Development and Applications of the Technique of Residual Stress Measurements in Materials

Summary Report of the 1st RCM

held at IAEA, Vienna, Austria

15-19 May 2006

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Summary

1. Background:

Research reactors have the potential to provide the necessary infrastructure for a wide range of scientific and technological developments around the world. They have provided a wealth of information in the field of physics, chemistry, biology, geology, materials science and medicine as well as for industrial applications.

Neutron scattering has played an important role in studying structure and dynamics of condensed matter. The special nature of neutron interaction with matter provides important complementary and supplementary data to other techniques. The location of hydrogen atoms in the presence of heavy elements, for example, can only be determined by means of neutron diffraction studies. Crystal structures of biological systems, like amino acids and polypeptides, have been elucidated using single-crystal neutron diffraction. The properties of magnetic materials can be studied at microscopic scale using neutrons and they have been useful in both scientific and industrial applications.

The large penetration depth and selective absorption of neutrons make them a powerful tool in non destructive testing (NDT) of materials with large samples. Residual stress formed in a material during manufacturing, welding, utilization or repairs can be measured by means of neutron diffraction. In fact neutron diffraction is the only NDT method, which can facilitate 3-D mapping of residual stress in a bulk component. Such studies are important in order to improve the quality of engineering components in production and to optimise design criteria in applications. The technique has applications in nuclear technology like testing pipes and tubes and weld joints etc. Anisotropies in macroscopic properties like thermal and electrical conductivities, for instance of fuel elements, and mechanical properties of materials depend on the textures developed during their preparation or thermal treatment. Such textures can be studied using neutron diffraction techniques.

Neutron diffraction (ND) and X-ray diffraction (XRD) are based on the same principle and are complementary. In its simple form the instrument for residual stress measurement is a two axes powder diffractometer with some specific requirements and/or attributes and can be installed on a medium flux research reactor to improve the effective utilization. ND can probe thick specimen in bulk while XRD is suitable for surface measurements and yields very localized information at the specimen surface, not always representative of the bulk sample.

There are some facilities having well designed, optimised and characterised instruments. The expertise and infrastructure exists to develop and maintain the facility. For convenience sake such facilities are defined here as “type A” facilities. On the other hand there are many research reactors where either the instrument is not available or is not optimised, basic infrastructure is not available or trained manpower is missing. Such facilities remain under utilized. For convenience such facilities are defined here as “type B” facilities.
Following facilities / capabilities are either available or could be planned and developed for effective utilization of neutron beams:

- Significant gains can be achieved by using focusing monochromators and/or larger vertical detector coverage.
- Option for significant improvement by the reduction of the instrumental background, especially for long counting high instrumental background is the most serious limitation.
- Measures for reducing the background are fast neutron filters (sapphire, silicon single crystal).
- Improved shielding around the monochromator and the detector (usually borated PE).
- To perform a Monte Carlo type analysis (McSTAS, VITESS, RESTRAX) to precisely identify effective ways for improvement.

In addition development of auxiliary equipment like:

- Bending devices (for elastic properties, fatigue).
- Load frame (for elastic properties, fatigue, anisotropy of elastic and plastic properties).
- Eulerian Cradle (for preferred orientation)
- Furnace (to study phase transformations, thermal stresses, stress relaxation)

The equipment would be useful for the investigation of certain materials science problems and for other applications.

Some well-developed centres (type A) have instruments with auxiliary facilities and the necessary infrastructure to run and maintain it. However there are many research reactors where either the facility is not there or is not optimised (type B). Since it is recognized that such an instrument could be fruitfully used with a medium flux reactor, a cooperative effort between developed and developing facilities would be successful.

**Type A facilities are defined as those having following characteristics:**

- Well developed instruments and techniques – cold source, guide tubes, focusing devices
- Well developed detecting / data acquisition systems.
- Capability of fabricating and maintaining advanced equipments.
- Willingness to collaborate with and act as mentor to a type B facility.

**Type B facility is defined as the one with following characteristics:**

- Non optimised instruments
- Under utilised facilities
• Lack of trained manpower and infrastructure for maintenance of equipments
• Desire to work and improve the existing system in co-operation with type A facility.

The aim of the present CRP is to bring these two facilities together to develop a good facility for residual stress measurement, bring in young workers in this field who can maintain the facilities and desirous of improving the existing set ups or building new facilities.

1.2. Overall Objective

The overall objective is to develop the technique of residual stress measurement including the design of instruments, the process of data acquisition and analysis and expertise – for application as non-destructive probe in material technology and industry.

The CRP will meet the objective of the Project D 2.01 “Effective Utilization of Research Reactors”, to promote the utilization of research reactors.

1.3. Specific Research Objectives

The specific objectives of the CRP are:

• To optimize the neutron beams for residual stress measurement using modern simulation techniques.
• To enhance the beam intensity using modern neutron optics, like focusing and beam guides, beam convergence.
• To develop standardized, low cost, detectors/data acquisition systems.
• Standardization and/or comparison of data from various instruments.
• Develop collaboration/teamwork towards networking for better utilization of research reactor resources
• Utilization of instruments for testing fabricated and or specially treated components

1.4. Expected Research Outputs

• Well designed / optimised Residual stress measurement instrument.
• Improved beams, detection systems and processing.
• Sustainability of research reactor utilization and operation
• Active collaboration between developed and developing laboratories.
• Trained manpower.

Instruments for Neutron scattering are installed and used at research reactors in many MSs but the systems are not optimized for potential applications and attracting stakeholders. This fact has been brought out at various discussion meetings. Improvements in resolution are normally achieved at a cost in intensity. This can be compensated by suitable choice and design of detectors as well as by employment of
tricky focussing components. For an instrument exhibiting good resolution, one needs to employ a fast counting system.

This CRP will help in understanding these aspects of design of the instrument and its applications among the research reactor community. The training qualified specialists who will be able to take up developmental work in future, in addition to operating existing facilities.

2. Proceedings of Research coordination meeting

2.1 Introductory presentations

This was the first Research Coordination Meeting (RCM) of the CRP on “Development and application of the technique of residual stress measurements in materials using neutrons.” The purpose of the meeting was to reach an agreement on the coordinated aspects of the CRP, applicable protocols, collaboration between participants for team work, refine research objectives, goals and milestones and the actions to be taken by each participant. Eight participants and the IAEA Scientific Secretary attended the meeting.

(1) Mr. Pavol Mikula  
Czech Republic
(2) Mr. Rainer Schneider  
Germany
(3) Mr. Gyula Torok  
Hungary
(4) Mr. Amitabh Das  
India
(5) Mr. Anastausis Youtsos  
Netherlands
(6) Mr. Javaid Bashir  
Pakistan
(7) Mr. Ion Ionita  
Romania
(8) Mr. Andrew Venter  
South Africa
(9) Mr. Shrinivas Paranjpe  
IAEA (Scientific Secretary)

Mr. Vitoly Balagurov from Russia was invited as a consultant to the meeting.

Mr. N Ramamoorthy, Director, Division of Physical and Chemical Sciences, could not attend the meeting because of other last minute appointment. Mr. Guenter Mank, Head, Physics Section welcomed the participants and gave the opening remarks. Mr. Shrinivas Paranjpe welcomed the participants.

The names of Mr. Andrew Venter and Mr. R. Schneider were suggested for the chairperson and rapporteur for the meeting respectively and were accepted. The meeting Agenda was then approved with some modification. Mr. Shrinivas Paranjpe presented the activities on related to research reactor utilization in the Division of Physical and chemical sciences in the IAEA. He gave an overview of the CRP, its background, the objectives and expected output and outcome.

The first two days were devoted to the presentations of the project proposal followed by discussion on each proposal.

A broad framework for the CRP was then formulated. The project proposal include design development of instruments for residual stress measurement by the developing facilities to the applications of the techniques in developed facilities. There were brainstorming discussions on the minimum requirements for design and fabrication of a
spectrometer for residual stress measurement, common activities under the CRP and collaborations. The project proposals are listed in table 2.1.
### Table 2.1 Project proposals, principal investigators & Project Titles

<table>
<thead>
<tr>
<th>Country</th>
<th>Project Investigator</th>
<th>Project Title</th>
<th>Contract No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Czech Republic</td>
<td>Pavol Mikula</td>
<td>Optimization of resolution and luminosity properties of strain/stress diffractometer</td>
<td>RA-13564</td>
</tr>
<tr>
<td>HMI, Berlin, Germany</td>
<td>Rainer Schneider</td>
<td>Standardization procedures to enhance the repeatability and reliability of stress measurements / Establishment of the new strain …. Diff at NECSA</td>
<td>RA-13615</td>
</tr>
<tr>
<td>Hungary</td>
<td>Gyula Torok</td>
<td>Improvement of neutron beam performance and sample environment in residual stress</td>
<td>RC-13507</td>
</tr>
<tr>
<td>BARC, Mumbai, India</td>
<td>Amitabh Das</td>
<td>Development of neutron spectrometer for residual stress analysis</td>
<td>RA-13587</td>
</tr>
<tr>
<td>HFR, Petten, Netherlands</td>
<td>Anastasious Youtsos</td>
<td>Transfer of HFR / Petten scientific/technological know-how to reactor neutron facilities with an interest in developing their own capability on residual stress analysis based on neutron diffraction</td>
<td>RA-13584</td>
</tr>
<tr>
<td>PINSTECH, Pakistan</td>
<td>Javaid Bashir</td>
<td>Development &amp; application of the technique of residual stress measurement in materials</td>
<td>RC-13614</td>
</tr>
<tr>
<td>PITESTI, Romania</td>
<td>Ion Ionita</td>
<td>The implementation of the technique of residual stress measurements at the focusing crystal neutron diffractometer installed at the channel of the INR PITESTI medium flux TRIGA reactor</td>
<td>RC-13579</td>
</tr>
<tr>
<td>NECSA, Pretoria, South Africa</td>
<td>Andrew Venter</td>
<td>Standardization procedure to enhance repeatability of strain results</td>
<td>RC-13558</td>
</tr>
</tbody>
</table>
3. Proceedings of the meeting

3.1. Presentations and Discussions
During the first two days participants introduced their facilities, activities and envisaged project proposals.

Based on the discussions and aims with the CRP, a scheme of the various activities associated with of the project outlines was compiled as given in Table 3.1. The activities are relevant to both developed and developing facilities. This served as reference to identify regions of common interest.

Table 3.1. Activities associated with measurement of Residual Stress:

<table>
<thead>
<tr>
<th>Technical co-operations and standardization</th>
<th>Instrument Refurbishment programs</th>
<th>Knowledge Transfer Trainee programs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance of Hardware Modules</strong></td>
<td><strong>Assessment of Existing Instruments</strong></td>
<td><strong>Instrument technicians</strong></td>
</tr>
<tr>
<td>• diffraction (monochr., detector, optics)</td>
<td>• definition</td>
<td>• electronics</td>
</tr>
<tr>
<td>• manipulation</td>
<td>• production</td>
<td>• IT / software</td>
</tr>
<tr>
<td>• electronics</td>
<td>• investigation by proved instruments</td>
<td>• mechanics</td>
</tr>
<tr>
<td>• interfaces</td>
<td>• definition of experiments</td>
<td></td>
</tr>
<tr>
<td>• sample environment</td>
<td>• definition of protocols</td>
<td></td>
</tr>
<tr>
<td><strong>Performance of Software Routines/ Data formats</strong></td>
<td><strong>Upgrading of Instruments</strong></td>
<td><strong>Scientists</strong></td>
</tr>
<tr>
<td>• instrument control</td>
<td>• collection of instrumental parameters</td>
<td>• trainee program for young scientists</td>
</tr>
<tr>
<td>• data evaluation (algorithms)</td>
<td>• assessment of the instrumental quality</td>
<td>• experts for instrument testing/commissioning</td>
</tr>
<tr>
<td>• data formats</td>
<td>• MonteCarlo Simulations</td>
<td></td>
</tr>
<tr>
<td>• protocol</td>
<td>• Definition of specific refurbishment programs</td>
<td></td>
</tr>
<tr>
<td>• interfaces</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mr. Youtsos gave an overview of the recently published standardisation document on the neutron residual stress method titled “Non-destructive testing standard test method for the determination of residual stresses by neutron diffraction” reference CEN ISO/TS 21432: 2005 and is available at cost from any national standards institute. Based on this document, as well as IAEA-TECDOC-1457 the minimum requirement of a residual strain scanner was defined as:
Flux at sample position > 5 \times 10^4 n/s/cm^2

FWHM should be less than 0.8° (\Delta d/d less than 7 \times 10^{-3}) at 2\theta = 90

Suggested wavelength range of 1.2 and 3Å

Detector: Position sensitive detector,

Horizontal detector resolution better than 3mm at 1m sample-detector distance equivalent

Sample rotation omega table accuracy, though not very critical, should be better than 0.5°.

Accuracy of sample centering within the gauge volume better than 50µm

XYZ Translation table with resolution better than 50µm, min. load 5kg

These minimum requirements are considered as essential when establishing a neutron strain scanner that would enable investigations of industrial samples. In case of large samples like those coming from industries including nuclear industry it may be necessary to have sample table with load carrying capacity as large as 500kg.

3.2. Components of a neutron scanner:

A typical neutron strain scanner consists of four sections

1) the source (reactor, collimation, monochromator, neutron optics)

2) the sample table:
   (a) slit system, sample manipulation in xyz, omega, chi and phi
   (b) sample environment facilities like furnace, high pressure cell, tensile rig etc.

3) the detector (shielding, positioning system, position sensitive neutron detector and electronics, detector efficiency)

4) data acquisition/visualization (DAS)

In addition it is essential to have a good data analysis system including interface from DAS to analysing software.

3.2.1. Source

A neutron strain scanner is basically a powder diffractometer with suitable modifications necessary for the measurement. Improvement in intensity and flux at sample are for example help in improving the quality of measurements. Instruments of the first generation i.e. already existing powder diffractometers at developing facilities, usually mosaic monochromators consisting of Cu-, pyrolytic graphite or Ge are being used. The use of horizontal focusing devices such as bent silicon or germanium crystals improves the instrument efficiency by at least one order of magnitude.

3.2.2. Sample Table and Environmental Facilities

It is important to note that the detector, monochromator, the primary and the secondary slits should not be disturbed during the experiment. Only the sample has to be positioned relatively to the gauge volume. This could be achieved by an accurate manipulation
system that allows the movement in all three directions. A cradle or cradle section will help to tilt the sample to access the strain directions of interest automatically. The precise alignment of the primary and secondary slits with respect to the center of the sample table is essential. This is of extreme importance for successful $d_0$ measurements.

### 3.2.3. Detector

The use of a position sensitive detector is advantageous in fast data collection and avoiding the movement of detector during measurement. It is advisable to have at least a linear position sensitive detector. An area detector will have more advantages: (a) Usually the vertical extension of the detector is larger, so the general instrument performance is increased linearly (b) it allows the assessment of grain size and texture effects. That is very important for the analysis of the data.

In some cases it is necessary to check the gamma sensitivity of position sensitive detector. If it is more that $10^{-4}$ an electronic tuning can help, otherwise the reducing the gamma background by suitable shielding is the solution.

Epithermal or fast neutron background is higher near to the reactor core at many instruments. It cannot be assumed that neutron detectors are not sensitive to high energy neutrons in general. To take care of this effect outer coating of the detector shielding should be made of paraffine or polyethylene to moderate the neutron background to an appropriate energy level, followed by cadmium or boron carbide plastic to capture the thermal neutrons. In order to reduce the neutron background from the sample a radial collimation can be used, together with a secondary slit and defining a larger sensitive volume in the center of the sample table. Thus only medium accuracy is needed. Otherwise in case of single detector a high accuracy is needed.

### 3.2.4. Data evaluation

For the data evaluation one has to consider that the peak shifts to be determined are very small. So the peak fitting has to be done in the same way (same background model, same peakshape, same software). It is important to consider grain size and texture effects.

### 3.3. The workplans

On Thursday the project proposals were reviewed under the groupings of existing hardware, personnel skills and expertise, projects associated with new designs, new developments, new experiments and new calculations, in conjunction with intended projects and developments under the submitted CRP’s to identify regions of common interest to facilitate partnerships. The refined work plan of each participant is given in 3.2.

Workplans as given in the proposal are:

#### 3.3.1. Budapest

- Modelling by Vitess different experimental situations
- Testing converging neutron collimator / bender system
- Developing furnace & load frame
- Personnel training in use of techniques
3.3.2. Czech Republic
- Monte Carlo simulation for the optimum design of a diffraction instrument for type B facility
- Design & preparation of neutron monochromators
- Training fellows for manipulation with focusing monochromators
- Assist installing focusing monochromator in type B facility
- Provide training in micro strain & grain size from peak profile analysis—data evaluation.
- Development & construction of a prototype of dispersive monochromator

3.3.3. Germany
- Provide necessary Support for HMI type strain scanner at NECSA, South Africa.
- Training in development of facilities or expertise for partners under CRP

3.3.4. India
- Design of instrument
- Procurement of components—monochromator, PSD, sample manipulator
- Fabrication of essential components
- Installation of instrument, calibration
- Residual Stress measurement using complimentary techniques
- Measurements using weld joints etc / benchmarking

3.3.5. Netherlands
- Transfer HFR-Petten technology know-how to facilities interested in developing their own capability of residual stress measurements using neutron diffraction
- Training fellows on all aspects related to potential of technique, range of its applications
- Guide partners in aligning, calibration of instrument

3.3.6. Pakistan
- Instrument modeling via McSTAS/Vitess for optimization of the existing powder diffractometer for residual stress measurements
- Training of fellows for gaining experience in residual stress measurements
- Instrument development, calibration, optimisation etc
- Develop instrument control & data acquisition system
- Develop data analysis & visualization system
• Test measurement

3.3.7. Romania

• Convert the existing powder diffractometer to residual stress measuring instrument--- contacts Dr Youtsos from Petten, Netherlands and Dr Mikula from Rez, Czech Republic
• Improvement of pneumatic bending system
• Increase of angular positioning precision
• Adaptation of instrument control system
• Test, install and calibrate PSD

3.3.8. South Africa

• Exchange of personnel for gaining experience.
• Collaboration with type A facility for discussions, advice for improving instrument.
• Fabrication of calibration cell.
• Alignment of instrument.
• Assess the performance of the instrument using standard sample geometries.
3.4 Refined workplans including team work

The workplan for each project proposal was refined after discussion on the proposed workplan and needs of each participants for collaboration and for its effective implementation. This was essential to bring the output of the CRP in a coherent form. The workplan at a glance for the CRP is given in the table 3.2. Following sections give the action plan of each participant:

3.4.1. Hungary

- Implementation of Radial Collimator
- Monte Carlo Modeling of BNC Instruments
- Movement in Z direction of BNC Instrument
- Round Robin measurement1,2
- Hardware of in situ tensile stress and heating

Collaborators

- HMI (Consultation in Radial collimator, Z movement, Round Robin)
- NPI Consultation (monochromator, stress rig)
- JRC (Round robin, Z movement)
- BARC, PINSTECH, PITESTI (detector)
- NECSA (Monte Carlo, detector)

Schedule

<table>
<thead>
<tr>
<th>ACTION</th>
<th>May 2006</th>
<th>November 2007</th>
<th>May 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collimator /slits for gauge volume oscillating radial collimator</td>
<td>Start development</td>
<td>implement</td>
<td></td>
</tr>
<tr>
<td>Electronics of automatic movement</td>
<td>Start of development</td>
<td>implement</td>
<td></td>
</tr>
<tr>
<td>Movement in z direction</td>
<td>start development</td>
<td>implement</td>
<td></td>
</tr>
<tr>
<td>Hardware of in situ tensile stress and heating</td>
<td>draw</td>
<td>construction</td>
<td>implement</td>
</tr>
<tr>
<td>Round robin 1/2</td>
<td>Start 1 impl</td>
<td>2 impl</td>
<td></td>
</tr>
<tr>
<td>Monte Carlo Modeling of instrument</td>
<td>Start/ implement</td>
<td>implement</td>
<td></td>
</tr>
</tbody>
</table>
3.4.2. Czech Republic

a) Development of focusing monochromators for residual strain/stress scanners

b) Monte Carlo simulations of instrumentation optimum performance and its resolution function and the luminosity. – Virtual experiment

Collaborators:
HMII Berlin – MC simulations, focusing monochromators development
LNF Dubna - MC simulations, focusing monochromators development
PINSTECH Pakistan - focusing monochromators development
BARC Mumbai - focusing monochromators development

Schedule

<table>
<thead>
<tr>
<th>ACTION</th>
<th>May 2006</th>
<th>November 2007</th>
<th>May 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focusing monochromators</td>
<td>Design and fabrication</td>
<td>Testing</td>
<td>Measurement</td>
</tr>
<tr>
<td>Monte Carlo simulations</td>
<td>Optimization of the instrument performance</td>
<td>Calculations of resolution functions and instrument luminosity</td>
<td></td>
</tr>
</tbody>
</table>
3.4.3. Germany

a) Instrument development and commissioning at NECSA/SA

b) Development of a virtual experiment simulation software based on McStas MonteCarlo Simulation code

c) Development and Fabrication of Round Robin sample 1 together with analysis software

d) Development of instrument control software and data formats

e) Development and testing of bent Si-monochromators

Collaborators
NECSA South Africa – development and commissioning of new strain scanner, Trainee
PINSTECH Pakistan – development of a virtual experiment simulation software, Trainee
JRC Netherlands – Round Robin 1&2, virtual experiment simulation, Trainee
NPI Czech Republic – bent Si-monochromators – virtual experiment simulation

Schedule

<table>
<thead>
<tr>
<th>ACTION</th>
<th>May 2006</th>
<th>November 2007</th>
<th>May 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>NECSA strain scanner</td>
<td>Design phase</td>
<td>Commissioning</td>
<td>Common Research programs</td>
</tr>
<tr>
<td>Bent Si-monochromator</td>
<td>Design and fabrication</td>
<td>Testing</td>
<td>Measurement</td>
</tr>
<tr>
<td>Round Robin 1</td>
<td>Design and fabrication, Development of evaluation software</td>
<td>Measurement and Instrument benchmarking</td>
<td>Refurbishment of instrument according to Monte Carlo simulation and measurement results</td>
</tr>
<tr>
<td>Round Robin 2</td>
<td>Definition of experimental protocol</td>
<td>Measurements</td>
<td>Measurements and benchmarking</td>
</tr>
<tr>
<td>Virtual experiment - Trainee program</td>
<td>Definition of the actions to establish the trainee program Conception of the software</td>
<td>Realization of the software in Petten / Berlin / Islamabad</td>
<td>Experimental validation of virtual results and adaption of the software to the various instruments</td>
</tr>
<tr>
<td>Instrument Control Software</td>
<td>Conception phase</td>
<td>Development and Tests</td>
<td>Tests and Commissioning</td>
</tr>
</tbody>
</table>
3.4.4. India

1. Optimization of instrumental parameters by Monte Carlo simulation
2. Optimization of resolution and intensity on the sample (NPI)
3. Participation in round robin exercise

Collaboration: Hungary, HMI, NPI for simulation

Schedule

<table>
<thead>
<tr>
<th></th>
<th>June 2007</th>
<th>June 2008</th>
<th>June 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC simulation</td>
<td>Simulation to optimise the parameters for monochromator and beam optics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution and intensity optimization</td>
<td>Procurement of monochromator and its rotational and driver stages to be made functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation of the Instrument</td>
<td>Experiments to standardize the instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round robin exercise</td>
<td>Participate in round robin exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument functionality</td>
<td></td>
<td>Instrument expected to be fully functional by this time</td>
<td></td>
</tr>
</tbody>
</table>
### 3.4.5. Pakistan

- **a)** Instrument development
- **b)** Virtual experiment

**Collaborators**

- NPI Czech Rep – instrument development / virtual experiment
- HMI Germany - virtual experiment, trainee program
- JRC Netherlands – virtual experiment, trainee program
- BNC Hungary – Detector evaluation

**Schedule**

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization of Instrument</td>
<td>Simulation via McStas/Restrax</td>
<td>Evaluation of Design and Modification</td>
<td></td>
</tr>
<tr>
<td>Background minimization</td>
<td>Simulation</td>
<td>Implementation</td>
<td></td>
</tr>
<tr>
<td>Calibration/testing of PSD</td>
<td>Implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Instrument control and data acquisition system</td>
<td>Implementation</td>
<td>Continuation</td>
<td></td>
</tr>
<tr>
<td>Development of data visualization and analysis software</td>
<td>Implementation</td>
<td>Continuation</td>
<td>Continue</td>
</tr>
<tr>
<td>Testing/optimization of instrument</td>
<td>Implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurements on test samples</td>
<td>Implement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round Robin 1</td>
<td>Participate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round Robin 2</td>
<td>Participate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Simulation Software</td>
<td>Implement</td>
<td>Continue</td>
<td>Continue</td>
</tr>
</tbody>
</table>
### 3.4.6. Romania

Collaboration: Czech republic

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
<td>Translation table</td>
<td>Design approval</td>
<td></td>
<td></td>
<td>fabrication</td>
</tr>
<tr>
<td>Evaluation of the possibilities to use the existing focussing instrument for stress determinations</td>
<td>Theorical Approach &amp; Discussions with Dr.N.C.Pop</td>
<td>Final conclusions</td>
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<tr>
<td>Reactor core optimization</td>
<td></td>
<td>Core configuration computational optimization</td>
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<tr>
<td>Bending device</td>
<td>Realizing the new pneumatically bending device</td>
<td>Testing</td>
<td>Modifications of the instrument control system</td>
<td></td>
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<tr>
<td>Detector</td>
<td>Information gathering</td>
<td></td>
<td></td>
<td>Completing the PSD with 2 more detectors; procurement &amp; testing</td>
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<tr>
<td>Improvement the angular positioning precision</td>
<td>Find the technical solution</td>
<td>Testing</td>
<td>Realization</td>
<td></td>
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<tr>
<td>Realization of the modified control system</td>
<td></td>
<td></td>
<td>Realization of the required modifications</td>
<td>Testing the individual modifications &amp; modified control system</td>
</tr>
</tbody>
</table>
3.4.7. South Africa

- Exchange of personnel to gain experience in the setup, calibration and data treatment in a cooperative study on laser bent samples with HMI:

- Heat transport modeling to be done in cooperation with JRC (Greece??) to identify regions of high strains on which the residual strain measurements will be focused.

- 3D strain mapping (through thickness 8mm, across width 60mm along laser path at HMI.

- Production of representative δ₀ samples.

(1) Establish automated instrument alignment setup procedure at Necsa:

- Familiarisation with HMI system through trainee period.

- Fabricate and commission calibration cell.

- Implement digital camera and image processing system.

- Implement incident beam manipulation stages

(2) Optimise and assess performance of new NECSA instrument:

- Optimisation of ORDLA detector electronics to minimize gamma sensitivity.

- Monte Carlo modeling of instrument geometry to improve peak to background ratio.

- Measurements on Round Robin samples.

Collaborators: HMI, NPI, BNC, JRC

Schedule

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<tr>
<td>Cooperative research project on laser bent samples</td>
<td>Activities as outlined above</td>
<td>xxxxxx</td>
<td>xxxxxx</td>
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<tr>
<td>Establish automated instrument alignment setup procedure at Necsa</td>
<td>Activities as outlined above</td>
<td>xxxxx</td>
<td>xxxxxx</td>
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<tr>
<td>Optimise and assess performance of new NECSA instrument</td>
<td>-Minimise gamma sensitivity of ORDELA detector (?)</td>
<td>xxxx</td>
<td>xxxx</td>
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<tr>
<td></td>
<td>-Monte Carlo modelling of instrument geometry</td>
<td>xxxx</td>
<td>xxxx</td>
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<tr>
<td></td>
<td>--Measurement on round robin samples</td>
<td>xxxx</td>
<td>xxxxx</td>
<td>xxxxx</td>
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</table>
3.4.8. The Netherlands

- Transfer HFR-Petten technology know-how to facilities interested in developing their own capability of residual stress measurements using neutron diffraction
- Training fellows on all aspects related to potential of technique, range of its applications
- Guide partners in aligning, calibration of instruments
<table>
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<tr>
<th>MS</th>
<th>Present Status</th>
<th>Hardware</th>
<th>Software</th>
<th>Requirements</th>
<th>Partnerships</th>
<th>Plans within CRP</th>
<th>New Applications / Capabilities</th>
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<tr>
<td>Hungary G. Torok</td>
<td>1st gen. operationa l</td>
<td>Detector Shielding Sample Env.</td>
<td><strong>MonteCarlo</strong></td>
<td>Sampletable Radial Coll.</td>
<td>HMI, NPI, JRC</td>
<td>Virtual Exp.</td>
<td>Geology, Thin Films, Nano, Bones</td>
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<tr>
<td>Czech Rep. P Mikula</td>
<td>2nd gen. operationa l</td>
<td>Monochr.</td>
<td><strong>MonteCarlo</strong></td>
<td></td>
<td>ALL</td>
<td><strong>Virtual Experiment Monochrom. Dev. Round Robin 1&amp;2</strong></td>
<td>Irradiated Samples Sample Environment</td>
</tr>
</tbody>
</table>

Items in **bold** indicates the expertise is available in the MS
3.5. General activities within the CRP

Round Robin Experiments

1. Validation of Instrument

A sample for the evaluation and standardization of the instruments has been defined. It consists of a pure iron rod of a diameter of 2mm and a vertical extension of 1cm. The sample will be build and provided by HMI. Together with the sample the experimental protocol will be defined and delivered to the partners. A special data evaluation routine will be supplied by HMI. Raw data as well as a protocol and the results of the evaluation will be shared amongst the partners. Protocol, software and data will be available on a specific web page.

The participants agreed to share the raw data and evaluation steps followed during the validation and experiment

2. Residual Stress Sample

Within the VAMAS/RESTAND program a standardization round robin sample was defined and build which is well investigated by nearly 15 institutions. It exhibits huge residual stresses and a very steep stress gradients. An appropriate experimental protocol is available from the VAMAS project. There was a proposal to use the same sample for the CRP project. Anastasious Youtsos will check the availability of these samples for this project.

3. Virtual Experiment

During the meeting the need for a virtual experiment simulation tools was proposed and agreed to develop /improve the code in order to simulate instrumental setups as well as intended experiments.

4. Conclusion

The work plan for the first phase for 2006 – 2007 was formulated. The plan will be reviewed during the second RCM.

It was suggested that the second RCM be held during September 2007 at HMI Berlin (tentatively).
## List of CRP Participants

<table>
<thead>
<tr>
<th>Name</th>
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<th>Address/Contact Details</th>
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<tbody>
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Agenda of the First RCM of the CRP
On
“Development and applications of the technique of residual stress measurements in materials”

May 15, 2006

0900-0930  Registration
0930-1030  Welcome & Opening Remarks
            G. Mank, Head Physics section,
            Welcome remarks,
            Introduction of participants
            Selection of the chairperson and Rapporteur
            Approval of the Agenda
            Shriniwas Paranjpe
            Background of the CRP, activities under Effective utilization project in NAPC, IAEA

1030-1100  Break
1100-1230  Anastasius Youtsos, , Petten, Netherlands
            Overview of the facility and proposed plan
1230-1400  Lunch Break
1400-1530  Gyula Torok, BNRC, Hungary
            Proposed plan: Improvement of neutron beam performance & Sample environment in Residual stress measurement
1515-1530  Break
1530-1700  Rainer Schneider , HMI, Berlin
            Activities on RS measurements at HMI and proposed plan under the CRP
1700-1730  Discussion on the collaborations

May 16, 2006

0900-1030  Amitabh Das, BARC, India
            CRP proposal & action plan: Development of a neutron spectrometer for RS measurement
1030-1100  Break
1100-1230  Andrew Venter, NECSA, South Africa
CRP Proposal & action plan: Standardization procedures to enhance repeatability of strain results

1230-1400  Lunch Break

1400-1530  Javaid Bashir, PINSTECH, Pakistan
CRP proposal & action plan

1530-1600  Break

1600-1730  Pavol Mikula, NPI, Czech republic
CRP Proposal: Optimization of resolution & Luminosity properties of strain/stress diffractometer

May 17, 2006

0900-1030  Ion Ionita, INR, Romania
CRP Proposal & action plan: The implementation of technique of RS measurement at the focussing crystal neutron diffractometer at TRIGA Reactor, INR, Pitesti.

1030-1100  Break

1100-1230  Discussion on a Joint Plan of Action under the CRP, guidelines for cohesive approach as a team

1230-1400  Lunch Break

1400-1530  Anatoly Balagurov, JINR, Russia

1530-1600  Break

1600-1730  Development of CRP –activities, action plan

May 18, 2006

0900-1030  Exploring new collaborations between various participants

1030-1100  Break

1100-1230  Possible new participants and facilities

1230-1400  Lunch break

1400-1530  Discussion on the Proposals improvement of
work-plans, Draft report.

1530-1600   Break
1600-1730   Discussion on the Proposals improvement of work-plans, Draft report, Plan for next meeting

May 19, 2006

0900-1030   Discussion of the summary Report
1030-1100   Break
1100-1230   Finalising the Report.
1230-1400   Break
!400-       Wrap up