Heat-Accumulation Stoves: Numerical Simulation of Two Twisted Conduit Configurations

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Abstract

An important part of the society considers an increased share of renewable energies as an integral part of a strategy towards a sustainable future.
For heat supply, this can be achieved using solar thermal collectors, borehole heat exchangers or trough the combustion of biomass.
A traditional stove in the Alpine regions is the heat-accumulation stove, made of refractory blocks and a covering of ceramic tiles.
This particular kind of stoves consist of a combustion chamber, where woody material is burned, followed by a twisted conduit where the high temperature flue gas flows, giving off heat to the refractory.
The internal geometric arrangement of the conduit, with rapid sequence of curves, as well as its shape and roughness, influence the hydrodynamics of the flue gas.
The thermodynamic properties of the refractory material, its mass and its geometric arrangement, are other main parameters of the stove's functionality.
Sometimes a coating, made of panels of refractory material, is constructed around the twisted conduit in order to create an air cavity, where the thermal energy is redistributed by natural convection.
This article follows two papers presented in previous COMSOL conferences (Stuttgart 2011, Boston 2012) and shows two applications in two configurations of the twisted conduit, in the absence of the external coating: in the first case the conduit is developed in two dimensions, on a vertical plane (Figure 1), in the second case is developed in three dimensions (Figure2).
The hydrodynamic flow is described by the k-ϵ model, the buoyancy is taken into account with the simplifying assumption of Boussinesq, the heat transmission is treated into its three components: conductive, convective and radiative. This last is treated with the Discrete-Ordinate Approximation method S2 for what concerns the size of the solid angle of radiation.
The numerical results are compared with experimental measurements performed in the same configurations. The experimental data were also used to determine the initial and boundary conditions of the numerical calculations.
The trends over time of mean velocity in the section, mean temperature and mean pressure, in some sections along the conduit, are reported.
The results obtained in tests on the conservation of mass and energy, their dependence on the

choice of the calculation mesh, the conditions of instability that occurred during processing, are showed.
The calculations were performed using a middle computing power (intel i7 processor, 24 GB ram). The computation times were rather long, so as to reduce the possibility to thoroughly investigate the matter in a technically acceptable time.
The currently obtained numerical results deviate significantly from the experimental data and does not allow to perform a sensitivity analysis of the physical phenomenon to changes in involved physical parameters.
Several clues suggest that a greater detail in the mesh calculation can improve the agreement between the numerical data and the experimental ones.

Figures used in the abstract

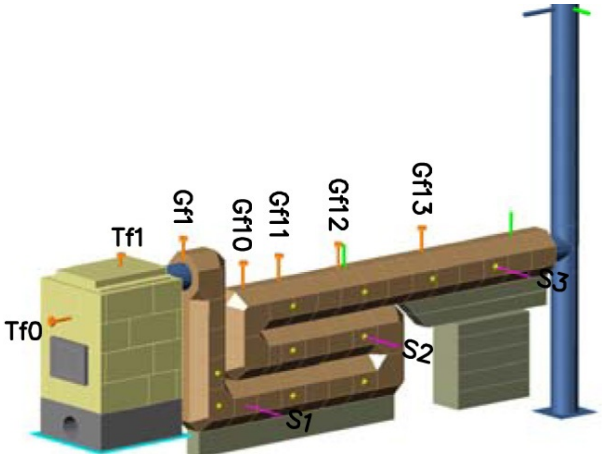

Figure 1: first configuration of conduit, developed in two dimensions, on a vertical plane

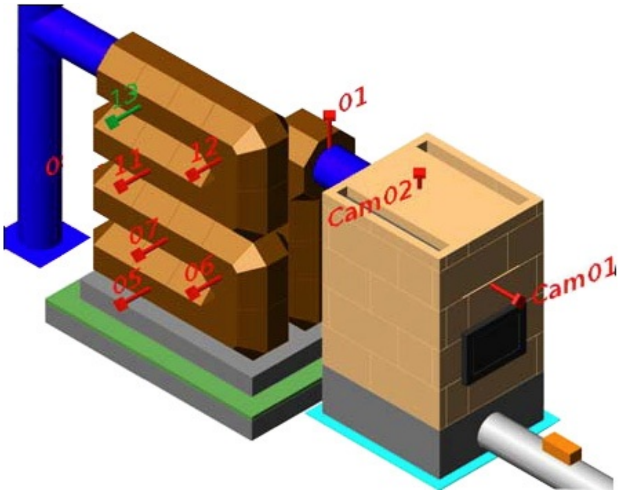

Figure 2: second configuration of conduit, developed in three dimensions, with horizontal and vertical curves