Numerical Modeling of Combustion Stability in Emergency Oxygen Generators

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Emergency oxygen for airplane passengers is typically generated by combustion of solid chemical mixtures based on sodium chlorate decomposition. Relatively low combustion temperatures and slow front propagation are characteristic features of these low-exothermic systems. Both industrial observations and our prior experiments show that the combustion process is characterized by significant oscillations of the product oxygen flow rate caused by pulsating front propagation. These pulsations decrease the efficiency of oxygen generators, and their alleviation is the goal of our research.

In this work, a computer model for combustion wave propagation in gas-generating systems is developed. Reactant melting and convective heat transfer from the generated gas are key steps in the process. For this reason, we numerically investigate the effect of reactant melting on filtration combustion front propagation stability in gas generating mixtures.

The formation of melting regions is demonstrated in cases with significant convective gas-to-core heat transfer. When the latter is involved, no condensed phase temperature gradient is required to heat the core and this permits expansion of the thin melting front to a wide melting region. Numerical simulations demonstrate the oscillatory behavior of both front velocity and oxygen flow rate (Figure 1). It is shown that, by decreasing the effective heat of reaction, reactant melting is detrimental to combustion front stability. In accordance with prior theoretical results for simpler cases, the simulations demonstrate growth of pulsations with increasing reaction activation energy. A strong stabilization of front propagation is observed when combustion temperature reaches the melting point of reaction product (Figure 2). These results identify the important factors responsible for pulsating behavior of chemical oxygen generators.

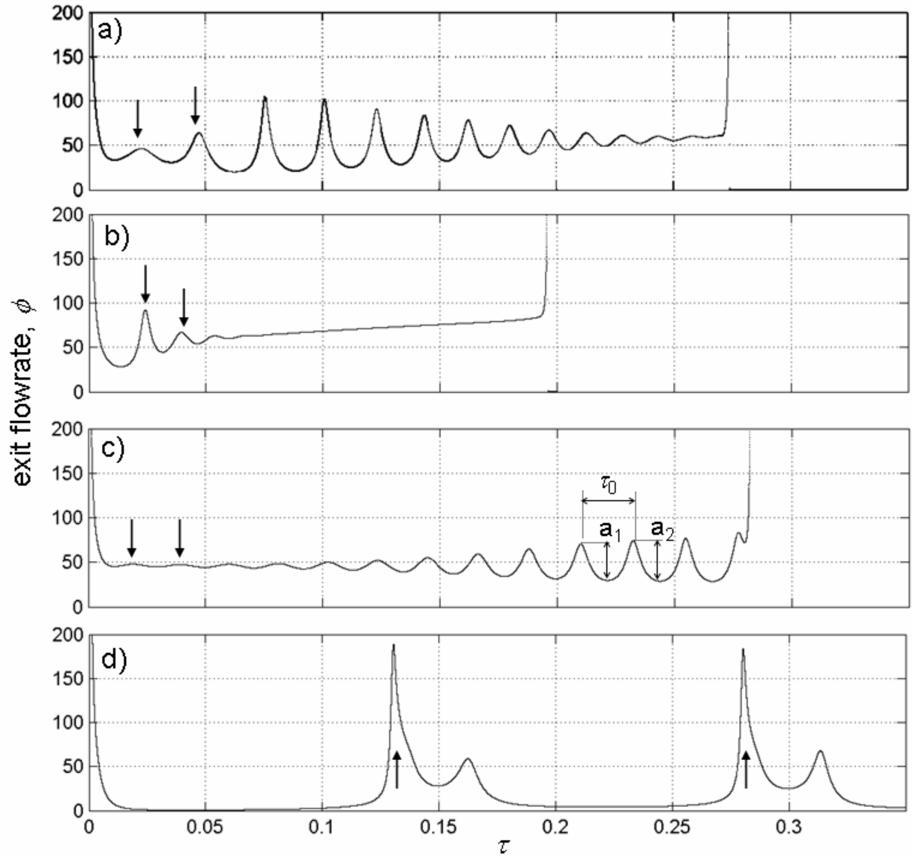

Figure 1. Gas generation for (a) both melting and convective heat transfer (α>0), (b) no melting of $NaClO_3$, (c) α=0 and no $NaClO_3$ melting, (d) α=0 and $NaClO_3$ melts.

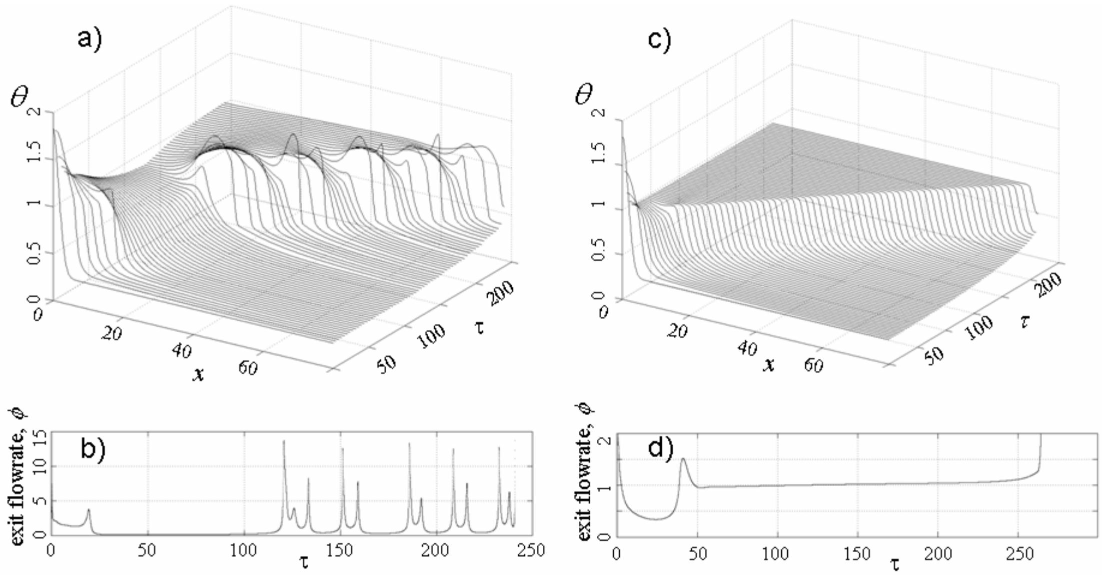

Figure 2. The stabilizing effect of product melting. Temperature profiles (a, c) and exit flow rate (b, d) evolution for cases with (c, d) and without (a, b) NaCl melting, respectively. In the no-melting case calculations, T_m for NaCl was artificially set to 2000 K.