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Thermal Analysis of Heating Pad Application Using Computational Fluid Dynamics

Nurul Izyani Kamarudin[1], Nofrizalidris Darlis[1]*, Norrizal Mustaffa[1], Norrizam Jaat[1], Syafiqah Ruqaiyah Saiful Azam[1], Khairul Nizam Mustafa[2], Muhamad Mohshein Hashim[2]

[1]Department of Mechanical Engineering Technology,
Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia,
Jorak, 84500 Bukit Pasir, Johor, MALAYSIA

[2]MY Flexitank Industries Sdn. Bhd,
Perusahaan LPK Fasa 3,
08000 Sungai Petani, Kedah, MALAYSIA

Email: *nofrizal@uthm.edu.my

Abstract: Undetermined coefficient method is proposed to derive higher order schemes for solving Burger's equation. The undetermined coefficient method was proved that some well-known schemes can be derived although their original derivations are different from each other. In this proposed method for solving the 1-D Burger's equation, stability and accuracy of the new scheme are analyzed by comparing the computed results with exact solutions of one-dimensional pure convection equation. Effectiveness of the proposed method is also analyzed by comparing with the results using other schemes. This scheme was applied to simulate hydraulic jump in one-dimensional flow with different ratios of initial upstream water depth to downstream one. From the obtained results, it shows that this new scheme has the ability to simulate a moving hydraulic jump well.

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*Corresponding Author:

Nofrizalidris Darlis,
Department of Mechanical Engineering Technology,
Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia,
Jorak, 84500 Bukit Pasir, Johor, MALAYSIA
Email: nofrizal@uthm.edu.my

1. Introduction

Heating pad was a mechanism for heating element and used for heat the liquid inside the flexitank to completely liquidise. Generally designed as a heating pad and placed the entire length and breadth of the container. The heater pad is placed below the flexitank to allow maximum exposure to the heat source. The average time it takes to heat a container of liquid is about 4-6 hours but it depends on the temperature and specific heat of the actual liquid [1]. A flexitank is one of storage equipment for liquid such as water or oil, usually, they used many types of products for the safest, most innovative, effective and economic way to transport bulk liquid items from one place to another [2]. In some country with lower temperatures, a liquid will be freeze in some way. So, the heating pad is very necessary to dilute the liquid to facilitate the discharging process. To reduce the time taken, some research on critical thermal for heating pads need to be conducted. The aim of this study is to analyse the thermal efficiency of heating pad using numerical method. The numerical analysis of heating pad geometry can be performed using SolidWorks Flow Simulation rather than using experimental method thus, save cost and time to conduct the experiment.

1.1 Heating Pad

The most significant factor in the heating pad system was developed engineered to safely heat highly viscous products to achieve the viscosity levels required to discharge from a flexitank. Heater pads provide a safe and efficient way to lower the viscosity of a product and ensure that liquids can be pumped at the destination. That steam is properly discharging from the outlet tube and slowly increase the steam pressure into the heater pads [3]. Besides that, the different inlet pressure of heating pad can increase on the temperature and take time to melt the liquid.

1.2 Thermal Properties of Heating Pad

Thermal properties are those of materials which are related to its heat conductivity. In other terms, there are the properties that such a metrials exhibits when heat is applied towards it. Thermal properties include part of a huge issues of material physical properties. Thermal properties are properties of a material that determine how it relates when subjected to heat or heat fluctures, as shown in Table 1.

Table 1 - Thermal Properties

Property	Value
Material	EPDM Rubber
Density	0.9 kg/m^3
Specific Heat	1800 J/(kg*K)
Conductivity Type	Isitropic
Thermal Conductivity	0.29 W/(m*K)
Melting Temperature: • Temperature	432 K

1.3 Thermal Performance

Thermal energy of analysis is a complexes task that usually require the use of large theoretical equation are certain system. There is not easy to simplified natural or forces convection, phases change the phenomena and radiation heat transfer. A considering their interaction with the other parts of system under studies. Therefore, most of the engineer and researchers in the thermal field turn into computational models. It's also tests benches that can help them understand all the processes [4]. There are three different types of heat transfer: conduction, convection and radiation. A temperature difference must exist for heat transfer to occur. Heat is always transferred in the direction of decreasing temperature. Temperature is a scalar, but heat flux is a vector quantity. A conduction is occurring in stationary material as the result of the vibration of atom or the molecules in material. It is governed by Fourier's law of heat conduction, which in one dimension is written as simply stated the heat flow per unit area is proportional to the negative of the temperature gradient. The proportionality constant is called the thermal conductivity, and it has units of Watts/meter/K or Btus/ft/*R. The thermal conductivities of typical materials vary widely by material, and it also depends on the temperature of the materials [5]. Convection is the term used for heat transfer mechanism, which takes place in a fluid because of a combination of conduction due to the molecular interactions and energy transport due to the macroscopic (bulk) motion of the fluid itself. In the above definition, the motion of the fluid is essential otherwise, the heat transfer mechanism becomes a static conduction situation. When the term convection is issued, usually a solid surface is present next to the fluid. There are also cases of convection where only fluids are present, such as a hot jet entering into a cold reservoir. However, most industrial applications involve a hot or cold surface transferring heat to the fluid or receiving heat from the fluid [6]. A radiation differed from conduction and convection of heat transfer mechanisms. The sense that does not requires the appearance of the material medium to occur. There is energy transfer by a radiation a occur at speed of the light and suffers no attenuations in a vacuum. The radiation can be occurred between two bodies separated by a medium colder than a both bodies [7-11].

2. Methodology

SolidWorks 2019 was used to create a computational domain of heating pad. The design was being simulated using SolidWorks 2019's Computational Fluid Dynamics (CFD) flow simulation. Next, the model's steady state established. Following that, in the setup step must be set. Finally, the flow simulation can be run and the data established as shown in Figure 1.

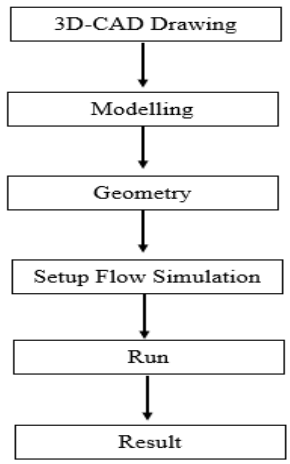

Fig. 1 - Flowchart SolidWorks Flow Simulation Setup

2.1 Geometrical Modelling

SolidWorks 2019 was used to create all of model for simplified heating pad simulation and SolidWorks 2019 also was run with the critical thermal using Flow Simulation. A simplified model is simulated to study the heating pad performance via different inlet with different thickness as shown in Figure 2.

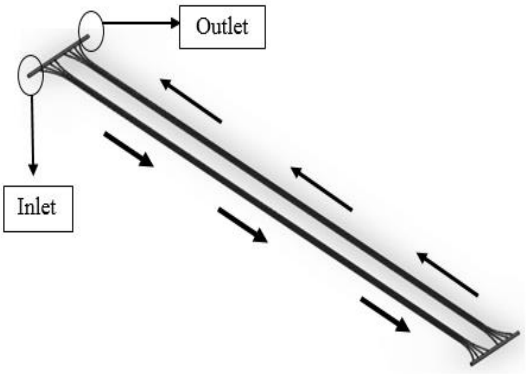

Fig. 2 - Simplified Heating Pad

2.2 Design of Heating Pad

Based on Figure 3 (a), (b) and (c) shows the different thickness diameters which are 3mm, 4mm and 5mm on a heating pad. The different thickness diameters used between the heating pad and flexitank to analyze temperature distribution. However, the effect of temperature distribution was increased with difference bar which are 1 Bar, 2 Bar, 3 Bar and 4 Bar.

Fig. 3 (a) - Design of Heating Pad 3mm

Fig. 3 (b) - Design of Heating Pad 4mm (Benchmark)

Fig. 3 (c) - Design of Heating Pad 5mm

2.3 Geometry Meshing

The mesh is a term that refers to the process of representing a model into a finite number of elements. It is also the most critical step in this analysis of a flow simulation. The mesh quality controls the correctness of the outcome. SolidWorks is used to mesh the model. Figure 4 mesh of computational domain show how the mesh is formed. The models were meshed using the previous model approach. The local mesh generation is used for the global meshes as shown in Figure 4.

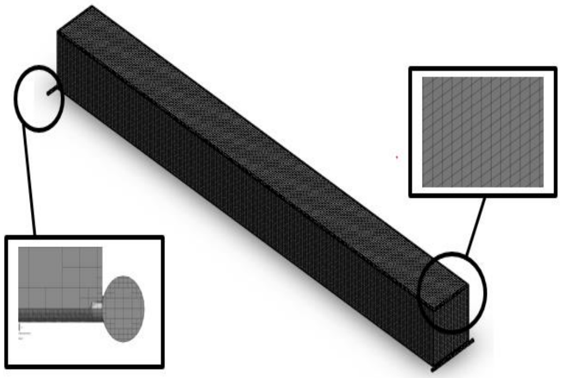

Fig. 4 - Geometry Meshing

3. Results and Discussion

3.1 Mesh Quality Validation

Mesh quality is playing an important role in an accuracy of the result. This software used an important to examined the measure quality of element the mesh [8]. This refined the mesh has a difference converged solution to the rough mesh to its can be seen the goals value changing and convening on new value. Once is fully converged; the mesh is refined again until the number of refinements specified has been reaches [8]. Figure 5 shows a mesh quality of the pressure vs level refinement. Based on this figure, there are slightly significant change of the pressure with an average relative error below 1% in pressure from level refinement between 6 to 7. Thus, a mesh quality of that geometry was achieved.

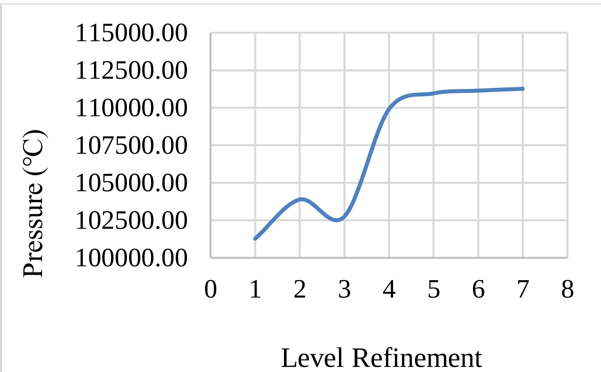

Fig. 5 - Mesh Quality Validation

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3.2 Temperature Distribution in Heating Pad

Effects of temperature distribution can be seen in Tables 2 and 3 and from that, the difference in temperature distribution was increased with difference bar which are 1 Bar, 2 Bar, 3 Bar and 4 Bar. Table 2 shows the contour of temperature distribution at the inlet of the heating pad tube for different inlet pressure. It can be seen that the contribution of inlet pressure has a great influence on heat distribution in the heating pad tubes. Given the results obtained, uneven distribution of temperature contour in the heating pad tube. Generally, it is clear from the contour displayed in figure 3.2 that the colour of the red contour in the heating pad tube clearer can be seen for 3 and 4 bar. Next, by observing the colour contour, the colour of red clearer can be seen on the contour for the 3bar. Followed by the 4bar, the appearance of colour red contour become clearer rather than 1 and 2 bar. This indicates that the red colour represents the heat while the blue colour represents the initial/ cold. This shows that increasing the inlet pressure will increase the temperature inside the heating pad tube since the red colour appearance clearer can be seen at the inlet pressure 3 and 4 bar while 1 and 2 bar the red colour can be seen with not much.

Table 2 - Temperature Distribution in Heating Pad

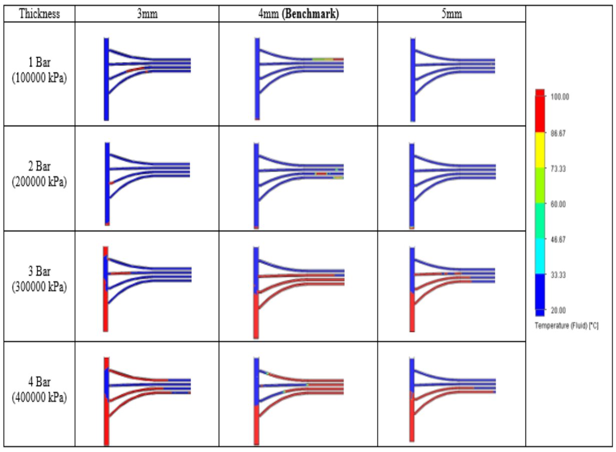
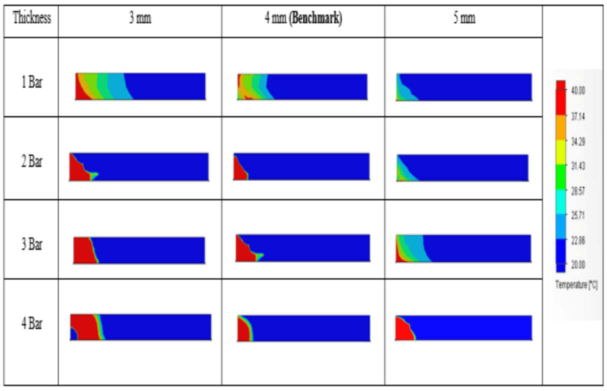


Table 3 - Temperature Distribution on Flexitank



3.3 Temperature Distribution on Flexitank

Table 3 illustrate the temperature distribution contour and Table 4 indicate the maximum temperature of flexitank for different thickness of heating pad tube which is 3 mm,4 mm and 5 mm, respectively. At the condition of 1bar inlet pressure, 3mm thickness tube of the heating pad shows the red colour clearer can be seen rather than 4 and 5 mm the thickness of heating pad tube. The same goes for the increase of the inlet pressure, the red colour clearer obviously can be seen at the thickness of 3mm of the tube heating pad. The red colour of the contour represents the higher temperature while the blue colour represents the room temperature. This situation shows that between three designs of different thicknesses, the thickness of 3mm is more contribute to the enhancement of the overall temperature distribution. In a nutshell, decreasing the thickness will increase the temperature distribution on the flexitank.

3.4 Maximum Temperature

Figure 6 of temperature maximum vs pressure are the value of temperature maximum to show the heat transfer from the heating pad to the flexitank through the inlet to the outlet by using the heat source which is steam. Next by observing the temperature maximum vs pressure, the colour blue clearer can be seen on the point from the middle of the parameter inlet pressure 1 bar till 4 bar in thickness tube 3 which is 6.6mm. Followed by the colour orange, the point of temperature maximum and pressure release at 1bar and 2bar but the point rise from 3bar to 4bar in thickness tube 4mm which is 5.6mm. The point of grey still maintains the rise at 1bar, 2bar and 3bar but the point in thickness tube is 5mm which is 3.6mm high-rise at 4bar.

Table 4 - Maximum Temperature

Pressure	Thickness Tube		
	3 mm	4 mm (Benchmark)	5 mm
1 Bar	47 °C	38 °C	33 °C
2 Bar	50 °C	40 °C	38 °C
3 Bar	55 °C	52 °C	40 °C
4 Bar	58 °C	55 °C	50 °C

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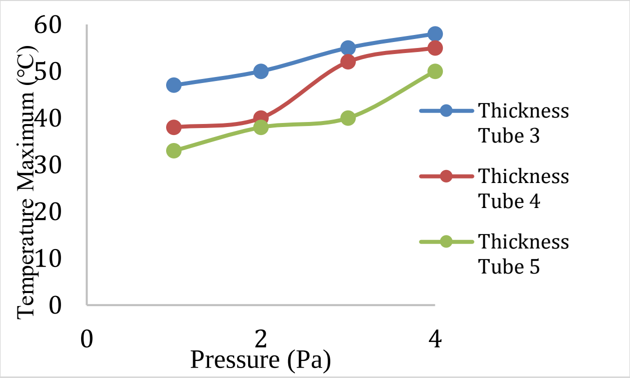

Fig. 6 - Maximum Temperature Vs Pressure

3.5 Pressure Losses

Another factor is pressure losses that affect the flow performance. The previous study has reported that the pressure losses between 100000 Pascal to 400000 Pascal was the best choice and the previous study stated that the lowest flow could be the more pressure losses in the heating pad. Hence, the pressure losses lower below than 400000 Pascal are used as a reference in this study. Figure 7 shows the increased pressure losses at each of 1 bar till 4 bars in thickness tube 3 mm, 4 mm and 5 mm. In the present study, the result shows that it was contrary to the previous which the inlet starts at the around of surface tube. These contrary results might be occurred due to the geometry of the heating pad that does not support calculating the geometry of the heating pad in its geometry as a previous study even shows that the simplified geometry the similar. In summary, all the pressure losses of the heating pad do not exceed the preference value which is between 100000 Pascal to 400000 Pascal and this shows that the geometry design of the heating pad is feasible as the different pressure arises between each bar are approximately around less than 1 percent.

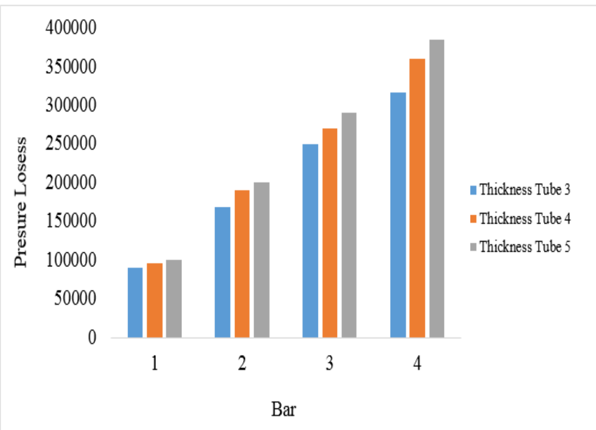

Fig. 7 - Pressure Losses

4. Conclusion

A flow heat distribution of steam inside the heating pad had been studied with a different parameter of the inlet tube. The geometry design of this simplified heating pad. In conclusion, numerical simulation of different inner diameters of the heating pad was conducted and heat transfer of the heating pad was analysed. The comparison of different thickness tube heating pad which is 3mm, 4mm and 5mm with the previous research had been investigated in this present study. The result shows that the steam arranged at the inside of the heating pad can greatly improve the heat transfer as it improves the pressure distribution and temperature distribution. The finding also indicated that the heat transfer of the heating pad is good for better performances during the pressure increases of calculated unevenness, the geometry of the heating pad can make an increased pressure compared with the simplified in which the middle-pressure inlet flows the heat transfer. The 3-dimensional design of the heating pad was analysed by using numerical simulation which is an efficient and feasible method of analysis. This analysis was carried out based on computational fluid dynamic theory. The result shows that three main assessment measures are heat distribution, pressure distribution and pressure losses of the heating pad, the geometry heating pad follows these previous design requirements.

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