Comparison of 2D and 3D Heat Transfer Models around the Coolant Channel in the HTR-PM Side Reflector

G.J. Auwerda, Y.H. Zheng, J.L. Kloosterman, D. Lathouwers
Delft University of Technology
Mekelweg 15, 2629 JB, Delft, The Netherlands
phone: +31-15-2783827, g.j.auwerda@tudelft.nl

1Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing 100084, China

Abstract – In the HTR-PM pebble bed reactor heat is produced in a cylindrical core surrounded by a graphite reflector. The helium coolant flowing down through the core first flows up through 30 coolant channels in the reflector, cooling the reflector. Heat is also transferred through the reflector in radial direction to the pressure vessel and other surroundings. Usually heat transfer in the reflector region is modelled using a 2D axi-symmetric geometry, modelling the region containing the coolant channels as a homogenized mixture of coolant channel and graphite reflector using a porosity value, sometimes using very coarse meshes. In reality temperature gradients in angular direction will exist around the coolant channels, possibly effecting both heat transfer to the coolant in the channels and heat transfer through the graphite around the coolant channels to the outer boundary. This paper investigates the accuracy of the 2D model for calculating the temperature and heat transfer around the coolant channels in the side reflector by comparing calculations for a fine and a course 2D mesh with a 3D mesh in which the coolant channel geometry is explicitly modelled. Two cases were investigated, one representing full power operation, and the other a loss of forced coolant incident with no helium flow through the coolant channels. Calculations were performed with the pebFoam OpenFOAM solver. The course 2D mesh resulted in large errors in the reflector temperature field, overestimating the temperature drop across the coolant channel region. The 2D fine mesh compared reasonably well with the 3D mesh, although it resulted in both an overestimation of the effective heat transfer rate to the coolant channels and an underestimation of the effective resistance to heat transfer in the reflector around the coolant channel in the radial direction, both of which can lead to an underestimation of reflector and core temperatures.

I. INTRODUCTION

The pebble bed nuclear reactor, a high temperature gas cooled reactor design, is one of the main candidates for next generation nuclear power plants [1]. Key features include the passive safety of the reactor, higher thermal efficiency due to higher coolant outlet temperatures, and the possibility of on-line refuelling by extracting pebbles at the bottom of the bed and adding pebbles to the top. In these reactors, the fuel is contained within graphite spheres, which form a randomly packed bed in a cylindrical core cavity surrounded by a graphite reflector. The helium coolant first flows upwards through coolant channels in the graphite reflector, and then via a plenum downwards through the pebble bed, removing the fission heat. Heat is also transferred from the pebble bed to the graphite reflector, which is cooled by the cold helium flowing upward through the coolant channels. These coolant channels are arranged in a ring in the reflector at equidistant positions. Finally a small portion of the heat is transferred through the reflector and via various core components to the outside.