MODELING OF RADIATIVE HEAT TRANSFER IN PROBLEM OF MELT-VESSEL INTERACTION DURING IVMR

D.Kamenskay [1,2], A. Filippov[1,3]
[1]: Nuclear Safety Instituite of the Russian academy of sciences, B. Tulskaya 52, Moscow, Russia
[2]: kdd@ibrae.ac.ru, [3]: phil@ibrae.ac.ru

Abstract

Radiative heat transfer may play noticeable role in severe accident progression but in simulations it is usually modeled quite simplistically. In general, we are interesting in heat transfer between the melt surface and surrounding structures that is the problem of heat transfer in non-uniformly heated enclosure with the gas of definite optical properties. Physical mechanisms of radiative heat transfer (RHT) differ from heat conductance and convection that makes modeling of RHT quite more difficult. Most of the models are based on simplified or very simplified approaches to solution of the main RHT equation. The paper describes application to the melt-structure interaction problem of two models dealing with participating or non-participating medium. The models are implemented in the HEFEST code: view factors model for transparent gas and Rosseland model for optically dense gas. The application area of these models is bounded by optical properties of the medium. The contribution of RHT in the total heat transfer in the SA reactor depends on melt temperature.

The actual properties of steam as a main absorption component allow consider the gas within the RPV, in some extent, as non-participating and use view factors model to take into account the shape of the enclosure and its temperature distribution. For preliminary estimations the quite more simple Rosseland model may also be tried to see the qualitative effects. In most cases of severe accident simulations it will be used beyond the area of its applicability and will overpredict the heat radiation effects. But this model may be useful as upper estimate since it does not require the building of the view factors matrix for the enclosure, which in general changes during the simulation. The comparative examples are considered in the paper.

The influence of heat radiation on the system state during IVMR is studied. The cases of inverse and normal stratification of the melt in the cooled reactor vessel were investigated using view factors and Rosseland models. In case of normal stratification (metal atop oxides) there is no significant melting of the steel wall above the melt. In case of inverse stratification the upper oxidic melt has much larger temperature and its irradiation is able to melt the significant amount of the wall steel. In these calculations the ways of formation of the inverse/normal melt stratifications are not considered.

Another factor of the melt state influenced by upper thermal radiation is the lateral heat flux from the melt to the RPV wall – in case of more intensive surface radiation the lateral heat flux onto the vessel wall is smaller. This increases the safety capacitance in IVMR. Furthermore, the exact calculation of redistribution of the heat power generated in the melt – along the wall and structures, through the direct contact or heat radiation, is important for total heat balance in IVMR simulations for whole NPP using the system code.

Keywords: severe accident, melt-structure interaction, heat radiation, IVMR.