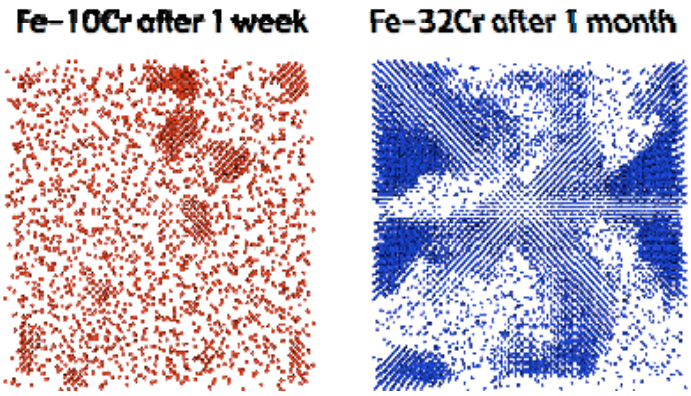

Figure X.3: Positions of Cr atoms in initially random FeCr alloys after simulated thermal ageing.

For lower Cr concentrations than 9%, no segregation is observed, In Fe-10Cr, the spherical shape of the precipitates are those typical for the nucleation and growth mechanism, expected to occure for positive curvatures of Gibbs' energy, while in Fe-32Cr, the precipitates have the diffuse shape typical for spinodal decomposition. The compostion of the precipitates is similar to those found experimentally, with Cr concentrations ranging from 50-90%. While the present version of the two-band model enables for the first time to simulate the formation of the alpha-prime phase in Fe-Cr, it needs to be extended to take into account the effects of magnetism. This work is in progress.

Concerning the primary damage production in neutron induced collision cascades, extensive simulations were performed by molecular dynamics using different sets of potentials. These potentials (created by us and other authors) predict different displacement threshold energies (for the creation of a single Frenkle pair).

Contrary to expectation, it was found that the total number of Frenkel pairs produced in high energy cascades did not correlate with the displacement threshold energy. Instead a correlation with the stiffness of the potentials was found. Potentials with high interstitial formation energy, as the one fitted for iron by us were observed to result in less dense cascades and small defect cluster sizes. The number of final defects produced by the different potentials was however largely independent on how the cascade behaved at peak time.

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D. Terentyev, L. Malerba, R. Chakarova, K. Nordlund, P. Olsson, M. Rieth and J. Wallenius
Displacement cascades in Fe-Cr: A molecular dynamics study
Journal of Nuclear Materials 349 (2006) 119.

Kai Nordlund, Janne Wallenius and Lorenzo Malerba
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Christina Lagerstedt
Simulation of radiation damage in Fe and FeCr
Licentiate thesis, KTH (2005).

D. Terentyev, C. Lagerstedt, P. Olsson, K. Nordlund, J. Wallenius, C.S. Becquart and L. Malerba
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Advanced analysis methods for non-stationary processes in reactor cores

Research Leaders: Professor Imre Pázsit, Department of Nuclear Engineering (former Reactor Physics), CTH, Göteborg and Docent Ninos Garis, Swedish Nuclear Power Inspectorate, Stockholm.
Scientist: Carl Sunde, Department of Nuclear Engineering, CTH, Göteborg

Background

Diagnostics of reactor cores with noise methods is usually performed with FFT based spectral analysis, such as auto and cross spectral power densities. Such an analysis makes an implicit use of the fact that the system is stationary, at least during the measurement period on which the spectral analysis is made. In other words the status of the system is assumed to be unchanged over several tens of thousands of the periods of the characteristic frequencies of the system.

Nevertheless, the state of the syste often changes during a much shorter period. Non-stationary processes and transients are in fact quite common in reactor systems, such as the occurrence and development of local and global core instabilities in BWRs, the short-term changes of vibration properties (core-barrel, fuel assembly etc) in PWRs, and the various phenomena in two-phase flow (vortex shedding, slug flow etc). Apart from temporal transients, spatial transients or non-stationarities may also occur, such as in the spatial structure of two-phase flow.

Powerful mathematical methods have been developed and applied lately for the analysis of such processes, out of which wavelet analysis is one of the most promising.

Goals

The purpose of the project is to introduce the use of analysis methods of non-stationary processes, and primarily wavelet analysis, into the noise diagnostic work of our Department and to explore their possibilities for diagnosing non-stationary processes. We expect to elaborate new methods for understanding the mechanism, and even predicting or early detection of the occurrence and intermittence of non-stationary processes and instabilities, and to elaborate reliable methods of parameter estimation under non-stationary circumstances. The methods will be tested on measurements taken in Swedish power plants.

Organisation

The reactor diagnostic group is headed by Prof. Imre Pázsit, who is also the leader of this SKC – supported PhD project. The procject has been going on since July, 2002. Dr. Christophe Demaziere, university lecturer, is also supporting Carl Sunde on some aspects of the project.

The members of the reference group are: Pär Lansåker Forsmark, Henrik Eisenberg OKG, Henrik Nylen Barsebäck, Ninos Garis SKI, Johan Larsson Ringhals, and Camilla Rotander, Westinghouse.

Methodology

The methodology is similar to traditional noise analysis work, which consists of both evaluation of measurements, and elaborating models of the reactor and its processes to expedite the interpretation of the measurement analysis. Hence both theoretical model development and analysis of measurements is involved. In the analysis part, in contrast to the FFT tool, used in the traditional methods, continuous (CWT) or discrete fast wavelet transform (DWT) is used. A large part of the activity in 2005 concerned developing physical models and investigating their properties as well as comparing them with measurements.

Activity and results - with focus on 2005

1. Core barrel vibrations. A paper submitted to Nuclear Technology on the formerly developed, two-dimensional two-group model of core barrel vibrations was accepted for publication [1]. The results of the model were compared with measurements by in-core detectors from Ringhals 3 and 4. Unfortunately, the measurements were not able to detect the large local component predicted by the model (See Fig.1). The main reason is, as Fig. 1 shows, that it is not possible to place the detectors sufficiently close to the core boundary, where the local component exists. Another possible reason is

that the magnitude of the local component becomes much smaller if one takes into account the movement of the detectors together with the core. This phenomenon was investigated and proved in the adiabatic noise approximation. The results were reported at one of the two largest ANS topical conferences, and published in the proceedings [2]. The conclusion is that it is not possible to include the in-core detectors when analysing the shell-mode core-barrel vibrations. Instead the project will be focused on using only the ex-core detectors.

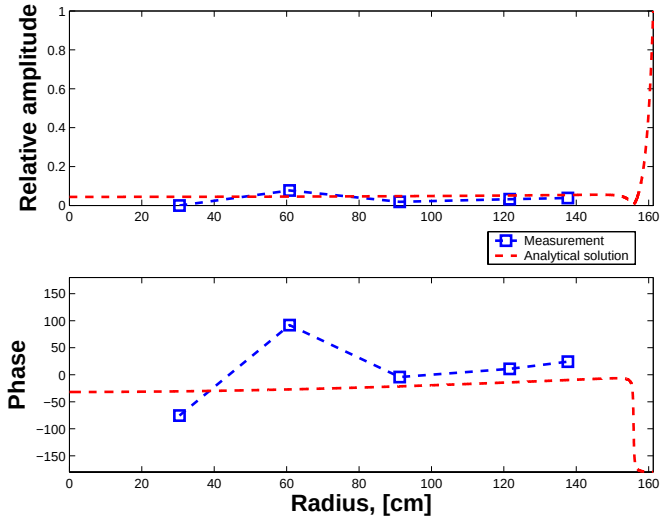

Fig 1 Comparison between calculations and measurements for possible diagnostic of the shell-mode core – barrel vibrations at Ringhals-,3 2005. The top figure shows the amplitude of the in-core detectors at the peak at 20 Hz. The lower figure shows the phase between in-core and ex-core detectors.

2. Detector string impacting. The research project about the detector string vibrations in Ringhals 1 by using spectral and wavelet analysis has continued during 2005, [3]. This year a higher sampling frequency of the measurements were tested in order to try to improve the wavelet method. However, the higher sampling frequency did not improve the results. A formerly submitted and accepted paper on the research results was scheduled to appear in print in 2005, [4].

3. Investigation on the use of wavelet techniques for BWR stability analysis. An extensive study was performed to investigate the efficiency of wavelet transform and filtering for improving the determination of the decay ratio (DR) in noisy signals and in the case of dual oscillations. These studies were made by a simulation model for damped oscillations of a resonant system, driven by a white noise force, so that the true value of the DR was known, and then independent white noise background was added. The final interpretation and summary of the results is still underway.

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Development of the Cf-252 method for reactivity measurements during core loading

Research Leader: Professor Imre Pázsit
Scientist: Johanna Wright, Department of Reactor Physics, CTH, Göteborg

Background

Measurement and monitoring of reactivity during the loading of a power reactor has a clear safety relevance. The methods currently available for this purpose are not satisfactory. The question of monitoring reactivity has received inceased actuality in connection with a few recent incidents and accidents (Tokaimura; Japan, 1999; Dampierre-4, France, 2002; Paks-2, Hungary, 2003). Methods of measuring reactivity in a subcritical system with a source are mostly based on the statistics of the subcritical chains, induced by the source neutrons. Such methods are the variance-to-mean or Feynman-alpha, the correlation or Rossi-alpha method, the source modulation (the only deterministic method) and the break frequency method. The first two have been tested and used extensively at research and zero power reactors. None of the methods have been tested or used extensively at power reactors.

An alternative method was proposed some time ago which is based on the so-called Cf-252 method. The essence is to use a Cf-252 neutron source, which is built together with an ionisation chamber. Such an arrangement is called a "Cf-252 detector". The detector detects each spontaneous fission event, leading to neutron emission, through the ionised fission products, but without absorbing any neutrons. Using two more ordinary neutron detectors in the system, and combining various auto- and cross-spectra between the CF-detector and the neutron detectors, the multiplication constant can be extracted in absolute values, without knowlegde of the delayed neutron fraction.

Goals

The purpose of the project is to identify the the most suitable method of reactivity measurements, with a preference for the Cf-252 method. For the latter, the goal is to get acquainted with the principles and the theory of the method, and develop it further. In the derivations of the formula used in the method that are found in the literature, several simplyfing assumptions are made. One objective of the project is to reduce the dependence of the method on these simplifiations. Test and study of other methods, such as the source modulation method, is also planned. The project is performed in collaboration with CEA France, as well as Nagoya University and KURRI (Japan). The understanding the importance and significance of the space-dependent effects due to the localised source is one important partial objective of the project.

Organisation

The reactor diagnostic group is headed by Prof. Imre Pázsit, who is also the leader of this SKC–supported PhD project. During 2005 he was assisted by Dr. Christophe Demaziere. There is another PhD student in noise diagnostics, Carl Sunde, whose project is also supported by SKC. The leader of the experimental activity at the Department is docent Anders Nordlund. There are two technicians who support the experimental part of the project. The members of the reference group are: Tell Andersson Ringhals, Ninos Garis SKI, Jan Hanberg Forsmark, Kjell Adielsson OKG, Marie Nilsson Westinghouse.

Methodology

The methodology of stochastic methods is based on the so-called master equation technique. The master equation is a balance equation for the temporal and spatial evolution of the probability distribution of the neutrons, precursors and detector counts in a multiplying medium. From the master equation one can derive equations for the moments, out of which the first two, the mean and the variance are used, or some functions of those, such as temporal correlations or power spectra. An analytic expression of some measured quantity, such as the time dependence of the relative variance of the detector counts (Feynman-alpha) or the auto- and cross spectra of the detectors in the Cf-252 method, is then used for fitting the experimental data and extracting the reactivity (through the prompt neutron time constant). The deterministic methods are based on the theory of power reactor noise, using the Langevin equation. This latter is the method to be used in the source modulation

technique. What regards the Cf-252 method, both tools are applicable, depending on the depth of the modelling of the case. To understand the significance of the space dependent effects, one needs though to use the Langevin equation for the modelling.

Results - with focus on 2005

In 2005 the study of the performance of the source modulation technique was completed. This included a general study of space dependent effects in source driven subcritical systems (ADS), and their application for the assessment of the method. The surprising result was obtained that the performance of the method, which is based on the application of the point kinetic approximation, does not become asymptotically exact in the limit of point kinetic behaviour of the core. In fact, the method has a systematic error even if the core behaves exaclty in a point kinetic manner. The reasons for this pathological behaviour were analysed and explained. The findings mean that the source modulation technique is less suitable for the monitoring the reactivity of an ADS than originally predicted. It cannot be used as an absolute method; however, it can work after calibration as a relative method.

The results obtained earlier regarding the pulsed Feynman alpha method and submitted earlier were accepted for publication and appeared in print (Refs [1] and [2]). Together with the results on the source modulation technique, a licentiate thesis was written and the licentiate examen was taken in May 2005 [3]. Simultaneously the results on the source modulation technique were submitted for publication, were accepted and the paper appeared in December 2005. The results were also presented at the ANS topical conference Mathematics and Computation, Avignon, September 2005 and published in the proceedings. The results were also reported in the research project with Ringhals [6].

The continuation of the work was partly planned by the extension of the investigation of the source modulation technique to realistic 2-D cores with the use of the noise simulator, developed by Christophe Demaziere. Such a preliminary work was performed and reported at the Global05 conference in Tskukuba, Japan, October 2005 [7].

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Use of intelligent computing methods (”soft computing”)" for flow measurements and two-phase flow diagnostics

Research Leaders: Professor Imre Pázsit, Associate Professor Anders Nordlund
Scientist Håkan Mattsson, Department of Nuclear Engineering, CTH, Göteborg

1. Background

The general goal of the project is to elaborate and use soft computing tools for novel methods of flow measurements. Correlation methods, in combination with neural network and other unfolding methods will be employed. The actual measurement data are produced with pulsed neutron activation, and the simulation data for the training of the network is produced by computational fluid dynamics (CFD) methods.

Pulsed Neutron Activation (PNA) is a method for activation of e.g. ^{16}O to^{16}N using neutron pulses from a neutron generator. In this way radioactivity can be produced at a suitable place in a water flow in a pipe. The signal from a detector downstream from the activation point can be used to make an accurate determination of the water flow.

The detector signal is measured as a function of time after the neutron pulse. One problem with the project is that extraction of data from this curve is not trivial. The main reason for the problems is thought to be that the activity in the pipe is not homogeneously distributed in the pipe. This, in combination with that there is a velocity profile in the pipe, will make the velocity of the activity change with the distance from the neutron generator. Another problem is that the velocity of the activity will not be the same as that of the water. These factors will affect the shape of the detector signal.

2. Goals

The objective of the project is the development and the use of intelligent computing methods ("soft computing") for flow measurements and two-phase flow diagnostics. Intelligent or soft computing is a terminology which refers to several new methods that have appeared in the area of signal analysis (neural networks, wavelets, fuzzy algorithms, neuro-fuzzy methods, fractal methods, genetic algorithms etc.). These methods open new possibilities of signal analysis and diagnostics, and they make improved and more effective applications possible.

The ultimate goal of the project is to develop a flowmeter that can measure the velocity of water in pipes.

3. Organisation

The Department of Nuclear Engineering is headed by Prof. Imre Pázsit, who is also the co-leader of this SKC–supported PhD project. The leader of the experimental activity at the Department is Associate Professor Anders Nordlund, and he is also the supervisor of Håkan Mattsson.

The reference group consists of Davide Roverso, Halden, Pär Lansåker, Forsmark, Sven Andersson, OKG, Ninos Garis, SKI and Nils Erik Nilsson, Ringhals.

4. Methodology and results

The PNA method can be said to consist of four parts: activation of the water, transport and mixing of the activity, detection of the activity and analysis of experimental data. All of these four parts have been studied within this project.

Calculations have been made to simulate the distribution of the acitvity in the pipe. This distribution was used as a starting point of the CFD calculations where the transport and mixing of the activity in the pipe was investigated. The commercially available CFD code FLUENT was used. Different detector response functions have been investigated to calculate the detector signal from activity in different parts of the pipe. These calculations has been evaluated together and found to agree reasonably with experimental data.

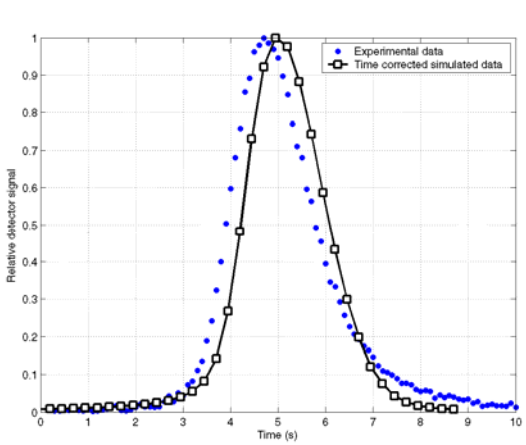


Figure 1: Calculated detector signal compared to experimental data.

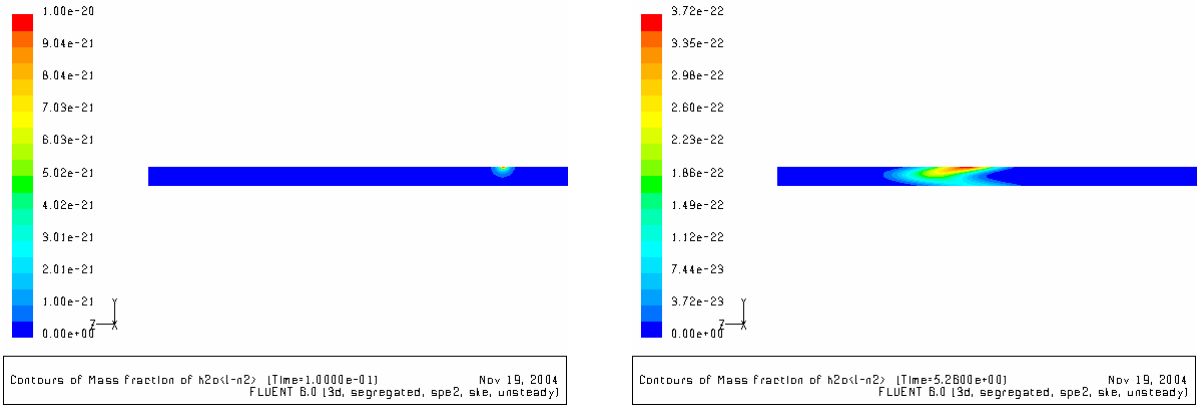


Figure 2: The activity distribution at two different times. The left picture shows the activity distribution just after the activation and the right picture shows the activity distribution five seconds later.

Results with focus on 2005

- A PhD thesis has been written: Pulsed Neutron Activation for Determination of Water Flow in Pipes.
- The results from the project was presented at the International Topical Meeting on Mathematics and Computation, Supercomputing, Reactor Physics and Nuclear and Biological Applications, France 2005.
- The results were presented at the 5th Pacific Symposium on Flow Visualization and Image Processing, Australia 2005.
- The results were presented at an informal meeting in Halden, 2005.

Positron techniques for investigation of radiation damage in materials

Research Leader: Docent Anders Nordlund
Scientist: Elisabeth Tengborn, Department of Reactor Physics, CTH, Göteborg

1. Background

Positron annihilation spectroscopy is a set of established techniques in the study of vacancy on open volume defects in materials. Due to its positive charge, the positrons can be trapped in such defects, resulting in a longer lifetime before annihilation. By measuring both the intensity and the positron lifetime, information about the defect concentration and type can be derived.
At the Department of Reactor Physics, Chalmers University of Technology, a beam with pulsed positron with variable energy is under construction. This will be one of only a few such facilities in the world. The pulsing of the positrons, in combination with a fast scintillator for annihilation gamma detection, enables direct lifetime measurements, while the variable energy of the beam facilitates depth scanning of material defects.

2. Goals

The objective of the project is the finalizing of the pulsed positron beam and the optimization of the beam parameters to achieve a measurement system well suited for positron lifetime spectroscopy in a wide range of materials. The PhD project will be much focussed on the properties of the beam and also on measurements on materials with different radiation induced vacancy concentration.

3. Organisation

The Department of Reactor Physics is headed by Prof. Imre Pázsit. The leader of the experimental activity at the Department is docent Anders Nordlund, also the supervisor of Elisabeth Tengborn.
Much of the beam construction is carried out in close collaboration with the University of Ghent, Belgium.

The reference group consist of Behnaz Aghili, SKI, Magnus Limbäck, Westinghouse, Mats Molin, Forsmark, Bengt Bengtsson, OKG and Pål Efsing, BKAB.

4. Methodology

The development of the positron annihilation spectroscopy facility requires the following:

- Finalizing the physical beam by adding an acceleration stage and a sample chamber.
- Optimizing the beam parameters such as parameters for pulsing (chopping, bunching systems), transmission (magnetic field, drift acceleration potential), main acceleration and detection system and data acquisition.
- Measurements on irradiated materials.
- Developing an algorithm to unfold experimental data with respect to the positron time distribution in the beam
- Modelling and interpretation of results.

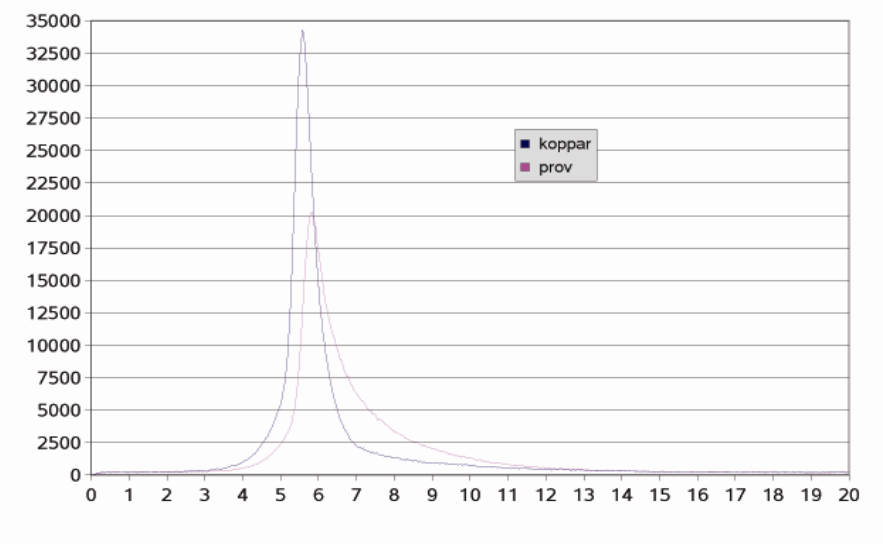
5. Results with focus on 2005

During the autumn of 2005 the beam was completed, with a new source and a sample chamber, and it is now possible to perform measurements at the facility.

Much of the research activities within the project during 2005 have been carried out in collaboration with the positron group at Helsinki University of Technology. The PhD student in the project spent 2 months there to learn some different positron based measurement techniques such as doppler broadening and continuous beam experiments.

The pulsed positron beam at Nuclear Engineering, Chalmers University of Technology

The experimental time spectra depend both on the possible life time components in the sample and on the positron time distribution in the beam. This time distribution has to be measured with a reference sample with very low life time, such as annealed Ni, for each experiment and the data have to be unfolded with this time distribution. An algorithm to perform this unfolding with large data sets has to be developed.



Pulse positron beam measurement with the Chalmers beam on both a copper reference sample (blue, short lifetime) and a semi conductor sample (red, long lifetime). Counts on y-axis and time in ns on x-axis.

The project is part of the EU-collaboration PERFECT, an integrated project within the sixth framework. This project regards irradiation damage effects in reactor components, mainly steel. The first progress report for our beam has been reported within the collaboration and the results are also documented in the report CTH-RF-189, Pilot experiments with the Pulsed Positron Beam at Chalmers University of Technology.

Preliminary results have alse been presented at the Halden research reactor.

Tomographic verification of the integrity of nuclear fuel assemblies

Research leader: PhD Staffan Jacobsson Svärd
Scientist: Tobias Lundqvist, Department of Nuclear and Particle Physics, Uppsala University

Background

The spent nuclear fuel from Swedish nuclear power plants will be encapsulated and stored in a final repository. In connection to this type of "difficult-to-access storage", the International Atomic Energy Agency (IAEA) sets safeguards criteria to ensure non-proliferation of nuclear materials. One such criterion is that the integrity of the fuel has to be verified.

Currently, there are no measuring techniques for verifying the integrity on the 100 % level, i.e. for ensuring that all declared fuel rods are present in a fuel assembly. However, in the report from the IAEA meeting "Coordinated Technical Meeting on Spent Fuel Verification Methods" in March 2003 [1], it is stated that tomographic technique is the strongest candidate for this type of verification.

Today, there are two groups in the world that work with tomographic techniques for irradiated nuclear fuel assemblies. At Uppsala University, a technique has been developed in an earlier project supported by SKC. In the PhD thesis presented [2], the applicability of the technique for two purposes was demonstrated; (1) Highly accurate determination of the pin-power distribution, and (2) Verification of the integrity of spent nuclear fuel.

Objectives

The objectives of the current project is to further develop the tomographic measurement technique from [2] and to adapt it especially for the safeguards demand of integrity verification of spent nuclear fuel, with focus on encapsulation and final reposition. The development will be based on the following techniques:

- Tomographic reconstruction using fast, analytic algorithms that enable on-line inspection.
- Image-analysis techniques of the images resulting from the on-line reconstructions.
- Tomographic reconstructions using algebraic techniques, involving modeling of the gamma-ray transport in the fuel. Such reconstructions enable highly accurate quantification of the activity content in individual fuel rods and, accordingly, give the possibility of making confident statements in the case of questionable integrity.

Preliminary studies using image-analysis techniques indicate that tomographic images can be used for both identifying the fuel type and for counting the number of fuel rods present, i.e. for verifying the integrity of the fuel. In addition, the possibilities to determine whether a missing fuel rod has been replaced or removed without replacement will be investigated.

Results in 2005

The work during 2005 has been focused on two main issues; (1) The development of analytic algorithms for tomographic reconstruction on spent nuclear fuel, and (2) Investigations of the background shielding required in equipment for tomographic measurements. The results have been presented in an internal report [3], respectively in a project report [4]. The first issue is somewhat more elaborately described below.

The application of analytic reconstruction algorithms on spent nuclear fuel is complicated because of the strong attenuation of gamma rays in the fuel material. In this work, three analytic algorithms have been developed and tested. The first is a basic algorithm, where the attenuation of gamma rays is omitted. The second algorithm incorporates attenuation, whereas the third algorithm also incorporates solid-angle effects. For all three algorithms, the geometry of the fuel assemblies is assumed to be unknown.

The development has been mainly based on simulated data of the SVEA-96S fuel type. The applicability of the algorithms on experimental data has also been demonstrated using data from previous measurements performed at the Forsmark 2 reactor on an irradiated assembly with a cooling

time of about 4 weeks. Three reconstructions of the experimental data are presented in figure 1, one with each algorithm.

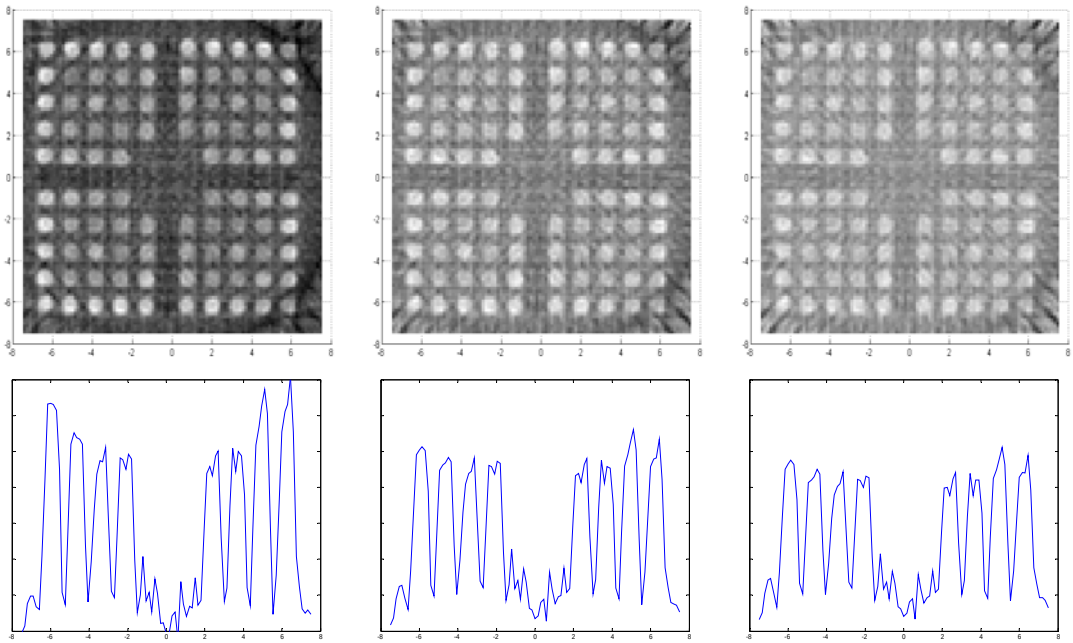


Figure 1. Images obtained when applying three analytic reconstruction techniques to experimental data from a SVEA-96S fuel assembly. Left is a basic technique, middle is an algorithm incorporating homogenous attenuation and right is an algorithm also incorporating solid angle effects. Below are reconstructed activities on a horizontal line in the image, covering a central row of eight fuel rods.

Qualitative visual inspection of the images gives at hand that all 96 fuel rods are present, i.e. the integrity is complete. The first image is the least inflicted by noise, but, as attenuation is not taken into account, the reconstructed activities in central rods are systematically lower than in central rods, thus disturbing quantitative analysis. The more detailed reconstructions show no such systematic effects, although the background level is higher. The plan is to eliminate this problem by setting a proper background level in the image-analysis procedure.

Besides presenting the results above, Tobias has in his first 8 months finished a 5-p course in image analysis and is half way through a 5-p course in computer-based measuring techniques.

Personnel and collaborations

The scientist is Tobias Lundqvist and the supervisor is Staffan Jacobsson Svärd.

Reference group

The reference group of this project consists of the following persons:
Kåre Axell – SKI, Björn Bjurman – Forsmark, Mats Thunman – Westinghouse and Göran Wiksell – OKG. (The position from Ringhals/Barsebäck is currently vacant.)

References

1. *Coordinated Technical Meeting on Spent Fuel Verification Methods, Vienna, March 3-6, 2003*. IAEA report, Vienna 2003.
2. S. Jacobsson Svärd, *A Tomographic Measurement Technique for Irradiated Nuclear Fuel Assemblies*, Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology 967, ISSN 1104-232X, ISBN 91-554-5944-7, Uppsala 2004.
3. T. Lundqvist, *Tomographic Methods Applied on Spent Nuclear Fuel Assemblies; Analytical Reconstruction Techniques*, Internal report at the Dept. of Radiation Sciences, Uppsala University, ISV-2/2005.
4. T. Lundqvist, *Simulering av strålintensiteter och strålskärmning i utrustning för effektmätningar på kärnbränsle*, Report to OKG and FKA, January 2006.

The ORCCA project

Research leader: Adjunct professor Carl Rollenhag, Mälardalens högskola
Scientist/graduate student: Ulf Kahlbom

The ORCCA project (Organisation, Risk, Communication, Culture, Analysis) is focused on the interaction among subcultures in nuclear organisations and particularly how organisational change management interact with cultural elements. The project is based on a cultural approach, which focuses on principles guiding the behaviour of organisations and its personnel.

The value of a cultural approach is that it enables a generic view of the social dynamics in a complex and diverse domain. The first part of the project was conducted in close cooperation with researchers in Finland in a study about maintenance culture. Assessment was made by means of maintenance core task modelling (Oedewald & Reiman 2003). The study also aimed to validate the methodology for contextual assessment of organisational culture (Reiman & Oedewald 2002).

The study contained many interesting observations about two maintenance organisations in two Nordic countries. Common to both plants was that the goals of maintenance tasks were clear. The personnel saw their work as highly important, even though the plants differed significantly on how the personnel perceived how their work contributed to the overall goals of the organisation. As a hypothesis, the researchers proposed that work activities and their context may be characterised in at least the following important general dimensions:

- Meaningfulness
- Communication climate
- Experienced control
- Structure.

These dimensions are complex dimensions and affect each other. Experienced control, for example, is dependent on meaningfulness, but also on communication climate and structure. Meaningfulness as a dimension was in the study found to exhibit significant positive correlation's with job motivation and job satisfaction (which both may be assumed to be output variables resulting from more specific factors). Positive communication climate was found to correlate positively with motivation and well-being. Introduction of complex and large matrix organisations was found to correlate with many difficulties. In fact, the more "matrix" used, the more communication was needed in order to support then functioning of the matrix. To some extent this increased need for communication seems to counteract the efficiency benefits looked for in the matrix arrangement.

Structure was defined as the degree to which people feel that goals, tasks, responsibilities etc are well defined. Judging from specific correlations among some of the items measuring structure, it was found that structure correlated positively with safety related items. This is perhaps an expected but nevertheless interesting observation that evokes general issues about how structure and flexibility interact in safety related activities.

It is interesting to speculate to what extent these general dimensions are affected by different management innovations and how they correlate to various structural arrangements (matrix organisations, line organisations etc). It could be suggested as god praxis to inspect the above dimensions when doing organisational changes, and especially when conducting risk analyses before these changes are made.

The first part of the project was finalized, submitted and accepted for publication in an international magazine. Due to unforeseen circumstances the second part of the project was delayed but in the fall of 2004 the project was again in full operation. In particular the focus was now on change management and a literature review investigating risk and organisational change has been conducted. Unfortunately very little was found about strategies and methods for conducting risk analysis *before* organisational change is launched. Interesting perspectives was, however, found in the context of research adopting a project risk management perspective. A tentative model for exploration of risk and change management was constructed.

Achievements in 2005

In 2005 a tentative model for evaluation of risks in association with organisational change management was tested on a nuclear organisation in Sweden (CLAB). The model showed to be promising and further evaluation will take place during 2006. Other data that may be used as input for refining the model has been collected from a nuclear power plant (reorganisation of a maintenance department at OKG in 2000). Together with researchers from VTT in Finland, a review of organisational methods in association with organisational change management has been performed and evaluated with data from Finland and Sweden. A report that issues recommendations delivered from this study will be presented in 2006 as well as preparation for a scientific paper. The main activity for 2006 will be to present a manual in which a method for making risk analysis of organisational change will be presented.

References

Oedewald, P. & Reiman, T. (2003). Core Task Modelling in Cultural Assessment: A Case Study in Nuclear Power Plant Maintenance. Cognition, Technology & Work 5 (4), pp. 283 – 293.

Reiman, T. & Oedewald, P. (2002**).** Contextual Assessment of Organisational Culture – methodological development in two case studies. In: Kyrki-Rajamäki, R. & Puska, E-K. (eds.), FINNUS. The Finnish Research Programme on Nuclear Power Plant Safety, 1999-2002. Final Report. VTT Research Notes 2164. Helsinki: Yliopistopaino.

Reiman, T., Oedewald, P., Rollenhagen, C. & Eriksson, I. (2004). Contextual assessment of maintenance culture at Olkiluoto and Forsmark. NKS-94. Nordic nuclear safety research, Roskilde. http://130.226.56.167/nordisk/publikationer/1994_2004/NKS-94.pdf

Reiman, T., Oedewald, P. & Rollenhagen, C. (2005) Characteristics of organizational culture at the maintenance units of two Nordic nuclear power plants. Reliability Engineering and System Safety. Volume 89, Issue 3, 1 September 2005, Pages 331-345.

Resultat- och balansrapport 2005

Resultatrapport

Alla belopp i SEK

RÖRELSENS INTÄKTER		**Not**	**2005**	**2004**
Nettoomsättning				
3691	Rekv medel SKI		5 229 937	5 654 172
3692	Rekv medel Westinghouse		2 903 733	2 927 884
3693	Rekv medel Ringhals		2 663 436	2 641 481
3694	Rekv medel OKG		1 998 458	1 981 817
3695	Rekv medel Forsmark		1 998 458	2 441 621
3696	Rekv medel Barsebäck		665 978	676 009
3791	Rekv lön SKI		172 561	166 208
3792	Rekv lön Westinghouse		103 547	99 735
3793	Rekv lön Ringhals		87 859	84 624
3794	Rekv lön OKG		65 907	63 482
3795	Rekv lön Forsmark		65 907	63 482
3796	Rekv lön Barsebäck		21 951	21 144
S:a Nettoomsättning			**15 977 732**	**16 821 659**
Övriga rörelseintäkter				
3991	Periodisering bokslut		-140 958	-987 809
3992	Medel från föregående år		987 809	805 328
S:a Övriga rörelseintäkter			**846 852**	**-182 481**
S:a Rörelseintäkter			**16 824 584**	**16 639 178**

RÖRELSENS KOSTNADER		2005	2004
Högskolesamarbetet			
6801	Forskarskolan	-790 156	-961 224
6804	Postdoc KTH	0	-200 000
6901	Lämnade bidrag KTH	-2 675 000	-2 866 667
6902	Lämnade bidrag CTH	-2 000 000	-1 500 000
6903	Lämnade bidrag UU	-1 000 000	-1 000 000
S:a Högskolesamarbetet		**-6 465 156**	**-6 527 891**
Doktorandprojekt			
6602	KTH-MV-1 Termodynamisk databas för Zr...	0	-800 000
6604	KTH-HL-2 Mikromekanisk modellering, klyv...	0	-73 167
6605	KTH-RT-5 Mechanistic modelling of DO...	0	-333 357
6606	KTH-RS-2 Distr. vätgas/ånga i inneslutn...	-1 089 000	-1 052 000
6608	CTH-RF-5 Analysmetoder för icke-stationär...	-800 000	-800 000
6610	GU-KE-3 Oxidationskinetiken Zicraloy	0	-150 838
6614	MTO-1 ORCCA - säkerhetskulturer	-232 000	-77 677
6615	KTH-HL-3 Non-linear US scattering...	-808 930	-631 237
6616	CTH-RF-6 CF-252 metoden för reaktivitets...	-900 000	-900 000
6617	CTH-RT-6 use of intelligent computing	-400 000	-400 000
6618	KTH-RT-7 Film thickness in a tube	-1 424 641	-901 000
6619	KTH-MV-2 Modellering av strålskador	-800 000	-800 000
6620	CTH-MV-3 Positronteknik	-400 000	-383 334
6621	RS-3 Jodkemi vid svåra haverier	-1 000 000	-1 000 000
6622	UU Tomografisk verifiering av kärnbränsle	-275 000	0
S:a Doktorandprojekt		**-8 129 571**	**-8 302 610**
Övrig verksamhet			
6570	Bankens avgifter	-1 403	-1 452
6590	Övriga lämnade bidrag	-50 000	0
6705	Marknadsföring och information	-129 588	-265 910
6800	Kontorsadministration och drift	-1 269 833	-666 567
6803	Stöd till teknologer	-44 585	-101 073
6900	Stipendier	-75 000	-75 000
6904	Adjungerad professur	-200 000	-200 000
6905	Lönekostnad inkl resor, föreståndaren	-517 732	-498 675
8300	Räntekostnader/-intäkter	58 284	0
S:a Övrig verksamhet		**-2 229 857**	**-1 808 677**
S:a Övriga externa kostnader		**-16 824 584**	**-16 639 178**
S:a Rörelsens kostnader		**-16 824 584**	**-16 639 178**
ÖVERSKOTT		**0**	**0**

Balansrapport

Alla belopp i SEK

TILLGÅNGAR		**Not**	**2005-12-31**	**2004-12-31**
Omsättningstillgångar				
Fordringar				
1790	Övriga interimsfordringar	**1)**	124 463	681 134
S:a Fordringar			**124 463**	**681 134**
Kassa och bank				
1940	Bankkonto i SHB		1 452 867	2 211 691
S:a Kassa och bank			**1 452 867**	**2 211 691**
S:a Omsättningstillgångar			**1 577 330**	**2 892 825**
S:A TILLGÅNGAR			**1 577 330**	**2 892 825**
EGET KAPITAL, SKULDER OCH AVSÄTTNINGAR				
Kortfristiga skulder				
2440	Leverantörsskulder	**2)**	222 457	1 671 059
2890	Övriga kortfristiga skulder	**3)**	1 025 648	39 294
2990	Övriga interimsskulder	**4)**	188 267	194 663
2991	Förskott från finansiärer	**5)**	140 958	987 809
S:a Kortfristiga skulder			**1 577 330**	**2 892 825**
S:A EGET KAPITAL, AVSÄTTNINGAR			**1 577 330**	**2 892 825**

Noter till Balansrapporten

1) Interimsfordringarna består av en förutbetald kostnad för Uppsala universitet ang projektet ”Tomografisk verifiering…” som gäller första kvartalet 2006 på 110 ksek samt en fordran på 14 ksek på WNU för utlagda kostnader inför Summer Institute 2006.

2) Leverantörsskulderna är fakturor som per 2005-12-31 ännu inte fallit till betalning, utan betalas i början på 2006.

3) De övriga kortfristiga skulderna på 1,026 ksek avser rekvisitioner avseende projekt och stöd till högskolor som först år 2006 faller till betalning. Dessa betalas i början på 2006.

4) Övriga interimsskulder består av en skuld till Westinghouse Electric Sweden AB som betalade 188 ksek för mycket på rekvisitionen för sista kvartalet 2005. Detta korrigeras i den första rekvisitionen på 2006.

5) Förskottet från finansiärerna består av det överskott från år 2005 som kommer att användas i verksamheten under 2006.

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