World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:11, No:06, 2017

Numerical Investigation on Transient Heat Conduction through Brine-Spongy Ice

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Abstract : The ice accretion of salt water on cold substrates creates brine-spongy ice. This type of ice is a mixture of pure ice and liquid brine. A real case of creation of this type of ice is superstructure icing which occurs on marine vessels and offshore structures in cold and harsh conditions. Transient heat transfer through this medium causes phase changes between brine pockets and pure ice. Salt rejection during the process of transient heat conduction increases the salinity of brine pockets to reach a local equilibrium state. In this process the only effect of passing heat through the medium is not changing the sensible heat of the ice and brine pockets; latent heat plays an important role and affects the mechanism of heat transfer. In this study, a new analytical model for evaluating heat transfer through brine-spongy ice is suggested. This model considers heat transfer and partial solidification and melting together. Properties of brine-spongy ice are obtained using properties of liquid brine and pure ice. A numerical solution using Method of Lines discretizes the medium to reach a set of ordinary differential equations. Boundary conditions are chosen using one of the applicable cases of this type of ice; one side is considered as a thermally isolated surface, and the other side is assumed to be suddenly affected by a constant temperature boundary. All cases are evaluated in temperatures between -20 C and the freezing point of brine-spongy ice. Solutions are conducted using different salinities from 5 to 60 ppt. Time steps and space intervals are chosen properly to maintain the most stable and fast solution. Variation of temperature, volume fraction of brine and brine salinity versus time are the most important outputs of this study. Results show that transient heat conduction through brine-spongy ice can create a various range of salinity of brine pockets from the initial salinity to that of 180 ppt. The rate of variation of temperature is found to be slower for high salinity cases. The maximum rate of heat transfer occurs at the start of the simulation. This rate decreases as time passes. Brine pockets are smaller at portions closer to the colder side than that of the warmer side. A the start of the solution, the numerical solution tends to increase instabilities. This is because of sharp variation of temperature at the start of the process. Changing the intervals improves the unstable situation. The analytical model using a numerical scheme is capable of predicting thermal behavior of brine spongy ice. This model and numerical solutions are important for modeling the process of freezing of salt water and ice accretion on cold structures.

Keywords : method of lines, brine-spongy ice, heat conduction, salt water
Conference Title : ICFMHTT 2017 : International Conference on Fluid Mechanics, Heat Transfer and Thermodynamics
Conference Location : Toronto, Canada
Conference Dates : June 15-16, 2017