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Chilled air production in cool–thermal discharge systems from ice melting under constant heat flux and melt removal☆

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Abstract

A new device of complete melt removal to produce the chilled air in cool–thermal discharge systems is operated with constant heat discharge flux from ice melting. Heat-transfer efficiency performance was considerably improved, compared with the device without melt removal, using the approximation solution of energy balances with integral boundary-layer analysis. The effect of the melt removal can effectively enhance the heat transfer rate, leading to improved performance. Numerical examples of inlet ambient air temperatures with the specified heat fluxes were illustrated and the results of the air mass velocity and the outlet chilled air temperature were also delineated.

Keywords: Cool-thermal discharge systems; Constant heat flux; Moving boundary; Chilled air; Melt removal

1. Introduction

The present study is concerned with the flow of heat through a parallel channel of infinite width of cool–thermal discharge systems [1–3], in which the heat discharge flux is uniform with complete melt removal from ice melting. A mathematical formulation is derived to evaluate heat transfer improvement on the device performance to produce chilled air. Actually, this work is an extension of the previous work [3] to estimate the time histories of the required air mass velocity and the produced chilled air temperature with the results of the ice melting thickness and temperature distribution in the ice layer

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obtained in the previous work. Three numerical examples, one constant inlet ambient air temperature and two other inlet ambient air temperatures varying periodically from sunrise to sunset, are illustrated to simulate practical systems. The new device introduced in the this work is to produce chilled air for air flowing over melting ice with removing melt immediately and completely, resulting in maximum temperature gradient between the flowing air and free ice surface, and hence the heat transfer rate from ambient air to the free ice surface is increased. Considerable improvement on device performance of the cool–thermal discharge systems is achieved by operating the device with complete melt removal, rather than without melt removal. Therefore, the introduction of melt removal concept to cool–thermal discharge systems has a positive effect of the heat transfer rate in the recyclic operation and hence creates a technically and economically feasible application.

The purpose of this work is to investigate the heat-transfer efficiency improvement in cool–thermal discharge systems with the complete melt removal and constant heat flux. This study discusses the effects of inlet air temperatures with the specified heat flux as a parameter. The results obtained in this work could be also applied to other cool–thermal discharge systems of convection coupled with heat conduction in the presence of a moving boundary.

2. Mathematical formulation

We considered placing a thin metal plate on the water surface to prevent both the non-uniform melting and the curved ice surface on the free surface due to airflow. Due to the large thermal conductivity, the heat-transfer resistance in the thin metal plate may be neglected, and the placement of a thin metal plate on ice surface may make the assumptions of uniform free-surface temperature and uniform heat flux, along the direction of flow channel, easier to be handled. The ice layer covered with a thin metal plate in cool–thermal discharge systems is considered to be semi-infinite and the ice layer temperature is at uniform temperature (T_∞) initially. The temperature distribution in the ice layer during the air-cooling

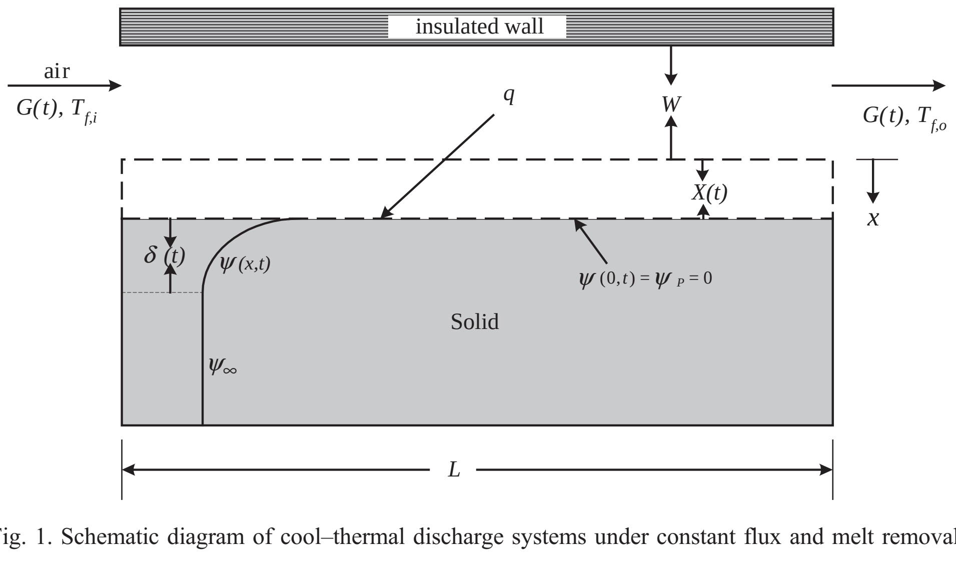

Fig. 1. Schematic diagram of cool–thermal discharge systems under constant flux and melt removal.