Unsteady simulations with a one-dimensional two-fluid model of a hydrogen peroxide catalyst bed

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Abstract

The last decade has seen an increase in interest in green rocket propellants as viable alternatives for currently used propellants such as hydrazine and hydrazine derivatives [1], which are highly toxic and/or carcinogenic. Hydrogen peroxide is considered to be one such alternative, used either as monopropellant or as oxidizer in a bipropellant engine. In both cases decomposition of hydrogen peroxide in a catalyst bed is required [2].

Several one-dimensional simple flow models have been developed and presented in the past. All of them are mixture models in which the gas and liquid are considered as one phase with properties based on the mixture properties of both phases, see for instance Bonifacio and Russo Sorge [3], Zhou and Hitt [4; 5] and Pasini et al. [6]. Zhou and Hitt [7] made a comparison between their model and the result obtained with a two-dimensional model for a catalyst bed developed by NASA, but any details about this model are not given.

An implicit assumption in mixture models is the existence of equilibrium between the fluid phases. However, there is reason to believe that such equilibrium does not exist. For example, the adiabatic decomposition temperature of 80wt.% hydrogen peroxide initially at room temperature is about 780K, while the critical temperature for peroxide and water is 739.5K and 647.3K respectively [8]. For this reason an unsteady one-dimensional two-fluid model has been developed and experimentally validated for a pellet based catalyst bed.

An Eulerian description is used for the fluid. Source terms are included that describe the catalytic as well as thermal decomposition of both fluids, the multicomponent evaporation of the liquid, the heat transfer between the fluids and the momentum exchange between the fluids as well as between a fluid and the catalyst pellets. The pressure-velocity coupling is accounted for by the SIMPLE algorithm extended to two-fluid models. The model uses an upwind discretisation scheme and is fully implicit. To enhance stability further special attention is paid to the implementation of the source terms. The conservation equations have been written in such a way that stability is guaranteed when one of the volume fractions approaches zero.

The final paper will discuss the requirements for numerical stability and present the results of transient simulations. In particular the influence of the pellet shape and dimensions on the startup characteristics will be investigated by means of a parametric study. Finally, a road map for improvement and further development will be discussed.

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