Neutron Beam Applications Using Low Power Research Reactor Malaysia Perspectives

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Abstract

The TRIGA MARK II Research reactor at the Malaysian Institute for Nuclear Research (MINT) was commissioned in July 1982. Since then various works have been performed to utilise the neutrons produced from this steady state reactor. One area currently focussed on is the utilisation of neutron beam ports available at this 1MW reactor. Projects undertaken are the development and utilisation of the Neutron Radiography (myNR), Small Angle Neutron Scattering (mySANS) and Boron Neutron Capture Therapy (BNCT) - preliminary study.. In order to implement active research programmes, a group comprised of researcher from research institutes and academic institutions, has formed: known as Malaysian Reactor Interest Group (MRIG). This paper describes the recent status the above neutron beam facilities and their application in industrial, health and material technology research and education. The related activities of MRIG are also highlighted.

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NEUTRON BEAM APPLICATIONS USING LOW POWER RESEARCH REACTOR MALAYSIA PERSPECTIVES

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1 Introduction

The TRIGA MARK II Research reactor at the Malaysian Institute for Nuclear Research (MINT) was commissioned in July 1982: the typical characteristics and schematic lay-out are presented in Table 1 and Figure 1, respectively. It is a 1 MW reactor which being used for reactor training and research related to neutron. Since then various works have been performed to utilise the neutrons produced from this steady state reactor. Projects undertaken are the development and utilisation of Neutron Radiography (myNUR) and Small Angle Neutron Scattering (mySANS) facilities, boron-neutron captured therapy (BNCT) feasibility study. To strengthen these activities, in 1999 MINT has formed a group known as Reactor Interest Group (RIG) and also has recently made known to the International Group of Research Reactor (IGORR). The following explains current development of beam-ports and thermal-column applications, and RIG related activities in promoting and enhancing research reactor utilisation in Malaysia.

2 Small Angle Neutron Scattering (SANS)

The construction of SANS was initially proposed in January 1986 aiming to provide Malaysian material engineers and scientists a versatile probe for materials characterisation, which based on neutron scattering concepts. The construction commenced in 1989 and completed by the end of 1994. The characteristics of the SANS is shown in Table 2.

From 1995 till 1996, many testing have been carried out, to verify the performance of the system. Analysing real samples and related activities on material and metallurgical studies have been pursuit starting from 1997. Several surfactant based colloidal samples had been irradiated. The samples were as follows:

i. Samples which exhibit transition from worm micelle to spherical micelle through doping process (by using surfactant and block copolymer) on worm micelle system.
ii. Samples which show the Camera phase to micro emulsion phase transition in a ternary system.
iii. Sample which have symmetrical transition of cubic phase for ternary system.
iv. Samples of liquid crystal surfactant which mixed with kaolinite clay to study its microstructure variation.

In 1999, SANS was suggested to be upgraded and some components need to be replaced. This was done in stages starting from beam conditioning components, beam collimation and beam detectionacquisition system. In addition, modelling of scattering intensities has also been started in early 1998. The hard sphere particles model is on-going modelling work on SANS scattering data pattern.

3 Neutron Radiography

The first neutron radiography facility was a test facility built at beamport #1, called NUR 1 at one of the radial beamports, of MINT's TRIGA reactor. It was a temporary facility for obtaining data verification and calculation for a better facility. This work was carried out in December 1983 till end of 1984. After a year of experimental study, the facility was dismantled. The experience and data gathered were then used to construct a permanent neutron radiography called NUR 2. It was built at beamport #3. The construction of the facility was started early 1985 and completed at the end of 1985. Both transfer and direct methods of neutron radiography can be carried out at this facility. The characteristics of the SANS is shown in Table 3.

At present a radiography image is recorded using a film, namely, Kodak SR film type. Studies which had been carried out using the facility were as follows:

i. corrosion and moisture detection in air-craft composite components.
ii. detection of root nodules in mutation research.
iii. leak determination in irradiated dry transfer tube for neutron activation analysis sample delivery system.
iv. inspection on electrical ceramic components.

At present the group intends to explore further improvement and development. This includes to develop another new facility using the tangential beam port. For this new facility, the activities will include designing collimator, exposure technique and others. The project will has already started in 2002, last year.

4 BNCT Preliminary

One area of potential reactor utilization identified is boron neutron capture therapy (BNCT). using the thermal column of the Reactor TRIGA PUSPATI (RTP). In BNCT treatment, a boron-containing drug is delivered to the tumour through intravenous injection to the patient. The tumour is then irradiated with a thermal or epithermal neutron beam – the alpha particle produced through the B(n,α)Li reaction will destroy cancerous cells of the tumour in the organ. Although BNCT is still an experimental approach in cancer treatment for human, the interest in this form of treatment has been renewed due to lack of progress in brain tumour treatments by other modalities over the last decades.

Preliminary study to establish the BNCT irradiation facility at RTP was initiated since early 2003, through collaboration between MINT and Universiti Sains Malaysia. For this preliminary study, the thermal column of RTP is used to study the neutron beam parameters and its dosimetric characteristic. The thermal column is selected as it has wide cross-section area that facilitates the irradiation of large samples. Thermal column has a graphite-filled aluminium container that penetrates the reactor tank wall and extend to the graphite reflector and has wide cross-section. It also has special graphite block which serve as movable stingers. In these stringers, the neutron beam quality will be studied and its dosimetric parameters will be measured using suitable phantoms.

Initial work to study neutron beam quality in the thermal column has been started since January 2003. The thermal and epithermal neutron fluxes in the stringers were measured using neutron activation method with Au-197 foil detector and Cd filter. Other detectors will be used to measure the various neutron fluxes in the thermal column. SAND II code is planned be used to obtain the neutron spectrum of the thermal column.

5 Reactor Interest Group (RIG)

In trying to revitalised the reactor utilization in Malaysia, MINT has initiated the forming of Reactor Interest Group (RIG) in the early 2000. RIG, which was formally launched at national level on 25 June 2002, is a loose grouping of parties who has interest in reactor utilization. With main objectives to arrest the decline of interest in reactor utilization for research and development as well as educational purposes, this grouping comprised of staffs from MINT, universities academics and other research institutes in Malaysia.

In promoting the uses of reactor at MINT, RIG has launched a series of discussion sessions with the universities academic staffs and other research institutes. Seminars and workshop were also conducted to identify various areas of reactor utilization where collaboration works between MINT, universities academic staffs and research institutes are possible.

To date, RIG has identified a few potential collaboration areas related to reactor utilizations. Amongst these areas are preliminary studies of new irradiation facilities such as Boron Neutron Capture Therapy (BNCT) and Prompt Gamma Neutron Activation Analysis (PGNAA), as well as enhancing and upgrading the present facilities i.e. the Neutron Radiography (NR) and Small Angle Neutron Scattering (SANS). Research and development (R&D) areas related reactor utilizations identified includes instrumentation of irradiation facilities, software engineering, bulk and advance material studies, etc.

RIG have suggested the following instrument utilisation areas and implementation approaches:

Areas of work:

- Characterisation of beam-ports and thermal column.
- Structure characterisation of new hard magnetic materials prepared by rapid quenching techniques.
- Precipitates in powder metallurgy.
- Morphology of natural poly-olefins blends, natural rubber polymer blends and cross-linking rubber materials.
- Porosity on nanometer-scale in cements, bio-materials, bio-composites, bone minerals and bone cements.

- Surfaces studies in magnetic CMR layers.
- Surface and interface properties in catalytic reactions.

Implementation approaches:

Enhanced beam-ports utilization at MINT (SANS, Neutron Radiography, Neutron powder diffraction, Neutron Reflectometry, Neutron Captured techniques - thermal column) would be desirable as long as the only Malaysian rector is in operation. This implies the creation of a centre of excellence in neutron beam applications with the following tasks:

- To set-up and operate neutron instruments on all available beam-ports.
- To teach neutron scattering, radiography, physics and dosimetry techniques.
- To conduct internal and co-operate in external research programmes using neutron beam techniques.
- To use of external neutron research facilities.

6 Conclusion

The current status of neutron beam-port applications and RIG' roles in strengthening the MINT (Malaysia) TRIGA reactor utilisation has been presented. Much work need to be done for system improvement/enhancement before the facilities can be fully utilised as one of the effective quality control and education tools in research and technology sectors. We believe that the facilities will provide advanced tools for MINT to pursue long term and speculative research and education programmes. IGORR members are welcome to provide ideas and technical assistances in promoting neutron science and technology as a beneficial sector in Malaysia, specifically and South-East Asia, in general.

Table 1 : MINT's TRIGA Characteristics (typical)

Rector Type	***TRIGA MARK II***
Maximum Power	***1 MW thermal (steady state)***
Pulsing Peak Power	***1,200 MW (pulse width 11 ms)***
Nuclear Fuel	***$U\text{-}ZrH_{1.6}$ (standard TRIGA)***
Enrichment	***20%***
Moderator	***Light Water (demineralised)***
Reflector	***Graphite***
Typical Neutron Flux	***1x1012 $cm^{-2}s^{-1}$ (Rotary Rack)***
Maximum Neutron Flux	***1x1013 $cm^{-2}s^{-1}$ (Central Thimble)***
Maximum Coolant Temperature	***49^oC***

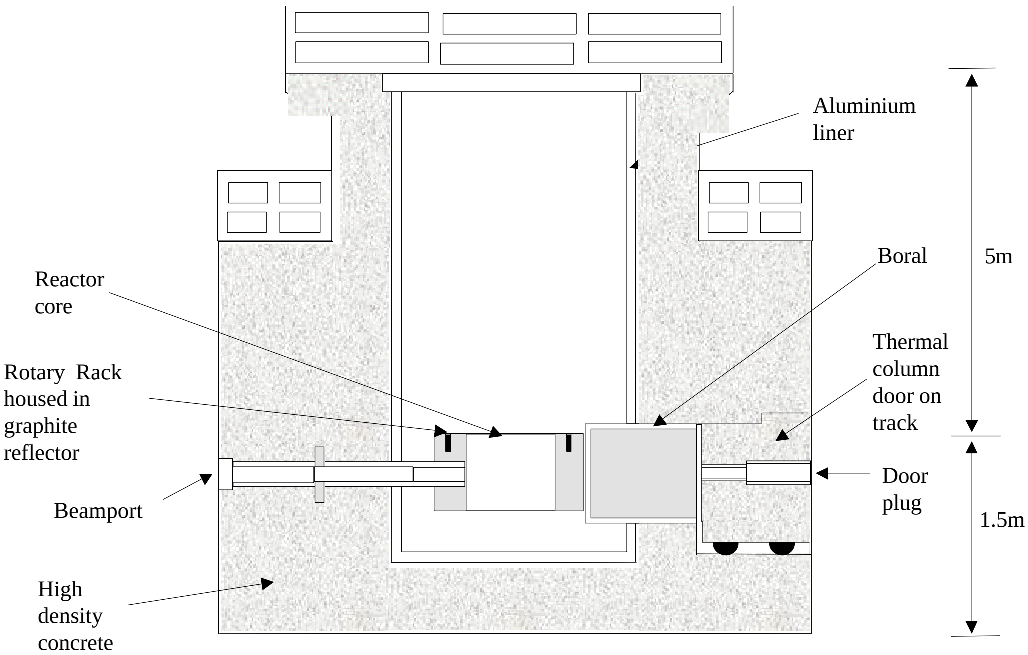

Figure 1. Vertical cross sections of Reaktor TRIGA PUSPATI

<u>Table 2: mySans Features</u>

Parameter	Specification
Beam port	Radial piercing
Monochromator	Three (double layer) set of ZYB highly Oriented Pyrolitic Graphite (HOPG) Crystal
Incident wavelength	0.5 nm
Wavelength resolution	5.2%
Source to sample distance	1-4 meter
Beam size at specimen	12 to 50 mm
Q range covered	0.0008<Q<0.036 nm
Maximum flux	1.7×10^4 n/cm^2/sec
Detector (RISO)	PSD (128 x128 pixels; 0.5 x 0.5 cm element dim., approx.)

<u>Table 3: myNUR Characteristics</u>

Physical dimension	
Collimator	Step Divergent
Length ; L/D ratio	200 cm; 37 to 75
Inlet aperture	5.4 cm
Measurement based on the condition : L/D = 37 and 750 KW reactor power	
Thermal neutron flux	1.04×10^5 n/cm^2/sec.
Epithermal	1.47 x 10^5 n/cm^2/sec
Gamma dose rate	36.7 R/hr
Neutron/gamma ratio	1.02 x 10^4 n/cm^2/mR
Thermal neutron characteristic measured using ASTM Beam Purity Indicator; Direct method (Gd foil and Kodak SR), exposure time 20 min	
Thermal neutron (C)	75.6 %(1987); 71.3 %(1995)
Epithermal neutron (EN)	2.4 %(1987); 2.0%(1995)
Scattered neutron (S)	1.83 %(1987); 1.0 %(1995)
Pair production (P)	0.61 %(1987); 1.0 %(1995)
Gamma (γ)	1.83 %(1987), 1.6 %(1995)
Radiographic sensitivity measurement utilizing ASTM Sensitivity Indicator; Direct method (Gd foil and Kodak SR), exposure time 20 min	
Visible gaps	All (1987); All (1995)
Visible holes through lead step	All (1987); All (1995)
Number of visible holes through acrylic step	6.6 (1987); 7 (1995)