EFFECT OF DISTRIBUTION OF VOLUMETRIC HEAT GENERATION ON MODERATOR TEMPERATURE DISTRIBUTION

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INTRODUCTION

Advanced heavy water reactor (AHWR) is a 300 MWe, vertical pressure tube type, boiling light water cooled and heavy water-moderated reactor (Sinha and Kakodkar, 2006). It is designed for high discharge burnup and large scale commercial utilization of thorium. The reactor incorporates features like core heat removal by natural circulation, negative void coefficient of reactivity under all event scenarios, easily replaceable pressure tubes, long design life, passive safety features, etc. The coolant flows in the high-pressure coolant channels consisting fuel clusters. To reduce the heat loss, coolant channels are surrounded by calandria tubes. Moderator is kept separately inside the calandria vessel which is pressurised by covergas pressure of 0.4 bar(g) and is in sub cooled condition with average temperature of around 62.5°C. Fig. 1 shows a typical the calandria vessel. The purpose of moderator is to maintain criticality in the reactor core by slowing down the high energy neutrons to a lower energy level where their probability of fission capture is greater. A large amount of heat (50MW) is generated within the moderator mainly due to neutron slowing down and attenuation of gamma radiations. To remove this energy, moderator is kept under continuous circulation through a heat removal system. Further, the location and orientation of the moderator inlet and outlet nozzles should be such that the local temperature is below boiling point. Therefore, it was thought desirable to understand the relative temperature and flow fields generated by uniform and non-uniform volumetric heat generations. Under these two conditions, an attempt has been made to understand the flow and temperature fields inside calandria vessel. The results of spatial distribution of volumetric heat generation on maximum moderator temperature was compared with that generated by uniform distribution.

Fig. 1: Quarter symmetry solid model of calandria.

Fig 2: Distribution of volumetric heat generation in calandria vessel.
RESULTS AND DISCUSSIONS

3D CFD simulations have been performed using the open source CFD code OpenFOAM 2.2.2 (2013). The standard steady-state solver buoyantBoussinesqSimpleFoam with heat generation as source term is used for simulation. The non-uniform heat generation in moderator was computed separately using Monte-Carlo technique (Suryanarayana, 2011) as shown in Fig. 2. Under the normal operating condition, total volumetric heat load to the moderator is taken to be 50 MW. The total flow rate through the sixteen inlet nozzles is 476 kg/s with 50°C of inlet temperature. Fig. 3 shows effect of volumetric heat generation distribution on temperature distribution in calandria vessel. When results of spatial variation are compared with uniformly distributed volumetric heat generation, it is observed that maximum moderator temperature come down by 6.4°C from 83.7°C. Fig. 4 shows comparison of centre line temperature for both the cases. In case of uniform heat generation, temperature at bottom reflector of calandria vessel is 56°C which is 6°C more than inlet temperature whereas in spatial variation it is equal to inlet temperature. Similar behavior can be observed in top reflector. This is because of very small heat generation in top and bottom reflector in spatial variation case. This is because nuclear heat generation in moderator at any location is dependent on power generation in the adjacent channels hence lower heat generation in reflectors region.

CONCLUSIONS

Moderator temperature fields in AHWR Calandria were simulated using OpenFOAM. Simulation was done for two different cases for normal operating condition with spatial and uniform distribution of heat generation. By taking spatial distribution of volumetric heat generation in CFD simulation, maximum moderator temperature comes down by 6.4°C when compared with the case of uniform distribution of heat.

REFERENCES

2. OpenFOAM 2.2.2, “User guide for OpenFoam 2.2.2”, www.openfoam.org, 2013