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Benchmarks of Subcriticality in Accelerator-Driven System at Kyoto University Critical Assembly

Cheol Ho Pyeon[1], Masao Yamanaka[1], Song-Hyun Kim[1], Thanh-Mai Vu[1,2], Tomohiro Endo[3], Willem Fredrik G. van Rooijen[4] and Go Chiba[5]

[1] *Research Reactor Institute, Kyoto University, Asashiro-nishi, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan*
[2] *Hanoi University of Science, Vietnam National University, 144, Xuan Thuy, Cau Giay, Hanoi, Vietnam*
[3] *Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*
[4] *Research Institute of Nuclear Engineering, University of Fukui, Kanawa-cho, Tsuruga, Fukui 914-0055, Japan*
[5] *Graduate School of Engineering, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan*
E-mail: pyeon@rri.kyoto-u.ac.jp; m-yamanaka@rri.kyoto-u.ac.jp; kim@rri.kyoto-u.ac.jp; maivu@rri.kyoto-u.ac.jp; t-endo@energy.nagoya-u.ac.jp; rooijen@u-fukui.ac.jp; go_chiba@eng.hokudai.ac.jp

Abstract - *Basic research on the accelerator-driven system is conducted by combining ^{235}U-fueled and ^{232}Th-loaded cores in the Kyoto University Critical Assembly with the pulsed neutron generator (14 MeV neutrons) and the proton beam accelerator (100 MeV protons with a heavy metal target). The results of experimental subcriticality are presented with a wide range of subcriticality level between near critical and 10000 pcm, as obtained by the pulsed neutron source method, the Feynman-α method and the neutron source multiplication method.*

***Keywords**: ADS, KUCA, Subcriticality*

I. INTRODUCTION

With the combined use of the uranium-235 (^{235}U)-fueled core at the Kyoto University Critical Assembly (KUCA) and the fixed-field alternating gradient (FFAG; 100 MeV protons) accelerator, experimental studies on accelerator-driven systems (ADS) are being conducted as basic research into kinetic parameters. ADS experiments with spallation neutrons (ADS-P) [1], which are obtained by combination of 100 MeV protons and a heavy metal target, were successfully carried out to investigate the neutron characteristics of ADS; the kinetic parameters were accurately analyzed through measurements and Monte Carlo simulations.

In previous studies [2]-[4] , in order to confirm the measurement methodology of subcriticality, the neutronics of ADS was experimentally examined by combining the KUCA core and 14 MeV neutrons generated by deuterium-tritium (D-T) reactions. Focusing on actual ADS experimental facilities, measurement of kinetic parameters was interestingly conducted in the ^{235}U-fueled core to investigate the characteristics [5] of a lead-bismuth (Pb-Bi) target and the effects [6] of a neutron spectrum made locally by Pb-Bi zone, with the spallation neutrons (100 MeV protons and Pb-Bi target). It is currently planned at actual ADS experimental facilities for Pb-Bi to be used as a coolant material for a fast neutron spectrum core and a target for generation of spallation neutrons. In the thorium-232 (^{232}Th)-loaded ADS experiments [7]-[8] with 14 MeV (ADS-DT) or spallation neutrons, characteristics of kinetic parameters were studied by varying the neutron spectrum at levels under the deep subcriticality level.

Through a series of ADS experiments at KUCA, experimental benchmarks of subcriticality were provided for the following cores: ^{235}U-fueled ADS core with 14 MeV neutrons [9]; ^{235}U-fueled and Pb-Bi-zoned ADS core with spallation neutrons [6]; ^{232}Th-loaded ADS core with 14 MeV or spallation neutrons [10]. In this paper, several experimental subcriticality measurements results were presented, having a wide range of subcriticality levels between near critical and 10000 pcm; results were obtained by the pulsed neutron source (PNS) method, the Feynman-α method, and the neutron source multiplication (NSM) method.

II. 235-U-FUELED ADS-DT EXPERIMENTS

ADS experiments with 14 MeV neutrons were carried out in the A-core (**Fig. 1**), comprising a highly-enriched uranium (HEU) fuel and a polyethylene reflector. The fuel assembly "F" (3/8"P36EU) is composed of 36 unit cells; upper and lower polyethylene blocks are about 500 and 630 mm long, respectively, in an aluminum (Al) sheath 54×54×1524 mm. Numeral "12" (3/8"P12EU) corresponds to the number of fuel plates in the partial fuel assembly used to reach critical mass.

Subcriticality was attained by full insertion of control and safety rods, and with the substitution of fuel assemblies for polyethylene ones. At KUCA, using the rod drop method, subcriticality was deduced experimentally by a combination of the worth of the control (C1, C2 and C3) and safety (S4, S5 and S6) rods; the calibration curve was determined using the positive period method. Furthermore, in the case of fuel substitution, because the reactivities of the control and safety rods varied with the substitution of fuel assembly rods for polyethylene ones, subcriticality was numerically obtained using the MCNP6.1 [11] code with the JENDL-4.0 [12] library. In the ^{235}U-fueled ADS