Conducting a heat flow study in a vessel with the presence of natural convection and phase change material (PCM)

by

Ahmad Muntari Hassan (160011088)

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Department of Mechanical and Production Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh

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Conducting a heat flow study in a vessel with the presence of natural convection and a phase change material (PCM)

Approved by:

Dr. Arafat Ahmed Bhiuyan

Supervisor and Assistant Professor,
Department of Mechanical and Production Engineering,
Islamic University of Technology (IUT),
Board bazar, Gazipur-1704.

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List of Acronyms

A porosity function

α thermal diffusivity coefficient, m2 /s ***C***
constant

cp specific heat, J/kg K

Fo Fourier number

g gravity acceleration, m/s

H height, m

h specific enthalpy, J/kg

k thermal conductivity, W/m K

L latent heat capacity, J/kg

Nu Nusselt number

P pressure, Pa

PCM phase change material

q' heat flux, W/m2

→***S*** Citation of Dynamics, N/m3

T Thermal , K

t time, s

U coefficient of heat transfer, W/m2

→***v*** velocity vector, m/s

W width, m

German indications

β temperature expansion coefficient, 1/K Δ
difference

μ dynamic viscosity, kg/m s

φ liquid fraction

ρ density, kg/m3

ε Constant

Subscripts

avg average

l liquid PCM

Acknowledgements

First and foremost, I have no words to express my deepest sense of gratitude to almighty ALLAH, who enabled me to complete my research thesis successfully . I hereby acknowledge my father **Dr muntari hassan** and my mother **Hajara hussaini** uniquely I would like to express my deepest and sincere gratitude for your love, support and motivation throughout my life thank you both for giving me strength to reach for the stars. much obliged to you for placing your expectations and believing in me. without you i'd never been the person i am today. Thank you for helping me to shape my life with positivity and passion. There are no words I can express how thankful and grateful I am to you. thank you for everything

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Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly

Abstract

Experiments on the liquid and convectional circulator heat transfer and cooling in a rectangular heat storage tank with natural circulation As a phase change material 0.1 to ten , paraffin is used (PCM). The effect of different Right-angle look ratios, ranging from 0.1 to 10, on heat transfer and liquid stream exhibitions is studied. It has been discovered that Proportions of aspects are significant in energy storage exhibitions, with the dissolving rate rising the dynamic range. Because of the normal convection of fluid PCM, the distribution district in the fluid PCM district is formed astonishingly. Furthermore, during different phases of the dissolving period, stream constructions and temperature fields are used to communicate heat transfer systems. Heat conduction is shown to be the predominant heat transfer mode during the dissolving stage first and foremost. Progress from a conduction to a convection system, Flux with controlling Center temperature difference. The Steadily for the past quantity technique is used for the mathematical demonstration, which is then tested with analytical outcomes.

Chapter 1

INTRODUCTION

LHT has been shown to be an excellent for the elevated power storage carrier mobility additionally, negligible charging (to dissolving) being required (solidification) The latent heat of solution-PCM is built up during the dissolution process, and then released by crystallization. A number of PCM calculations are calculated to increase the The process of heat transport between different flows of heat fluids. Because the PCM can be dissolved in a considerable width of rectangular barriers, such as hardening, metallurgy, and thermal energy, has created a wealth of possible applications, for example, such as this wide dissolving may be especially important. Also, in the mechanical applications, the conduction and natural convection were both overpowered by a heated, ionic wall located in an approximately rectangular configuration. In the literature on the topic of rectangular PCM, much of the work focused on exploring its runs has been done (refs. 2-7).

[9]partly described how two-dimensional dissolution can be tackled with finite models, which includes natural convection for distinct cases. The phenomena of octadecane dissolving in a square container with a Rayleigh number of 10 8 and a Stefan volume ratio of 0.1 were nearly the same as the results of dissolving sodium nitrate in a cube with a ratio of 10^8:0. The similarity between room temperature experiments can be utilized to run dissolving/solidification experiments on PCM [10] The team developed a model for dissolving PCM in a rectangular cavity in which they used three heat sources mounted on a vertical leading plate, also called the "tube." Thermal analysis has also shown that key boundaries have an effect on the PCM-based heat sink implementation. The relationships were calculated: a) between the degree of fusion and the parameter that best represents the heat absorption/transmission rate and b) between the latter and a variable that measures the amount of time needed to reach maximum temperature in order to approximate the former. According to the dimensionless instructions, relationships embracing a broad range of domains were developed. Artists will benefit from using generated approaches for PCM-based cooling systems Paraffin solid-phase change, for example, soft salts and fatty acids are of broad usage in thermal storage and thermal management due to their ability have especially increased in the thermal marketplace because of that As recently, there have been studies done on the possible effects of convection on melting conduct Change of lauric fatty

acids in a rectangular area with horizontal fins and vertical incomplete fins, [13 14 15]. investigated the rectangle-saturated liquids' To describe the transfer of softening heat, visualize the solid-liquid interface and thermal characteristics in the simulation. rectangular storage cavity effects on PCM dissolving heat flow is researched. Dissolving transportation problems of the dimensions of H 10 cm x L 10 x W 20 and heat supply supply of HS with wall heating on a horizontal H10xL20xW10xH20cm are examined in depth.

1.1 PCM classification

Despite the other phases existing, however, there will still be a focus on the solid-liquid phase change. thermal storage silastic solids are PCMs such as water and sugar-alcohol as well as salt hydrates More will be discussed in the following graphical representations of the class SPCMs The way to find PCM[34] is shown in Figure 7.

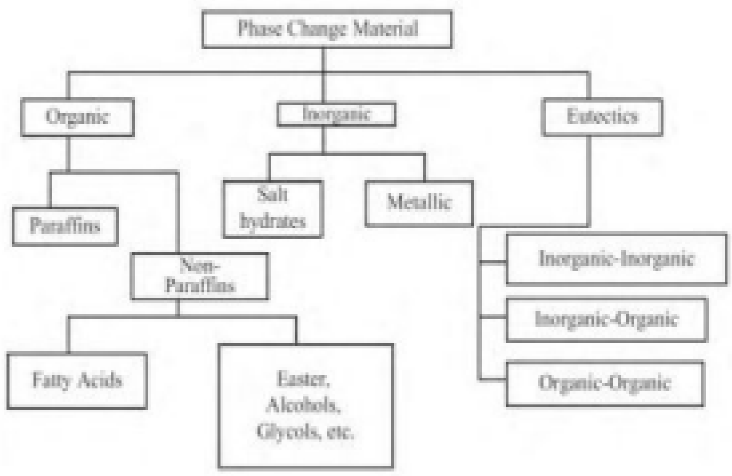

Fig.PCM classification in organic, inorganic, and eutectic [35]

Chapter 2

Description of the problem

Current research is being done on the melting PCM into rectangular cavities. Computational subtleties appear in Fig. 1. Simulation time is reduced by balancing the domain. In order to stay uniform, the temperature of the bottom wall is kept constant 343.15 K Though the walls are made from different materials, they are all built to be thermally shielded in the same manner. The Domain internal measurements are defined as: size, color, texture, and architectural style.: H x *W* i.e., PCM province in which H and W are the rectangular cavity 21 height and width, combined. by keeping the PCM concentrations In the 8 range of 0.1

constant H/W are chosen. (Table 1). The aluminum plates around the PCM are 2 mm thick. PCM material characteristics (paraffin C19-C20 [16, 17, 18]) with a phase change temperature 10 of 306.15-308.15 K and aluminum are listed in Table 2 There is no "PCM density" at the time of a zero-gravity zone. by dividing the temperature of the sample by the refluxed thickness, which gives you the pressure; for the phase-out method, it is calculated as :

$$\rho_{pcm} = \rho$$

$$\beta\times(T-Tpc)+1$$

Where υ is the fluid pcm density at the temperature of the phase change Tpc, and β is the coefficient of thermal expansion. Here, β = 0.001 K-1 Predicated on the ref . [19].

The liquid PCM's dynamic viscosity is:

$$\exp(A+\frac{B}{T})$$

where correlations are constant A = -4.25 and B = 1790 [20]. In addition, the thermophysical properties of the PCM in Table 2, including thermal conductivity k, phase change temperature Tpc, latent heat 20 L and specific heat cp.

CHAPTER 3

Procedures

Unsteady, non-laminar, and laminar fluid dynamics are a big deal in numerically modeling the heat and mass transfer process. We use the Navier-Stokes and energy equations, respectively. Also, the term "viscous flow" is irrelevant. as a mixture of enthalpy and enthalpy porosities [21, 22] The PCM is used to imitate the melting cycle in the vacuum chamber. Applying a simulation analysis to the PCM framework, the model can be drawn in two ways: refs. [23, 24, 25] obviously. Similarly, the equation describing the fluid flow and energy yields the following equations:

continuity:

$$\delta\,(\rho)$$
$$_{t} + \delta\,(\rho u\,)$$
$$_{i\,i} = 0$$

Momentum:

$$\delta\,(\rho u\,)\;(\rho u\;u\,)\;\delta\;u\;P\;g\;_{t\,i} + \delta_{j\,i\,j} = \mu\;_{jj\,i} - \delta_{i} + \rho\;_{i} + S_{i}$$

Energy:

$$\delta\;(ph)\;(\rho\Delta H)\;(\rho u\;h)\;(k\delta\;T)$$
$$_{t} + \delta_{t} + \delta_{i\,i} = \delta_{i\,i}$$

Whereρ, ui/→v and μ is the density, velocity/velocity vector, and dynamics viscosity of the liquid PCM, respectively. The pressure is P, the gravitational acceleration is g, and the time is t. The source of energy term →S for liquid PCM phase, given by:

$\to S = -A(\phi)\to v$

where A(φ) is the “porosity function” [26] and expressed as:

$$C(1-\phi)^{2}$$
$$A(\phi) = \phi + \varepsilon$$
$$3$$

where ε = 0.001 to avoid division by zero, and C = 1.0×105 17 is a constant spongy zone reflecting the microstructure of the front melting.

In addition, the definition enthalpy H is:

$$H = h + \Delta H$$

where, h is the specific enthalpy expressed as:

$$T$$
$$h = h_{ref} + \int \rho dT$$
$$c$$
$$T_{ref}$$

where href is the enthalpy of comparison at the appropriate set point T . the change of $_{ref}$ enthalpy (ΔH) due to the change in phase φL, i.e., ΔH = φL. φ is the liquid fraction during the phase change which occurs over a range of temperatures Ts < T < Tl , defined by: $\phi =$

$$0 \; If \; T < Ts$$

$$\phi = If \; Ts < T < Tl \; \frac{T-T_s}{T-T_{l\,s}}$$

$$\phi = 1 \; If \; T > T$$

Numerical models such as the one discussed in this article can be found in this entry . [27,28]. to give you an idea of how the two different ways in which PCM might be done, they have improvised ways of simulating PCM. results seem to have been arrived at by trial and error in a planned manner Shmueli et al.[29]. The entire framework's surface should be within the temperature range of 303.15 Kelvin. It's all done numerically without any obsessing about assumptions. This calculation is the starting point for the connection between external and internal pressure. The PRESTO plan is used to handle momentum and energy, while the quick adjusting system is accepted for pressure. The size and step have been picked based on an assessment of liquid independence Because of the 600000 grids and 0.1 mm of mesh, the calculations are carried out on a hexagonal coordinate system. Set the time step to at less than one fifth of a second, the quantity of iterations to zero.

Every next step is a privilege. when the grid size is decreased. Convergence is checked at each step by comparing the result to the convergence criterion of 10 to 5

CHAPTER 4

The prototype verification

First, some experiments are done in order to evaluate the The boundary element method of artificial intelligence is performed.[30]. In the rectangular cavity, Finned vertical heating wall's artificial convection is examined. The inside and outside dimensions of the rectangular test cells, which contain n-octadecan with a temperature change of 300.7 k, are equivalent to five aspect values, and the horizontal equidistant length of a fine and five fins is equivalent to 200 mm in each case. Vertical heaters are maintained at a constant temperature of 60 degrees Fahrenheit. Different walls are insulated with Styrofoam and are used for each cavity. Fig. 2 represents the liquid profiles versus time for present and future examination In figure 2, the predictions and actual values overlap, suggesting that there is a reasonable agreement between the two estimates. Due to this, the current numerical model, the validation of the model seems plausible.

CHAPTER 5

Discussion and results

Also significant are the Nusselt and liquid fraction, as the ratio of flow and transfer of heat has an impact on the rectangular cavity. It is white, plastic, and flaky at room temperature, even though it's a molten compound at that temperature by , where $\frac{V_l}{V_c}$

V is the volume of liquid PCM, and Vc is the volume of rectangular cavity. Fourier $_l$ number, Fo, is peruses

$$Fo = \frac{\alpha t}{H^2}$$

where α is thermal diffusivity coefficient of liquid PCM, and the time t. Time variation of the liquid ratio for various aspects is shown in Fig. 3 It exposes all properties regardless of order and/exposure proportion to each for a variety of stress deformations. The results of the aspect ratio in analysis show that melting rates are greatly impacted by the depression's dimensions. It appears that shorter level dividers are more efficient than extended periods. Additionally, in the presence of all vertical natural convection, heat transfer to the surface is done directly, which enhances the absolute heat transfer from the heated surface.

Nusselt number, Nu, which has space on both sides of a different-form algebraic capacities, is characterized as:

$$Nu = \frac{U_{avg}H}{K_L} = \frac{q'}{\Delta T} * \frac{H}{K_l}$$

7

where U_{avg} The average heat transfer coefficient between the heated wall and the liquid PC is calculated by adding together the length of the separation between the top of the heated wall and the liquid, the depth of the depression, and the height of the separation. In room temperature change cases, ΔT The difference between the temperature of the wall and the temperature of the phase change Thermal conductance KL refers to both liquid PCM thermal conductivity and mean heat flux from the heated wall. Nu is shown in Figure 4 for the most part, as the Nu ranking goes up, the majority of estimations will be correct It is interesting to note that as the wall began to melt, the temperature differentiation on the walls lessened. Also, due to the great aspect ratio of 10, the wall boundaries are behaving isothermal as well. Convection occurs regardless of whether the walls are thin or thick over time and tends to occur naturally as well. The stream flows vertically up the walls, along the neighboring the liquid interface slope The flow is taken from the base to the surface, where it gets hot and then cools off as it rises. With time approaching quasi-steadiness, the N is decreasing until a quasi-steady level is found.

The contours of strong liquid fraction 0.3 and 0.7 are found in Figure 5 and 6, respectively. It is observed that the rise in aspect ratios are less extreme. Depth of field is significantly influenced by the large hole width of the tunnel. However, when the melting fraction is 0.7 as shown in Fig. 6, the same structures emerge. That said, however, the front melts are not at the same angles. Natural convection can be identified in Fig. 6, as occurring with the ratio of 0.1 as warm and cool (liquid). In fact, conductivity is the most important for 0.1 because of the small base-length. Due to its extreme height, the most dangerous force of natural convection is directed vertically. As the melting progress of thermal stockpiles grows, their ratio also increases.

Conversely, the height of the melt layer increases along the symmetric line from the vertical wall to the ceiling. The lower part of the PCM starts to melt earlier than the upper part This has been observed during tests As a result of natural convection, warm liquid rises to the top of the warm ascension zone and a flow of liquid is created, and replaced. Conduction occurs between the hot inner wall and the cold PCM. The planned outcomes present a thin and unlikely design for the rectangular pit located close to the liquid distribution interface (Fig. 6).

CHAPTER 6

Final thoughts

The aspects of rectangular-base heated pits are also studied in this examination. The paraffin-like melting marvels (C19C20)as well as PCM are studied The results agreed with the analysis. This confirms that aspects are crucial to heat moves. He or changed the aspect ratio of the uncovered rectangular pit's melting rate. In the liquid PCM distribution, natural convection is the sole source of the lateral, rising currents of liquid. Also, the present outcomes give not just technical data into the PCM system, but a greater understanding of the fundamental natural convection and heat transfer processes in rectilin heat storage systems. As the statistics show, the primary Heat transmission mode is heat convection from the liquid to the gas phase. However, at later points in the melting process, convection gains the upper hand over conduction. Melt separation shut off the PCM upstream opens up to the most expensive emotional display of the convection flows.

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Table 1

Sores with various anamorphic lenses of 0.1 to 10

Anamor phi c lenses	0.1	0.125	0.167	0.25	0.5	1	2	4	6	8	10
H(mm)	3.5	4	4.5	5.5	8	11	16	22	27	32	35
W(mm)	35	32	27	22	16	11	8	5.5	4.5	4	3.5

10

Table 2

Paraffin characteristics and aluminum

Materials	Density /k g m^{-3}	Thermal conductivity /W m^{-1} K^{-1}	Heat specific /J k g^{-1} K^{-1}	Thermal gradient phase /K	Slow heat /kJ k g^{-1}	Dynamic viscosity/ kg m^{-1} s^{-1}

Paraffin liquid solid	750 850	0.15 0.22	2630	306.15-308.15 -	176000 -	0.00493
Aluminum	2719	202.4	871	-	-	-

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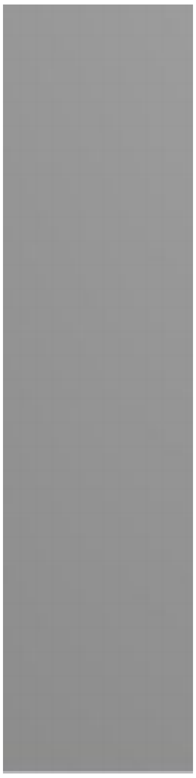
SKETCH 1



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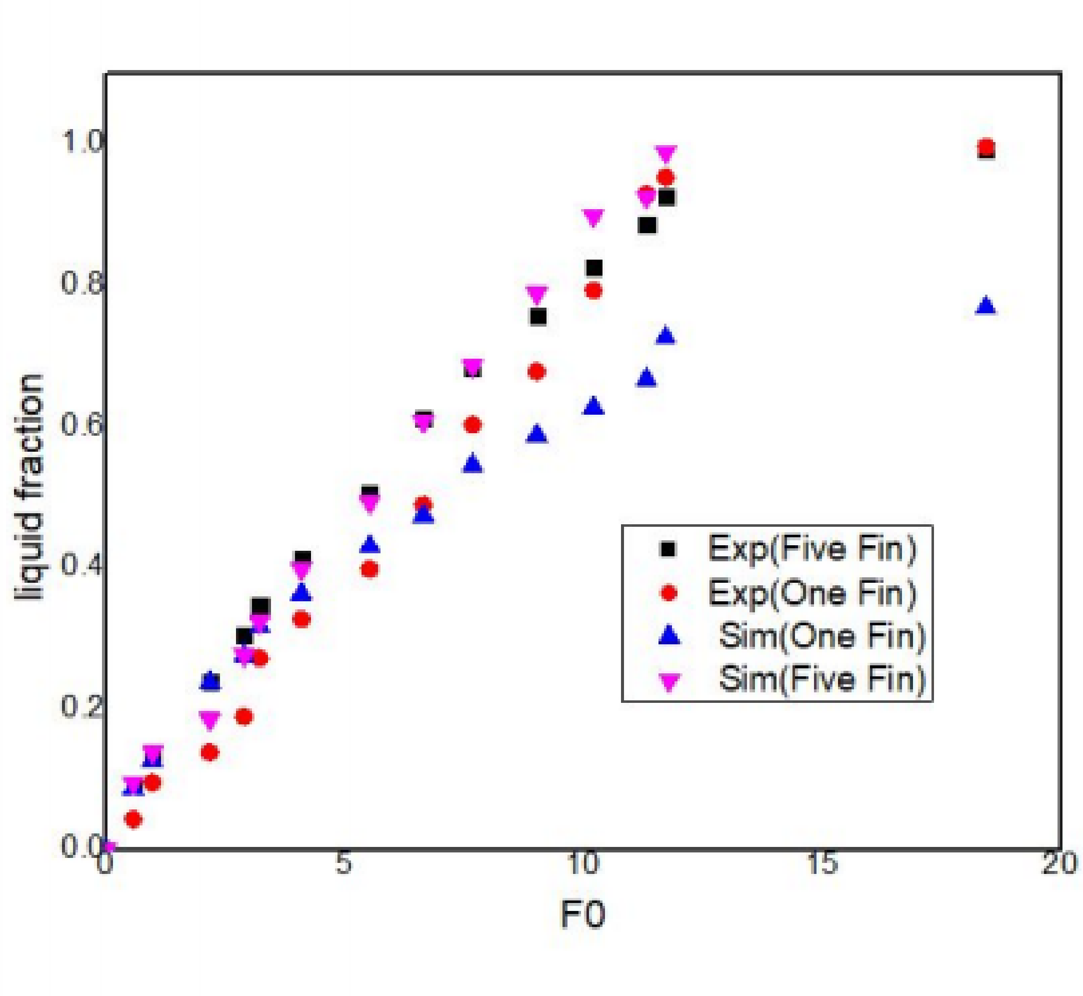
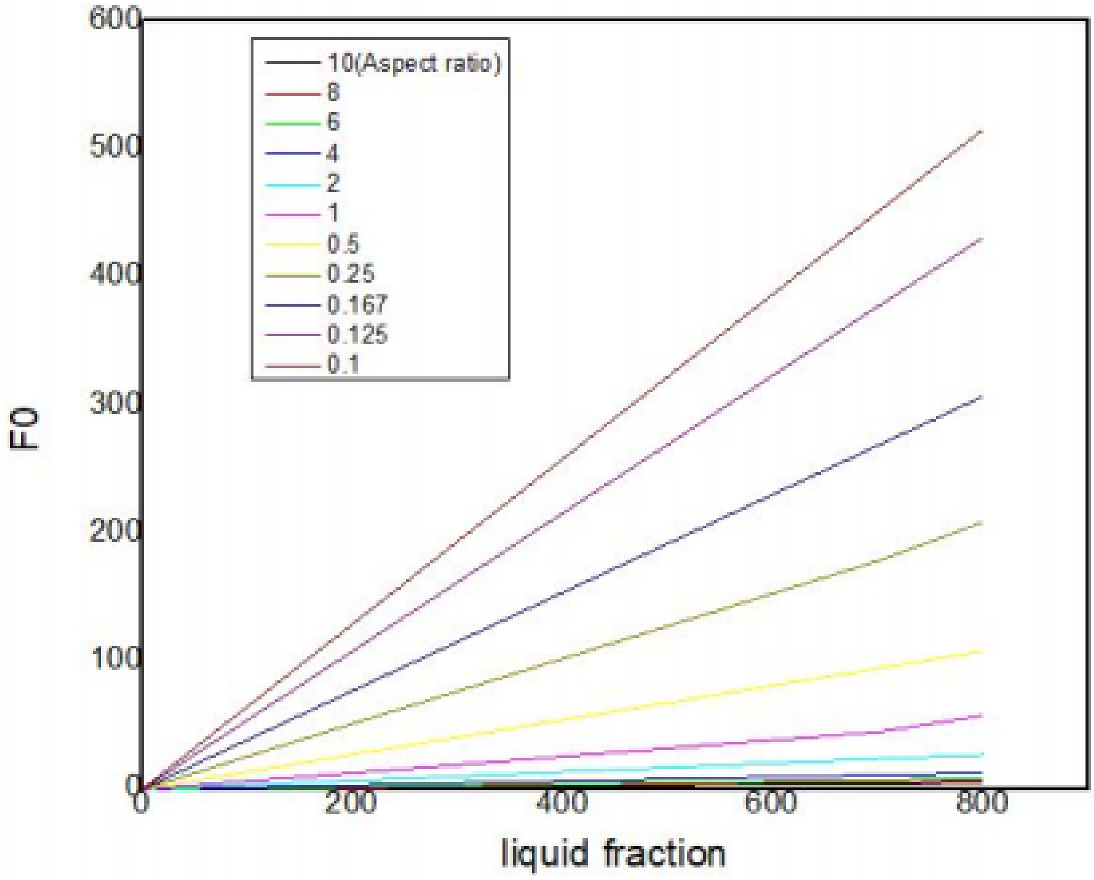
SKETCH 2



liquid fraction
F0
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
Exp(Five Fin)
Exp(One Fin)
Sim(One Fin)
Sim(Five Fin)

13

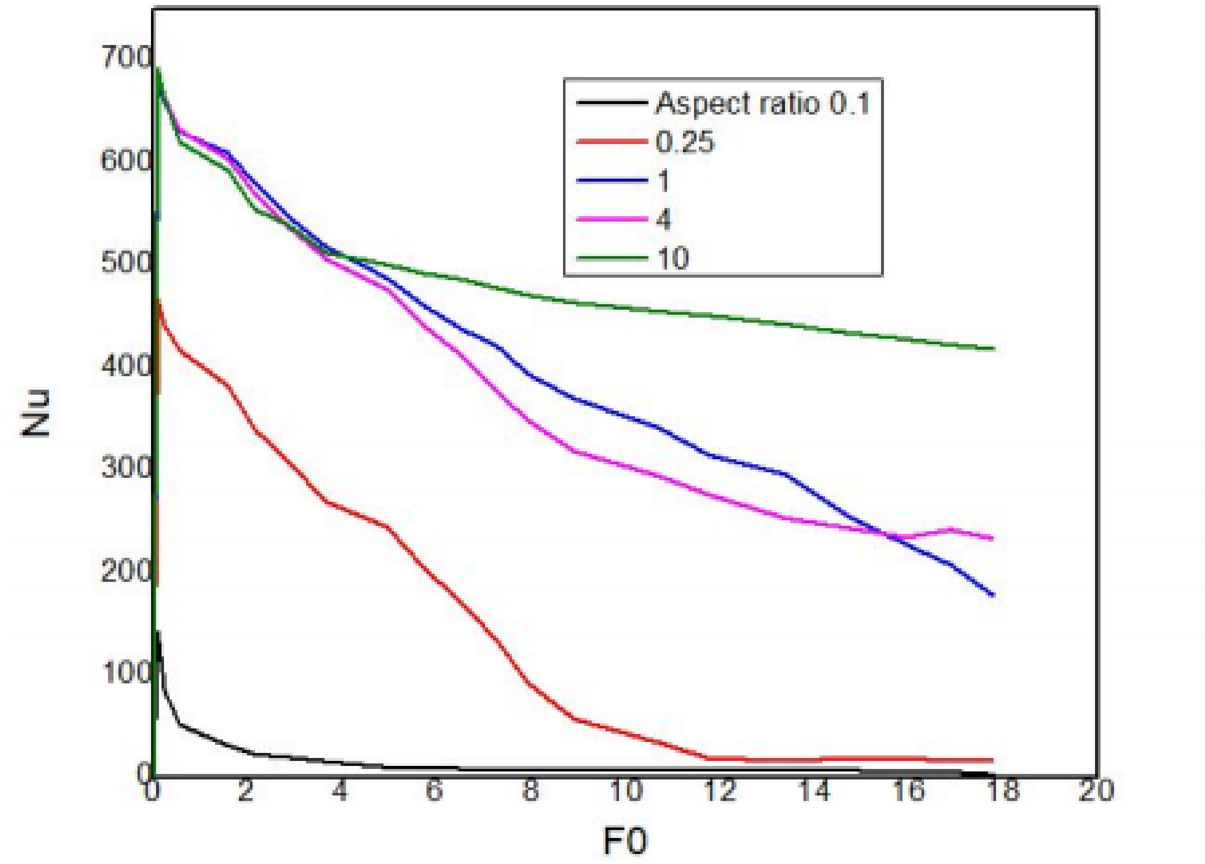
SKETCH 3



10(Aspect ratio)
8
6
4
2
1
0.5
0.25
0.167
0.125
0.1
F0
liquid fraction
0
100
200
300
400
500
600
0
200
400
600
800

14

SKETCH 4



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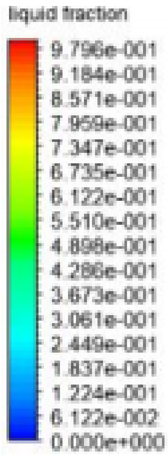
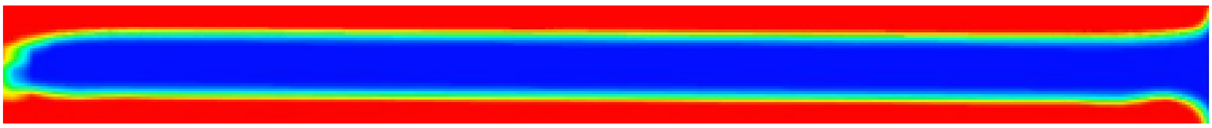
SKETCH 5

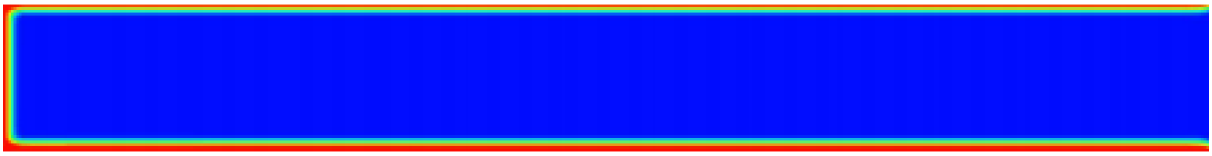


Aspect Ratio

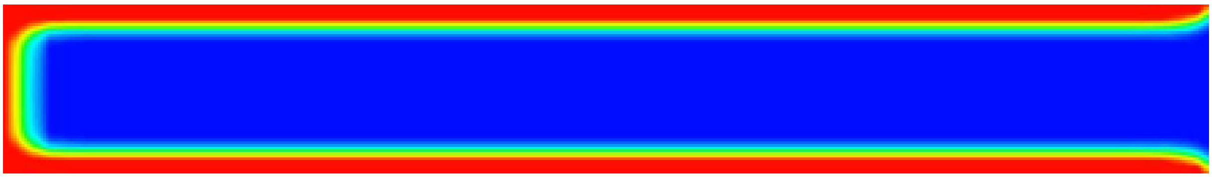
0.1



0.125

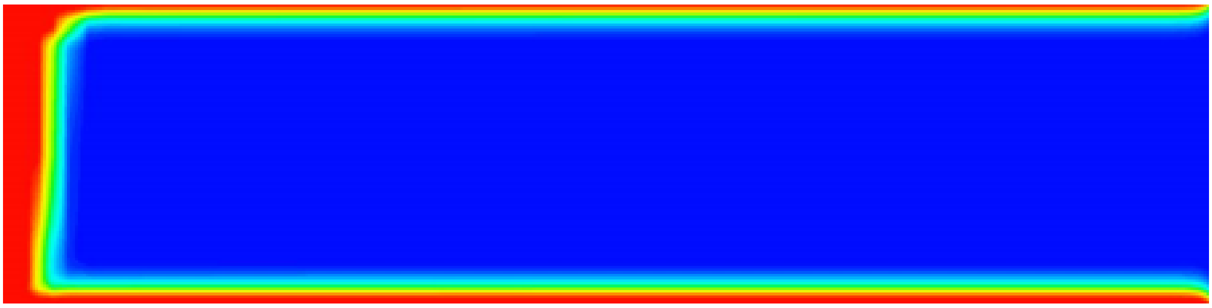


0.167

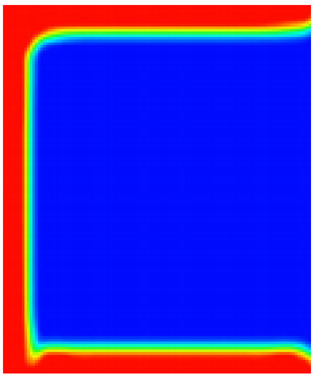


16

0.25



1



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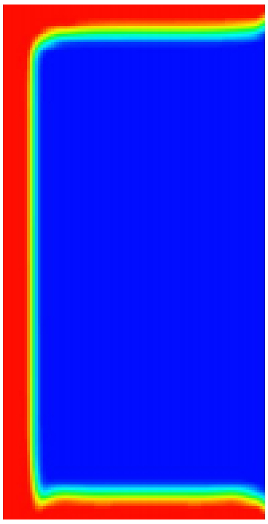

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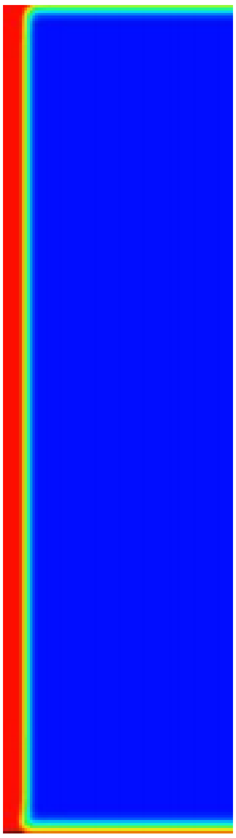

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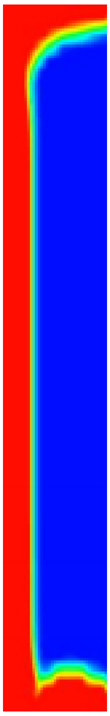

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8

10

SKETCH 6

Aspect Ratio 0.1

0.125

0.167

20

0.25

2

21

4

6

PUBLICATIONS

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