PRELIMINARY NEUTRONIC DESIGN OF SPOCK REACTOR: A NUCLEAR SYSTEM FOR SPACE POWER GENERATION

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ABSTRACT

Aim of this paper is to preliminary investigates the neutronic features of an upgrade of the MAUS [1] nuclear reactor whose core will be able to supply a thermoelectric converter in order to generate 30 kW of electricity for space applications. The neutronic layout of SPOCK (Space Power Core Ka) is a compact, MOX fuelled, liquid metal cooled and totally reflected fast reactor with a control system based on neutron absorption. Spock, that during the heart and launch operation must be maintained in sub-critical state, has to start up in the outer space at 40 K temperatures with the coolant in a solid state and it will reach the operating steady condition at the maximum temperature of 1300 K with the coolant in the liquid state.

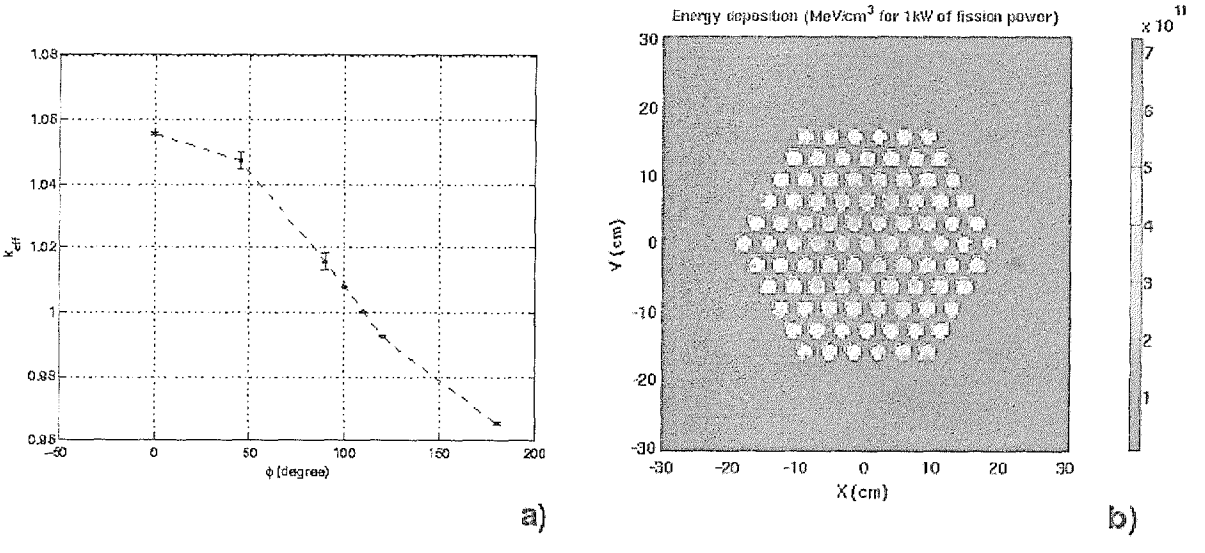

Fig.1: a) Keff vs synchronized control rods rotation angle. b) Energy deposition per kW at steady state.

The main design goal is to maintains, in the operating conditions of a typical space mission, the control of the appropriate criticality margin versus temperature and coolant physical state. For this purpose, a neutronic/thermal-hydraulic calculation chain able to assists the entire design process must be set up. As preliminary recognition, MCNPX 2.5.0 and FLUENT calculations were carried out.

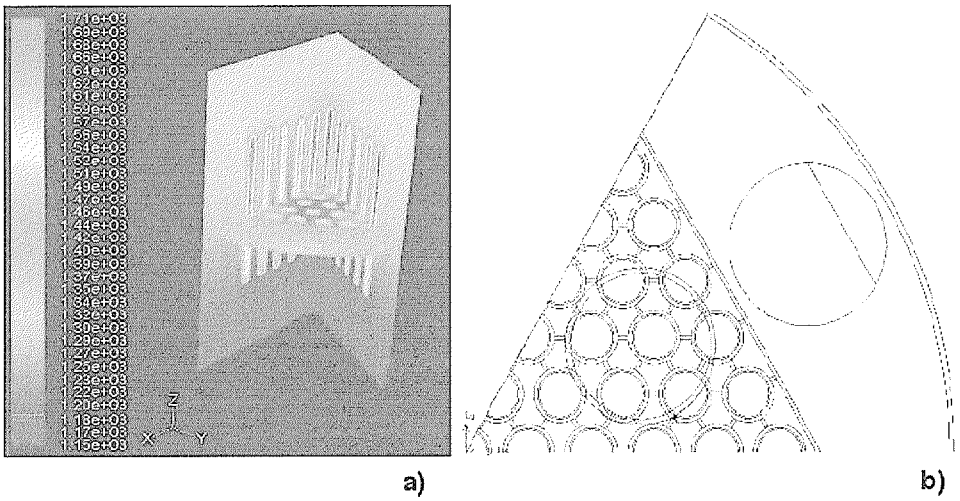

Fig.2: a) Temperature profiles in 1 sixth symmetric section of SPOCK. b) Plant view cross section of the same symmetric reactor element.

The emerging key features of SPOCK are: an equilateral triangular mesh of 91 cylindrical UO_2 fuel rods with a Molybdenum clad ensured by two grids of the same material, cooled by liquid Sodium and contained in an AISI 316 L vessel. The core is totally wrapped by a Beryllium reflector that hosts six absorber (B_4C) rotating control rods. The reactor shape is cylindrical (radius = 30 cm and height = 60 cm) with a total mass of 275 kg (fig. 2b). The excess reactivity was of 5000 PCM at 1300 K. A preliminary evaluation of the control rods worth (fig. 1a) and a power spatial distribution (fig. 1b) were also discussed. Through the definition of an ideal reference K_{eff} value at 300 K for the actual SPOCK configuration, a sensitivity analysis on various cross sections data and material physical properties was performed for the given mission temperature range, allowing consideration on the feasibility of the standard nuclear data sets for the design of space nuclear devices. Finally, FLUENT 6.2.16 preliminary calculations show (fig. 2a), for a hot pin fuel temperature of 1700 K, 325 kW_{th} were transferred to the coolant (Γ= 1.8 Kg/s, ΔT = 150 K) with the possibility to be converted in 30 kW_{el} by using an advanced thermoelectric converter system.

Reference

[1] M. Cumo, M. Frullini, A. Gandini, A. Naviglio, L. Sorabella "MAUS – 1.5 Nuclear Reactor for Space Electric Power", ICENES 2005- Bruxelles August 2005.