Development of a novel DOM radiation model in OpenFOAM

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1. Introduction – A complete radiation model based on the Discrete Ordinate Method has been developed to be included in OpenFOAM®, an open source platform for CFD simulations. The DOM model currently included in OpenFOAM® core is limited to thermal radiation, whereas the developed model includes diffuse and specular reflection, transmission between regions, media absorption and scattering, and three kinds of emission sources: isotropic, parallel, or cone-shaped. Absorption and scattering coefficients may be homogeneous or not, and scattering phase function may be isotropic or not.

DOM discretizes spatial directions in discrete ordinates as Finite Volume Method discretizes spatial positions in cells. A quadrature is the scheme of distributed directions, as a mesh is a scheme of distributed positions. This work shows the relevance in simulation results of the relative orientation between the mesh (spatial discretization) and the quadrature (directional discretization). The developed model adapts quadrature to emission sources, increasing the method precision without increasing the computational cost.

2. Methods – The model features were singly validated in simple geometries and under isotropic illumination, comparing results with analytical solution and the well-known CFD software ANSYS Fluent®. The model enhancements were tested in case studies with no isotropic light (parallel and cone-shaped sources), with a full set of simulations, studying the influence of single variables such as beam direction, cone opening, or directional discretization.

3. Results and Discussion – The simulations of no isotropic emission sources show relevant improvements in the developed model. Adapting the quadrature to the sources allows to trace the subtlest changes in direction or cone opening, avoiding saw tooth effects in cone emission sources (keeping a rounded shape, instead of adapting the front to squared ordinates sides). Finally, it defers the beaming effect in cones (as diffuse sources are composed of discrete rays, they have a limited distance before sources lose their shape and became beams). Image 1 shows a summary of some comparisons between simulations in the developed model (top), simulations in ANSYS Fluent® (bottom), and analytical solution (dashed black circles):

4. Conclusions – The developed open source module can be considered a tool with promising applications in the modelling of several photoactivated process, especially due to its integrability with other OpenFOAM modules.

Additionally, it has been demonstrated some advantages of this code over standard DOM, especially for the modelling of parallel beams (as can be considered sunlight) or cone-shaped emission sources (as LEDs): it increases their precision with no higher computational cost, and opens new possibilities in model parallelization.