

Nonlinear variable-diffusivity moisture transport in zero gravity porous media space applications

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ABSTRACT

The mass transport in porous media for space applications is complicated by the absence of the stabilizing gravitational potential. Generally, the spatially-resolved moisture diffusivity in porous media is a function of the local saturation. Formal solutions of very few specific variable-diffusivity parabolic flows are known. We are using the finite difference numerical methods to solve the nonlinear wetting and de-wetting diffusion dynamics in microgravity conditions. Two different functional relationships between the saturation and the moisture-diffusivity were considered. The half-saturation action-radius and the zone-of-influence of the porous suction tubes on the cold-plate porous material are especially adversely affected by the exponentially changing, saturation-dependent, diffusivity. Clogging and biofouling dramatically decrease dynamic response and performance of the porous media flow.

INTRODUCTION

NASA deep-space manned missions and LEO missions (e.g., ISS, STS) require an advanced life system to maintain the cabin air temperature and humidity at the comfortable conditions for human activity. In particular, the future long-duration manned deep-space missions depend on the reliable and lightweight Condensing Heat Exchanger for Space Systems (CHESS) which will be the core of the air conditioning system. Several different heat exchanger designs, including systems based on PM, have been used in the past (Petter et al., 1990; Unger et al., 1992; Scull et al., 1998; Westheimer and

Daidzic, 2003; Althausen et al., 2006; Daidzic et al., 2007; Daidzic, 2008). All of these systems had the main task of dependably removing heat and moisture from the re-circulating cabin air. However, current long-duration systems (e.g., ISS) require excessive maintenance and care and are not suitable for deep-space missions where no resupply is possible.

Porous Media has a long history of applications in space systems due to its desirable capabilities of containing and transporting liquid owing to capillary forces. Unsaturated PM provides capillary driving force which in the absence of adverse gravitational potential may be sufficient for reliable transport of the liquid (wetting) phase. However, a number of problems exist in reduced gravity environment, and one of the most pronounced is the air entrapment. It is almost impossible to get the disconnected non-wetting phase (air-pockets) out of PM (Sell et al., 1984; Schramm et al., 2003) in reduced gravity.

Another particularly troublesome problem in long-term variable-*g* operation of CHESS is the biofouling and clogging of PM (Roman et al., 1999; Stevik et al., 2004; Daidzic et al., 2005). This problem requires a special attention and no reliable study exist, to the best of our knowledge, on how to quantify this effect. Some recent results on hydraulic properties of clogged PM for CHESS were reported in Daidzic et al. (2005). There, the authors have used the tap ("dirty") and distilled ("clean") water and measured short-term and long-term clogging process. The long-term experimental simulation was obtained by increasing the flow rate through PM so that

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