3-D SPACE TIME KINETICS OF COMPACT HIGH TEMPERATURE REACTOR WITH FUEL TEMPERATURE FEEDBACK

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ABSTRACT

The Compact High Temperature Reactor (CHTR) is being developed as technology demonstrator for Indian High Temperature Reactor programme [1, 5]. Physics design of conceptual core of (Th-U$^{233}$) fueled CHTR is in advanced stage and various core configurations have been proposed. Reactor core operation at high temperature necessitates sophisticated safety and anticipated transients analyses including postulated LORA, LOCA, and power set-back transients in CHTR. Recently, efficient IQS module in ARCH with adiabatic fuel temperature feedback capability has been developed. For accounting fuel and coolant temperature feedbacks in the simulation of 3D space time transients in CHTR, module for lumped thermal-hydraulics as well as module for heat transfer from fuel to coolant are being incorporated in 3D space-time analysis code ARCH. The AER benchmarking results of ARCH-IQS code with Doppler feedback and results of anticipated transient without scram (ATWS) of (Th-U$^{233}$) fueled CHTR with the present capability in ARCH-IQS code have been presented in this paper.

CHTR CORE DESCRIPTION

In the current stage of conceptual design, the CHTR core (Fig.1) consists of 19 hexagonal BeO moderator blocks containing centrally located graphite tubes. In the central portion of graphite tube, liquid metal (Pb-Bi eutectic) coolant flows between the top and bottom plenum upward and returning through down-comer tubes located outside the core. The outlet/inlet temperature of coolant is 1000/900 °C. Each graphite tube carries within it the fuel inside 12 equispaced longitudinal bores of 10 mm diameter. These bores are filled with fuel compacts of approximately 35 mm length made from TRISO coated particles embedded in graphite matrix. The average fuel temperature is 1000°C. The TRISO particles are in the form of micro-spheres of (U +Th) carbide kernel (500 µm diameter) coated with three types of layers of soft pyrolictic carbon (90 µm thickness), SiC (30 µm thickness) and hard carbon layer (inner/outer 30/50 µm thickness). In the present design of CHTR core contains 2.7 kg U$^{233}$ in 8 kg of (U+Th) fuel for fifteen full power years of continuous operation. Gadolinium as burnable poison is added in kernel of the TRISO particles of central fuel assembly.

In the present design, the reactor has twelve control rods made of Ta & W in outer coolant channels for power regulation and set-back. It has two independent shutdown systems i.e. primary contains six shutoff rods similar to CRs will be inserted in six inner coolant channels and secondary having twelve axially moving cylindrical BeO blocks going out of the core. It has six burnup compensation rods in fixed BeO reflector blocks for coarse control of initial excess reactivity in the core. It is envisaged that reactor will be made critical at 200 °C core temperature. The present transient simulation of postulated ATWS case in CHTR has been carried out in the start-up core configuration [1].

RESULTS AND DISCUSSIONS

The current International trend is to perform integrated Neutronics-Thermal-hydraulics studies under larger multi-physics multi-scale framework. To develop multi-physics capability for safety and transient analyses of CHTR, efforts have been made to incorporate more efficient Improved Static (IQS) model [3] in the 3D space-time analysis code ARCH [2] with adiabatic fuel temperature feedback model. The viability of 3D space time kinetics code ARCH-IQS with Doppler feedback has been examined [3] with AER benchmark (Dyn002) [6] and the...
predictions of transient power and fuel temperature has been compared with KIKO3D (Fig. 2). The ATWS (2.47mk reactivity inserted in 2.8 sec and rising power arrested by fuel temperature feedback) case in (U$^{233}$-Th) fueled CHTR has been simulated with adiabatic fuel heating for Doppler feedback and also compared with point kinetics code PATH. The 5-group condensed homogenized cross-section of CHTR lattice at various core temperature have been generated with collision probability based code ITRAN [4]. The worth of control rod considered and Fuel Temperature Coefficient (FTC) have been computed with code ARCH. The FTC is computed as $-1.7 \times 10^{-5}/^\circ C$ (about 200$^\circ C$) and the worth of control rod is found to be 2.47mk (with $\beta_{eff} = 4.66$ mk) during approach to criticality. The power variation and maximum fuel temperature in the core during ATWS case in (Th-U$^{233}$) fueled CHTR with ARCH-IQS has been compared with point kinetics analysis and presented in Fig.3. The differences between the maximum fuel temperature predicted by ARCH-IQS and average fuel temperature predicted with PATH are due to power peaking in the core.

**CONCLUSIONS**

The case of ATWS in critical core of CHTR during first approach to criticality has been carried out with present Doppler feedback capability in IQS module of 3D space time analysis code ARCH. Results of benchmark analysis of ARCH-IQS have been found in very good agreement with other benchmarked codes. The results of 3D space time analysis of ATWS case in CHTR with code ARCH with adiabatic fuel heating has been compared with point kinetics analysis code PATH. These analyses with lumped thermal-hydraulics as well as with conduction model of heat transfer will be presented in full manuscript of this paper.

**REFERENCES**