Review Paper

Summary of Accelerator Driven System Sessions

P.K. Nema

Bhabba Atomic Research Centre, Mumbai, India

Abstract. Accelerator Driven System area of research has changed from a deterministically safe nuclear power reactor to a device offering fastest rate of incinerating the plutonium & minor actinides to dispose the radiotoxic spent nuclear fuel of Uranium fuel cycle. Important Advancement in Accelerator Technology are shown and discussed.

1. Introduction

The topical area of Accelerator Driven System (ADS) in the conference was covered in the following sessions:

- ADS: National and International ADS Programmes (ADS/INT).
- ADS: Experiments and Test Facilities (ADS/ET)
- ADS: Nuclear data (ADS/ND)
- Satellite Meeting : European Fast Neutron Transmutation Reactor Projects- MYRRHA/XT-ADS (SM/ADS).

About 5 to 10 papers in each of the 3 plenary sessions and the two satellite meetings on ADS were presented which covered activities related to various aspects of the R&D. In addition, similar topics were also covered in about 20 posters.

The main objective of R&D in the area of ADS over past two decades have changed from a deterministically safe nuclear power reactor to a device offering fastest rate of incinerating the plutonium & minor actinides to dispose the radiotoxic spent nuclear fuel of Uranium fuel cycle. In this way, the volume of radio-toxicity burden on a geological repository would be reduced by more than a hundred times while compared to that for open (once-through) uranium fuel cycle. In many member states of IAEA, the disposal of spent nuclear fuel is fast becoming a vexed issue for continuing with nuclear power generation. The topical area of ADS, thus, assumes an important role in the sustainability of nuclear energy.

2. The Plenary Sessions

2.1. ADS/INT

This session was devoted to explain the rationale, planning and progress in R&D before a realistic ADS could become deployable either as demo or on industrial scale. Many member states have preferred to make holistic approach in the initial R&D in which design issues like: high power proton accelerator (HPPA) systems, spallation target of heavy liquid metal and its compatible containment materials, reactor physics studies with minor actinides nuclear data, and sub-criticality monitoring

methods etc; have taken the centre-stage. This was theme of reported overviews from Japan, China and India.

In the context R&D in Germany and the one coordinated through European Union in the framework of Sustainable Nuclear Energy Technology Platform (**SNE-TP**), activities focused in the separation, partitioning of transmutation fuel from the spent nuclear fuel were reported. A significant development of successful GESA coating on stainless steel was reported in Germany which resists LBE corrosion up to 600^0C. There are also series of European activities on nuclear data measurements, and reactor physics experimental programme to overcome the limited accuracy in available nuclear data of actinide isotopes. While there is convergence in these activities which are extended from EUROTRANS frame work towards a demonstration ADS (MYRRHA/XT-ADS) device in Europe, the next stage for a full transmutation device (EFIT) has also been evolved into a sort of baseline design.

For most national ADS programmes, essential and more extensive work related to HPPA have progressed at low-energy end of 1 GeV linac. At higher energy in the linac's modular construction, all schemes rely on use of superconducting RF cavities. Enhancing the reliability of HPPA to allow only a few unscheduled beam trips annually is the prime concern while optimizing the architecture of the proton accelerating structure and RF electrical powering system. With careful design and quality improvement in supporting equipment such high levels of operational reliability seem feasible to meet *ADS reactor system demands in context of demonstration and industrial ADS.*

2.2. ADS/ET

A good number of experimental & test facilities (**ADS-ET**) set ups to study the concepts of ADS were reported in the meeting. Since ADS configurations in fast neutron spectrum would be most effective in the incineration of minor actinides, these low-fission power experimental set ups make use of 14-MeV fusion neutrons to drive the sub-critical core. This is a convenient and yet effective way to experimentally simulate up to 90% of spallation neutron yield in a 1 GeV HPPA-driven ADS. The sub-critical reactor test programmes were reported from Belgium, Japan, Belarus which rely on pulsed and continuous deuteron beams to generate neutrons by DD and/or DT fusion reactions. Progress of preparations for GUINEVERE test facility in Belgium was highlighted in a presentation. Main objectives common to these experiments would be to investigate online reactivity monitoring, sub-criticality determination and operational procedures in an ADS. Some results of operating systems in Belarus facility named YALINA and KUCA in Japan were reported in the meeting, which included keff measurements by pulsed neutron source (PNS) method and validation of code calculations of reactor physics parameters.

The facility design options for Mo-99 production in material test station of LANSCE accelerator and results of LBE irradiation under MEGAPIE experiment in 590-MeV cyclotron were reported from USA and Switzerland respectively. The latter experiment was operated for about 4 months and provided extremely useful operational experience of spallation target similar to the one in an ADS device.

2.3. ADS/ND

Nuclear data satellite meeting (**ADS/ND**) on ADS was focused on eliminating the uncertainties in the nuclear data used to model target spallation reactions with proton beam. Presently used modeling code calculations were presented and compared with experimental results to identify the discrepancies. There was also an illustration on basics of Intranuclear Cascade modelling (INC) codes which estimate high-energy particle transport in hadron-nucleus reactions such as in spallation target in ADS.

Application of spallation and photonuclear reaction codes in predicting light nuclei and residue yields were also presented in this satellite meeting to suggest the methodology for target designs.

There is necessity of good physics models validated on good experimental data to be implemented as spallation simulation codes. Further R&D on these issues has already been indicated in the WP4 plans

of FP7 projects of EC countries for particle interaction energies in range 150-600 MeV. The impact of these researches on target design, radioactivity production and materials damage were discussed in the meeting.

The work described included using pulsed photo-neutrons from a US electron linac facility in time of flight beamlines for accurately measuring the cross-sections of nuclei of interest in reactor technology. Use of similar facility and results of experimental data derived at somewhat lower energy neutrons were reported from China.

3. Satellite Meeting SM/ADS

The satellite meeting on European transmutation facilities MYRRHA/XT-ADS (**SM/ADS**) was a major technological information exchange event in this topical meeting. The two designs of demonstration and industrial ADS, the latter as transmutation facility were presented and discussed in a session. The adaptation of demo-ADS design MYRRHA of Belgium into European transmutation project objective of XT-ADS, and the associated R&D activities with results under EUROTRANS FP-programmes were the main features. A few technological breakthrough in the ADS area were reported as following:

- Windowless target design would be a certainty with successful experimental results at SCK-CEN, Belgium to alleviate perplexing issue of frequent beam window replacement in target module.
- Containment possibility of Polonium within LBE system volume where it remains as lead-polonide up to 500^0C, and that no serious vapour emissions were observed in the MEGAPIE operation. With Lead as target in an industrial transmutation fast sub-critical reactor, polonium residue would be three orders less.
- Successfully establishing alumina surface-coating on stainless steels by GESA process, and the active Oxygen control in the molten LBE system for high temperature applications up to 600^0C were reported

Search for high temperature materials for industrial-scale ADS to operate above 600^0C for high thermal efficiency and using more abundant lead as coolant-moderator would be synergetic with innovative GEN IV fast reactors. This fact helps in the sustainability of ADS as nuclear waste transmuter vis-à-vis fast reactors that are difficult to control while using minor actinides fuel in burner mode.

The encouraging response from countries in Europe for construction of a demonstration ADS within time frame of years 2018-20, and that of an industrial-scale ADS in 2030 as dedicated actinides incinerator were appreciated in discussions during this satellite meeting.

4. Conclusions

ADS offers good opportunities due to its inherent deterministic safety feature for:

- Development and qualification with safe in-reactor trials of new fuels and structural materials such as those needed in Gen-IV reactor systems with.

- Studies of alternative coolants such as lead and LBE in fast neutron spectrum.
- Studies of future innovative reactor systems for sustainable thorium utilization.

Current research, technology development status and potential of ADS make a strong case for enhanced international collaboration for which MYRRHA / XT-ADS is most advanced programme to meet the requirements of a demonstration technology. Having ADS in the domain of its mandate on peaceful uses of nuclear energy, IAEA should play a major role towards the realization of an ADS demonstrator. A number of structured coordinated research projects should be evolved by organising a few technical meeting of experts on ADS-related problems on subjects of nuclear data, cross-section measurements, materials development and coolant technology etc.