INTERNAL STRUCTURE OF COMBUSTION WAVES IN INSULATED POROUS MEDIA

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Air injection and in-situ combustion have long been considered as potential techniques for displacement and recovery of heavy oil. Despite a long history, only a small fraction of the total thermal recovery utilizes this technique. Some of the reasons are technical, such as combustion extinction and the necessity of (re-)ignition for sustained propagation within in-situ combustion in the presence of external heat losses. Thus mathematical analysis of this problem is important to predict these events.

In this work one dimensional gas-solid combustion is studied with combustion rate described by the law of mass action combined with the Arrhenius’ law. The latter says that the rate tends to zero slowly at absolute zero temperature. We consider a thermally insulated cylindrical porous rock containing solid fuel. Standard simplifications are made in order to formulate the physical model, for example the gas thermal capacity is considered negligible.

The reactive flow of air in porous rock containing solid fuel is governed by a system of balance laws for gas mass, oxygen mass and enthalpy. We are interested in examining the Riemann solutions for the parabolic partial differential equations governing the system, which supports a combustion traveling wave. In a previous work the Riemann problem for adiabatic forward combustion between gas and solid fuel was solved, but the combustion wave profile was not obtained.

In order to solve completely the Riemann problem we obtain the internal structure of the combustion wave. Asymptotic series expansions are used to obtain the approximate solution of the traveling wave. We validate our theoretical results with numerical simulations. Classical Crank-Nicolson scheme and hybrid schemes are used to compare the results for different dry gas-solid combustion models.