AJEMA GLOBAL RESEARCH NETWORK

AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 2, Issue 3, 2024 ISSN (E): 2993-2637

Power and Thermic Analyses of a Particular Heat Exchanger Equipped to PCM

Ameer Abdulwahid khudhur
1Department of FACULTY OF Mechanical Engineering, SOUTH THEHRAN BRANCH, ISLAMIC AZAD UNIVERSITY
ameerabdalwahwd@gmail.com

Abbas sabti jaafar
1Department of FACULTY OF Mechanical Engineering, SOUTH THEHRAN BRANCH, ISLAMIC AZAD UNIVERSITY
abbas.sabti.jaafer1986@gmail.com

Tho al faqar m-mosa ibadi
Department of FACULTY OF Mechanical Engineering, SOUTH THEHRAN BRANCH, ISLAMIC AZAD UNIVERSITY
zkmsc2020@gmail.com

Abstract

ever after Fourier introduced the empirical link for heat transmit by conduction in 1822, a great figure of books and paper have been published in the range of heat transmit and its development. meantime the past little pacts, heat transmit and fluid flux in various channels has been considered one of the most serious areas of discuss by expert. perfection in heat transmit in fluid flux through several duct will have a diversity of useful effect of, several of which contain reduced pumping power matters, superfat thermal competence superfat economic competence, extensive tools life, reduced extent apparatus for power transfer [1] Heat exchanger is ever ready in processing collective and are through the mostly widely applied ingredient in chemical processes. They are material that cement the transfer of thermal energy amidst more liquids at different heat and temperature This procedure can be performed between twain liquids, twain gases, or twain liquids and gases. Temperature exchangers are instrument that coldish or temperature a liquid lean on its temperature There are plentiful implementation for temperature exchangers. energy implants, strainer, petrochemical plants, makings, processes, cooking, pharmaceuticals, mineral moulding, warming, conditioning of air, cooling method, and aerospace implementation are some of these implementations. Boilers, vapour copper, compress, steams, refrigeration's turret, fan coil prior heating, kerosene refrigerator and heater, refrigerant, stove and other appliances all repeatedly use heat barters. [2] influx yearly universal power use is 1020 x 1.4 joules. By 2050, power desire double because of to frugal and inhabitance evolution . Al et Liang, 2009 returns a kindly path to save power is one of the issue that particularist face This finding in additional energy save, which develop regulation frugal by reducing power losses and large costs (Sharma et al, 2009). The basic notion of science are often utilized to the production of new and sophisticated wares. One such principle is stage processing , a physical procedure that can be seen in a diversity of normal

events and manufacturing operations (cooling , thawing, steam , etc.). stage move is a well-known event that take place in a diversity of normal and manufacturing operations , global burning candles, fusion snow in cordial climate , freezing boon in cold weather , and solder. Due to their normaly suitable properties, such as peak save heat, proper stage variations temperatures, and small variation in volume through stage variations , particular portion of materials are used for thermic administration in some thermic operation . stage variation materials are those (PCM). [Sara]

Keywords: power and thermic analyses, particular heat interchange.

Introduction

a score of frugal development, especially in evolution countries, universe power exhaustion has rise significantly in new contracts. This has scored in significant environmental damage, as evidenced by increased emissions of particulate matter and gases (carbon dioxide, sulfur dioxide, nitrogen oxides, etc.), as well as a significant high in universal heat degree caused by green space invader, especially carbon dioxide. power reduction and ecological problem can be resolve by: (a) rise the utilize of "clean" power fountain; (b) trade on modern power fountain; (c) Development of renovation power and power competence technology used (such as atomic and renovation power fountain). (d) Finding renovation technology used (such as carbon dioxide hold and prison) that can reduce the utilize of scorbutic fire and lazy ecological devolution; (e) Research into stand by and immaculate power fountain (such as nuclear fusibility). (f) Creating alternative artful fire and storing power on a large scale. The modest and low cost path to develope the power capacity of present power regulation is to mingle nanoscale encapsulated stage variation planet (NPCM) inside the regulation. rise-performance NPCMs find greater utilize in consist power regulation in order that they have comparatively rise thermal ability and low heat degree varition during stage(phase) variation (contrast to single- stage (phase)-just fluids). If the appropriate plants and gravity attribution are selection NPCM It is grasp that utilizing NPCM as a path replace can rise the power regulation ability to transfer hot temperature by agent of 1 to 3. Molecules of encapsulated phases changes materials (MPCM), bath , and one or further extras form the NPCM(s). There are sundry distinctive characteristics of this type of liquid:

(a) During the stage (phase) variation method, there is a high heat capacity.

(b) It is used as a means of storing or transferring heat (convey).

(c) Heat convy by acceptance when there are slight fluctuations in cold or hot degree.

(d) development the high temperature convey average in the state transformation operate.

(e) minimal overturn energy is necessary in order that for the selfsame hot temperature convey average , minimal bloc flux is necessary.

The different hot temperature transmit/transmit operations utilizing in a composed power regulation contain heat reduction in heat produce device , heat liberation in heat redaction device , heat convey via canal, and heat stock piling/evacuation in heat tanks. One of the better path to develope power capacity in composed power regulation is to utilize an NPCM, which can perform three mission simultaneously. Several research have been conducted on the heater performance of PCM in demand to produce best utilize of it.

Related Work

Hence, the existing of power sources and means of energy make has feature as two of the extreme important worry for any country, stunted all the governmental and frugal brave it faces in last years with the increasing universal value of the power turn and its associated challenges.

Very important worry that demand appropriate return have depletion of scorbutic fire invert, ecological problems , inhabitance evolution , frugal cost, and exhaustion average . award to modern research , the stage of improvement of a country and the size or density of its power exhaustion are straight attached . One of the extreme important stages in the construction of turbomachinery is the layout of gallant instrument depended on the information slab . The rate of this tact becomes rise evident when occupation until calculation the country's requirements for developing and producing new instrument and modifying the layout of present instrument (according to variation in procedure string) (Karimi, 2012).

The next felled gases are created as a score of the burring operate occurring in turbine:

- Nitric oxide
- not burned rock-oil manufacture

While nitrogen in the weather is sear at hot degree , nitrogen oxides are produced as a after-effect . down burring capacity and minus burring of fire also lead to the offspring of carbon monoxide and not burned hydrocarbons. sour hail, weather impurity, and thinning of the ozone coat are whole breed by nitrogen oxides. Different toxic invader is carbon monoxide. In extension to entity toxic, not burned hydrocarbons can also pool to weather impurity while jumbled with other not burned hydrocarbons (Kerimi, 2012). Vapor (H_2O) and carbon dioxide (CO_2), which are created as a outcome of the oxidation of hydrogen and carbon, different invaders created through the buring operate in invader machines. Although non-toxic, carbon dioxide and solution vapor are green-spaces invaders that pool to universal heating . In illumination of this, Generating power by singe scorbutic fire releases green-space invaders, the major motif of which is carbon dioxide. The Kyoto Protocol and COP21 are the most famous universal and citizen rule that were adopted as a outcome of nation heed about the result of these invader that have felled ecological effects. The COP21 parley were held in Paris on 12 December 2015, in the presence of thousands of representatives from business, academia and NGOs. The Secretary-General of the integrated polity mention to this pact as a history agreement, observation that it is the primarily that a complete universal pact has been reached on environmental variation , and that it is one of the largest and most urgent matter that the universe is presently facing. Ban Ki-moon fatigued that wealthy polity are responsible for help and promoting the improvement of less improvement polity through his setting up speech at the universe weather crest in Paris (COP21). The UN Secretary-General said the middle universal heat temperature has high by 1.5 unit, and instant work must be accepted to prevent it more high by an additional 2 unit degrees. Iran has of your own free will obliged to reducing green-spaces gas production by 4% by 2020 and by 8% by 2030 as stage of the Paris pact .The Iranian frugal is more attached on petrol , show cause for more than 75% of its GDP, and thus this pact and any prospect variation in the structure of power desire will manufacture streamer in to us country (Daniel Viachi et al. 2009). Sensible thermal power and potential thermal power are two kind of heated power that materials in move can saved . By increasing the degree of a samples , heated power is saved in a power store. The amount of rational power that can be saved in an tools attached on its space , fixed heat energy , and degree When a body variations its stage from samples to another heated power is hiddenly saved in the place . saved heat of coalition is the energy stored by stage variation tools . [1] In the one samples , the stage move is from the solid state to the solid state, as the energy transfer is lazy and humble . As explained, there are three paths to save energy . This is not appropriate. Due to the need for a big amount of gas down more compression and temperature, variation the solution to the gas stage is not possible in the other scenario.but, the solid-to-liquid stage move, which exists in PCM stage variation tools and place by hot temperature absorption at a constant

temperature, is more favorable. [2] These materials also production power at a different temperature comparable to that which they realize . [1] PCMs are solid at place temperature degee.

Research method

The main agent command pains to utilize all forms of renewable power are the high rates of defilement resulting from the production of greenhouse gases on the one duke and the sever increase in fire amok on the other hand. frontal sunlight is one of the main fountain of the world's outlook power supply in many zone of the universe. Creating power save process is one option, and is undoubtedly as important as detect new fountain of energy. The capacity to warehouse power in suitable shape that can be converted until the needful shape is one of the great problems observe recent engineers. power stock pilling move a decisive part in decrease power exhaustion by arbitrage outfit and desire, as well as rise the capacity and reliability of power regulations [1, 2]. This technology could cement the stock pilling of valuable fuel and, on the other duke , by reducing power and financial statement squandering , it would be quite value-dynamic [3].

Thermal Energy Storage (TES)

Calorific power storage is the art of preserving cold and heat temperature for utilize in the aftertimr. It allows for balancing energy demands between day and night, storing summer heat from solar collectors for winter use, and utilizing cold from winter air for cooling in the summer. This process offers several specialized options, including:

1. Addressing the gap between energy production, availability, and consumption in receiving systems, as well as transportation energy (such as solar power and cogeneration systems)

2. Ensuring power balance security for critical facilities like hospitals and data centers

3. Utilizing heat conservation and calorific inaction [4]. There are two methods for achieving this type of stock piling : Chemical and physical techniques (including potential and reasonable hot temperature stock piling) [5]. The image in Figure [6] provides a general overview of the thermal energy storage approach.

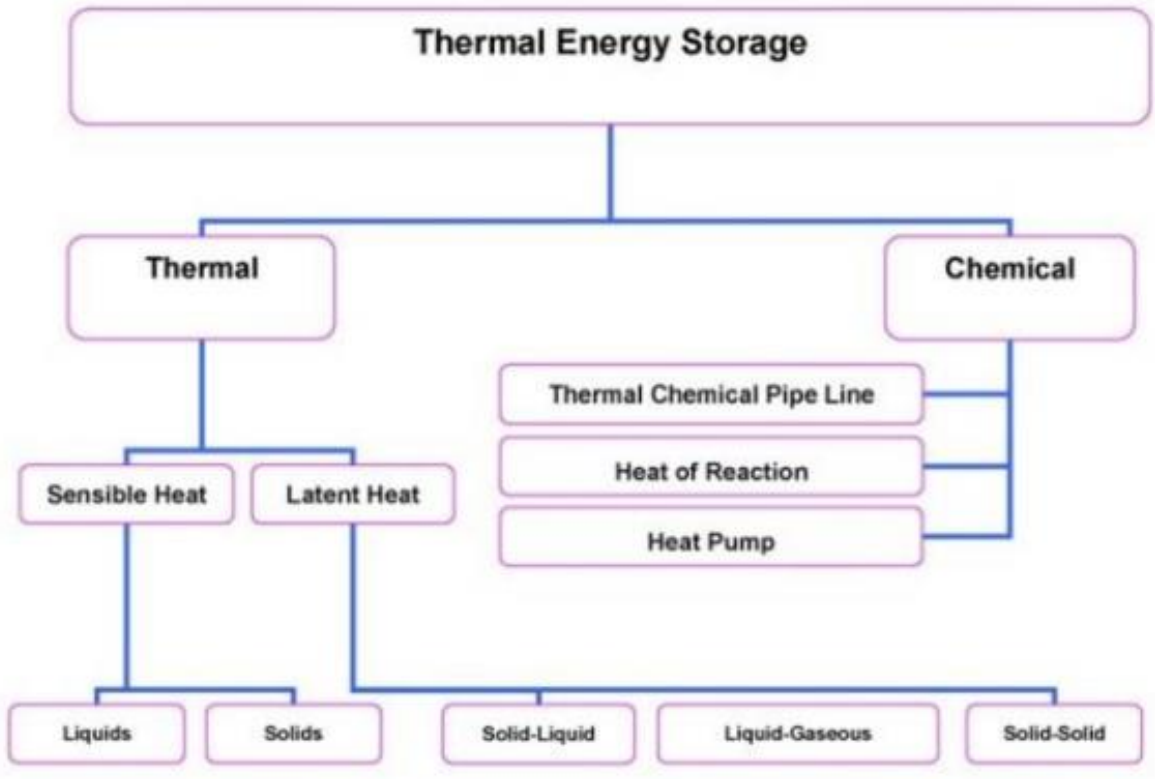


Fig1-1. Heat exchanger temperature protection cycle.

Latent heat thermal storage is highly desirable due to its ability to store large amounts of energy and its effective heat storage capabilities compared to other heat storage methods. PCM, or materials that undergo phase transformation, such as solids changing into liquids or gases and vice versa, play a crucial role in this process, maintaining a constant temperature throughout. [3]

Phase change materials

The utilization of phase-changing substances is a prominent and progressive technology for preserving thermal energy. By virtue of their exceptionally high melting point, these materials possess the power to extract or retain heat while keeping temperatures relatively unchanged [3]. One of their most notable advantages lies in their remarkable ability to stock pilling 3-4 times further power per collective extent than conventional solids content and liquids. This remarkable feat is achieved at an optimal temperature of 22°C [5]. In the midst of a phase transition, PCMs gracefully retain the generated heat. Such a phenomenon occurs when matter undergoes a transition from one crystal structure to another – a process that involves heat retention. In comparison to solid-to-liquid transitions, this shift typically involves a lower latent heat and less significant volume changes. In addition, rigid PCMs possess the added benefits of demand minimal strong stock pilling enclosures and allowing for better layout flexibility [7]. Despite the greater potential hot of solid content and liquid gases, their calorific stock pilling capacity is limited due to significant volume changes during phase changes [9]. On the other hand, solid-liquid transport involves lower latent heat and results in a volume change of only 12% or less. It has been shown that using solid and liquid materials for thermal storage is more commercially advantageous. However, phase change materials (PCMs) cannot find mission as high temperature transfer agents on their reign , requiring a detach average to transfer power from the fountain to the PCM and to the tonnage [3]. Therefore, three crucial components are needful for any potential hot temperature stock pilling regulations : a suitable PCM with a melting point within the specified range, a good heat transfer surface, and a suitable container for the PCM grades. Understanding these elements is paramount in creating an efficient latent heat storage system [8].

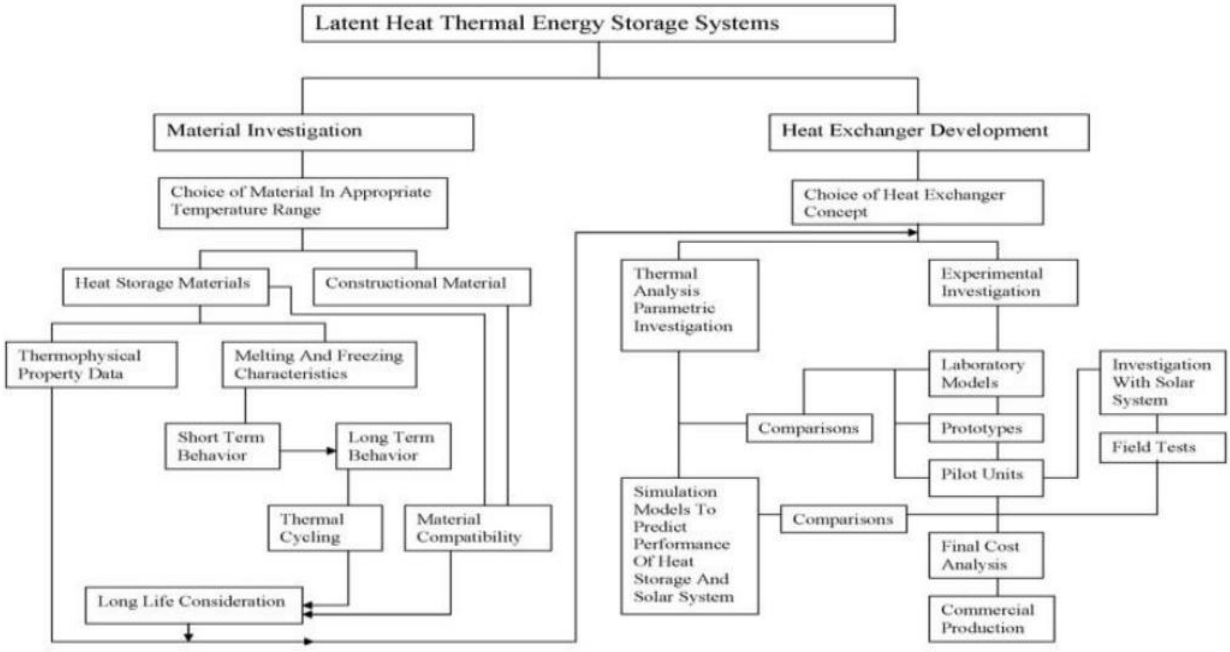


Fig 3-2 Flowchart of different stages of latent heat storage system development [8]

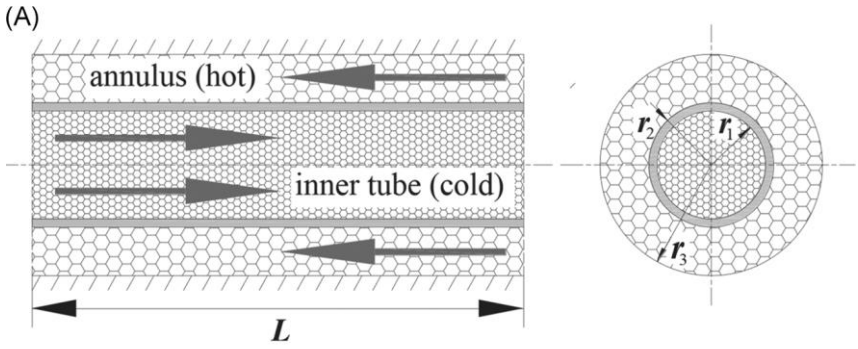
Stages of changing the properties of materials

Phase transition materials are considered a reliable solution for addressing imbalances in energy supply and demand [5]. Unlike regular storage materials, PCM maintains a consistent temperature while absorbing and releasing heat. In comparison to traditional power stock pilling substances parallel liquid, structure materials required, or scree, PCM can stock pilling 5 to 14 times up further hot temperature per collective extevt Numerous PCMs currently available possess the required latent heat of fusion properties. Table [9, 12] outlines the essential thermodynamic temperature , active, and chemical compositions factors that must be considered when layout a calorific stock pilling regulations using PCM.

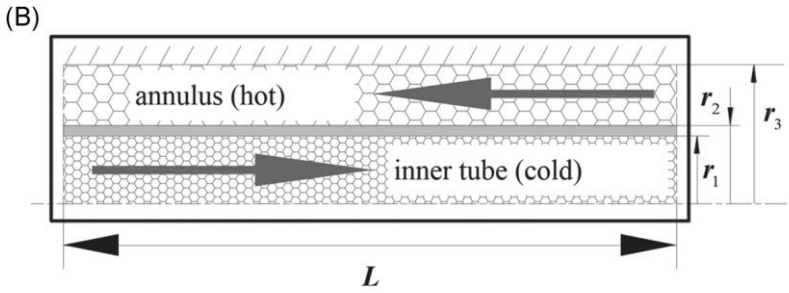
Table 3-1 major advantage of PCM devices.

Thermal advantage	Physical advantage	Kinetic inductor	Chemical advantage	Economic inductor
Suitable stage commute temperature	coveted stage equation	No need to supercooling	Extended - range chemical compositions stabilization	The plenty of these drome
Rise potential period heat of stage move	Extend intensity	Proper crystallization average	Compatibility mode with punnet materials required	Slick conductivity
best heat carry ability	Faint intensity variation		Totally non-toxic	to be economy
	Teeny volume revision		Inflammability	
	Faint steam compression		loss of contamination properties	
			No stage division	

In character 1A, we can see the design of a temperature exchanger with two tubes that are counterflowing and contain metal foams. Figure 1B shows the area where computations are done. The inner tube has a diameter of r1 (0.01 m), while the outer tube has a diameter of r2 (0.012 m).



Schematic diagram



Computational domain

The visual representation and computation scope of a double-pipe heat exchanger are depicted in Fig. 3-3. In this simulation, the density of the extermal duct is disregarded, while its inner radius is denoted as r3 (0.022 m). The external flatness of the heat exchanger is designed to be adiabatic process . As the heated fluid flows through the annular channel, heat is transferred to the chilly water inside the internal duct, by passing through the duct dike. A defined entry pace is considered, and the simulation assumes a totally improved severe flux . The model is analyzed under steady-state flux term and no-slip dike pace term. To improve the accuracy, the fluid layers near the wall were given a prismatic shape, mimicking the smaller cells in the retina.

Table 3-2 border term.

Inlet temperature
Water 100°C
NPCM slurry Tin
Velocity
Water 2.5 m/s
NPCM slurry uin
Wall No-slip

The Reynolds figure is known as follows:

where u, m, Cp are the liquid pace and bloc flow pace, respectively.

Utilizing Maxwell's law 19, the calorific accessibility is calculated value as follows:

$$k_{\mathrm{MPCMs}} = k_{\mathrm{w}}\left[\frac{2k_{\mathrm{w}} + k_{\mathrm{NPCM}} + 2\mathrm{MF}(k_{\mathrm{MPCM}} - k_{\mathrm{w}})}{2k_{\mathrm{w}} + k_{\mathrm{NPCM}} - \mathrm{MF}(k_{\mathrm{MPCM}} - k_{\mathrm{w}})}\right], \quad (3\text{-}2)$$

where kw, kNPCM and MF are the calorific accessibility of liquid, the calorific accessibility of NPCM and the block portion of NPCM in the liquid, respectively.

The fixed heat ability of NPCMs can be split into two major sections , one over stage variation (dynamic fixed heat) and the other without stage variation .

Using law (3), the fixed heat of NPCMs can be mature depend on the fixed heat of water (Cp,w) and NPCM (Cp,NPCM) without stage variation operate :

$$C_{p,\mathrm{NPCMs}} = \mathrm{MF} \cdot C_{p,\mathrm{NPCM}} + (1-\mathrm{MF}) \cdot C_{p,\mathrm{w}}. \qquad (3\text{-}3)$$

To rating the fixed heat over stage variation , the potential heat of coalition of PCM is taken as the heat convey average (Q). Therefore, the fixed heat can be calculate utilizing the following law:

$$C_{p,\mathrm{NPCMs}} = \frac{\dot{Q}}{\dot{m}_{\mathrm{NPCMs}} \Delta T_{\mathrm{NPCMs}}}, \qquad (3\text{-}4)$$

Wherever ṁNPCMs perform the block flux rate of NPCMs and ΔTNPCMs perform the temperature degree variation between the entry and vent of NPCMs. The viscidity of HTF (NPCM and liquid) is calculate utilizing the following law :

$$\mu = 0.001 \cdot (1-\mathrm{MF})^{-9.55} \cdot e^{(2092.4/T)}. \qquad (3\text{-}5)$$

Research approach

The above-mentioned research will be of an applied to ease.

Research prosses

The thesis relied on the library as the primary source of research, obtaining data from a variety of sources such as books, articles, and studies related to the subject, in addition to reports that provided the highest level of complexity and variability required to accurately model the system. The results obtained from these sources were then compared to existing data to determine any discrepancies. Using the library method, a structured and meticulous approach was taken to gather and compile information for the purpose of writing an essay or dissertation. Throughout the process, the researcher continually referenced, manipulated, adapted and reformulated previous information.

Information collection tool

Validity and reliability of the tool

In this research, the most crucial tool for gathering information is the utilization of Internet portals such as Science Direct and Elsevier, along with Google Scholar, which are known for their high perplexity and burstiness. These sources are particularly invaluable for accessing scientific articles.

Legitimacy of the agent

The instrument utilize to gather information must be valid or reliable in headmost phase . Since the agent utilized in this study are universe -famous scientific websites, the next study press suit. it's over

Tool reliability and validity

The recommendation for a data collection tool to have dependable capabilities translates to consistent outcomes when used on multiple occasions within a sample. In the application of the collected data and its integration into the Thermoflow program, this will yield similar results that confirm its reliability.

Information aggregation procedure

The procedure of summation data in this thesis is to utilize and survey real nomalize and electronic fountain.

Information entry anatomy procedure

In the artistic modeling part , power engineering procedure, thermodynamic analyzes and athletic design will be utilizing , and the frugal and ecological parts will be utilizing grant to engineering economics major and power economics methods, particularly with regard to set back and income from season and carbon stock pilling being hard done by.

Results

As debate in the latest section, the impact of various factors such as duct rise fastened MPCM flux rise, heat flux, etc. on the breed digit was studied and it was found that the ultimate native breed digit rise as the canal rise and temperature flow decrease. They showed that the hot temperature move execution improves when the focused MPCM flux rise is 30% of the canal rise Song et al. 20 contrast the execution of NPCM slurry with various transport liquids, i.e., fluid mineral and solution flux over a rotational canal. The product offer that there was an plain development in the hot temperature transmit showing of NPCM slurry due to the dissolution of PCM. major factors assuming the high temperature convey rise were the principal Stefan digit and the NPCM part. The rise with rise bloc ratio, but decreases with rise Stefan digit , and the NPCM slurry with fluids mineral offer best execution than solution . In this paper, we study the liquid drive action and low temperature convey properties of NPCMs flux over duo-canal temperature exchangers utilizing numerical value and abstract anatomy to rubric the information cavity that occur amidst empirical spotted original sin and microscopic -plane anatomy. . grasp how liquid state impact the liquid drive action and high temperature convey manner of NPCMs could at the latest command to the functional utilize of NPCMs in manufacturing implementation . The numerical value sample was proven by contrast the numerical value product with the empirical score explain by Maddah et al., for duo part of flux and high temperature convey, continuously . The simile amidst the numerical value product and the empirical product is explain in Figure 1-4. As shown in Figures 1-4 and 4-2, the information calculated for the sample product agree well with the empirical product for both Nusselt digit and contact degree for the riotous flux system. The variation of the rated empirical information of the connection result was 6.7% for the Nusselt digit and 4.8% for the degree of friction if the fluids was vacuous .

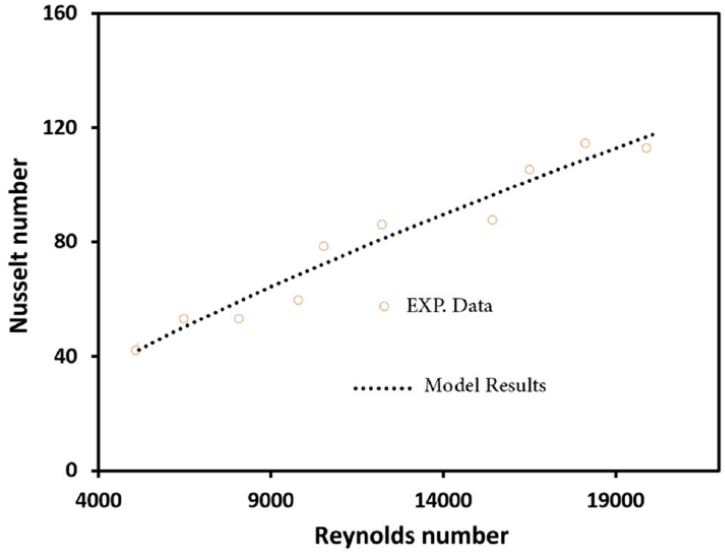


Fig 4.1 effectiveness of product for Nu no.

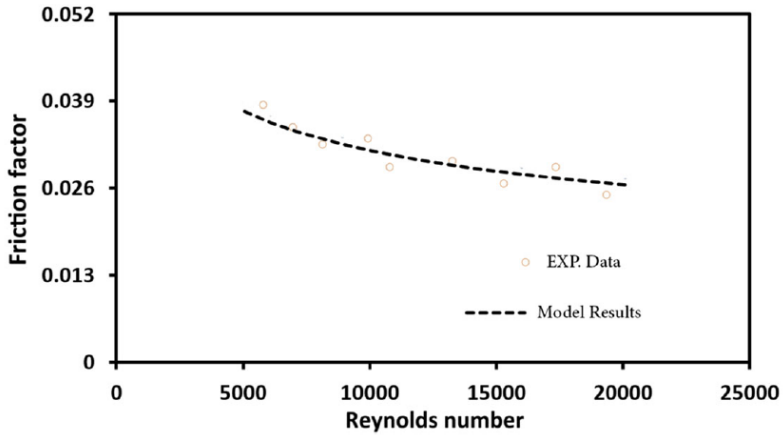


Fig 4.2 effectiveness of product for stage of contact .

Figure 3-4 explain the impact of NPCM entry flux average on high temperature convey. The character shows that as the flux average rise, the rate of high convey rise. The flux becomes turbulent as the mass flow rate increases due to the appearance of a larger Re digit. high temperature is rapidly conveyed for the area nigh the dike to the main line area beneath the influence of disorder. In addition, all NPCM particles in the cross section were found to be during the domain of stage convey degree however the NPCM samples in the main area were as yet fusion, the degree of the NPCM in the nigh-dike part rose over the stage convey degree (301.3 K), tick that the NPCM of the nigh-dike list had completely drawn . improve . The high temperature is ingest by the NPCM slurry as feasible high temperature once the NPCM list are fully drawn inside the canal.

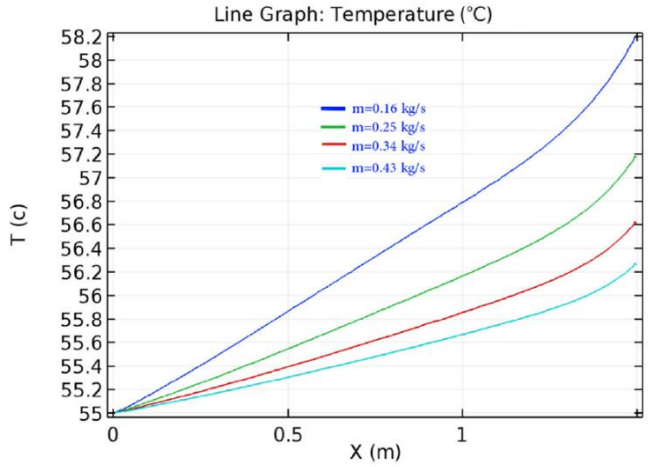


Fig 4-3 impact of cluster flux average of nano encapsulated stage variation plant on vent degree.

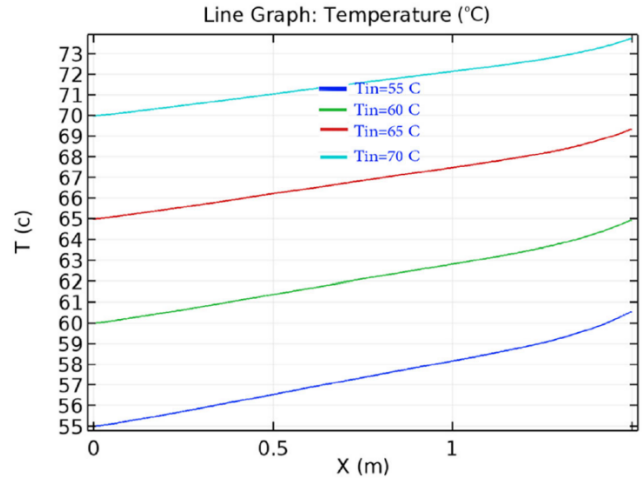


Fig 4-4. impact of entry degree temperature of nano encapsulated stage variation plant on liquid vent degree.

The producer NPCM flux degree of temperature decreases as the NPCM entrance temperature degree increases, as explain in the character. The temperature degree of the NPCM increase rapidly of the primary degree (temperature) to the stage variation temperature degree next the NPCM slurry flux inside the pipes, and then the hot and cold degree of the NPCM is within the range of the stage variation temperature degree in order that the rise of the entry temperature reason it to path the minimum stage variation degree temperature. As a product of power existent realize here as potential high degree , a tall-space temperature domine (300.1-301.3 K) is wealth . PCM fuze further fast and implement worst when capacity high temperature from the liquid inside the at maximum entry temperatures. A maximum entry degree also reduces the degree slope, reducing the heat transfer average .

Conclusions and future works

Psychological and numerically value modeling was utilized in this research to test how NPCMs flux over a duo-igniter hot temperature exchanger. Whenever modeling value and tentative value were contrast, yonder was were evermore a disease grade of pact. The heat transfer average raising by raising the bloc flux average and focus of the NPCM, however the heat transfer average is reduced by increasing the NPCM cold or hot degree debt to the least thermal tendency.

The liquid viscidity is straight affected by the higher NPCM focus, that reduces the Re digit at the selfsame liquid pace. minus steam wasted convey due to the lower Reynolds number, which also affected the heat transfer rate. However, the increased heat transfer capacity of absorption outweighs the reduced momentum transfer and in future work we can do this: -

- This is recommended
- Use alternative modeling
- Look at the temperature exchanger.
- It is bespoke till check further date variation aside form bloc flux average and focus.

References

1. Alizadeh M, Sadrameli SM. Development of free cooling based ventilation technology for buildings: thermal energy storage (TES) unit, performance enhancement techniques and design considerations—a review. Renew Sust Energ Rev. 2016;58:619-645.
2. Alizadeh M, Sadrameli SM. Numerical modeling and optimization of thermal comfort in building: central composite design and CFD simulation. Energy Build. 2018;164:187-202.
3. Mengjie S, Fuxin N, Ning M, Yanxin H, Shiming D. Review on building energy performance improvement using phase change materials. Energy Build. 2018;158:776-793.
4. Zeinelabdein R, Omera S, Gan G. Critical review of latent heat storage systems for free cooling in buildings. Renew Sust Energ Rev. 2018;82:2843-2868.
5. Saffari M, Gracia Ad, Ushak S, Cabeza LF. Passive cooling of buildings with phase change materials using whole-building energy simulation tools: a review. Renew Sust Energy Rev. 2017;80:1239-1255.
6. Royon L, Guiffant G. Forced convection heat transfer with suspension of phase change material in circular ducts: a phenomenological approach. Energy Convers Manage. 2008;49:928-932.
7. Zhang Y, Rao Z, Wang S, Zhang Z, Li X. Experimental evaluation on natural convection heat transfer of microencapsulated phase change materials slurry in a rectangular heat storage tank. Energy Convers Manage. 2012;59:33-39.
8. Clain P, Delahaye A, Fournaison L, Mayoufi N, Dalmazzone D, Fürst W. Rheological properties of tetra-nbutylphosphonium bromide hydrate slurry flow. Chem Eng J. 2012;193-194:112-122.
9. Zhang Y, Wang S, Rao Z, Xie J. Experiment on heat storage characteristic of microencapsulated phase change material slurry. Sol Energy Mater Sol Cells. 2011;95(10):2726-2733.
10. Royon L, Guiffant G. Investigation on heat transfer properties of slurry of stabilized paraffin during a melting process. Energy Convers Manage. 2011;52(2):1073-1076.
11. Huang L, Petermann M, Doetsch C. Evaluation of paraffin/water emulsion as a phase change slurry for cooling applications. Energy. 2009;34(9):1145-1155.
12. Wenji S, Rui X, Chong H, Shihui H, Kaijun D, Ziping F. Experimental investigation on TBAB clathrate hydrate slurry flows in a horizontal tube: Forced convective heat transfer behaviors. Int J Refrig. 2009;32(7):1801-1807.
13. Royon L, Guiffant G. Forced convection heat transfer with slurry of phase change material in circular ducts: a phenomenological approach. Energy Convers Manage. 2008;49(5):928-932.
14. Goel M, Roy SK, Sengupta S. Laminar forced convection heat transfer in microcapsulated phase change material suspensions. Int J Heat Mass Transf. 1994;37(4):593-604.

15. Delgado M, Lázaro A, Peñalosa C, Zalba B. Experimental analysis of the influence of microcapsule mass fraction on the thermal and rheological behavior of a PCM slurry. Appl Therm Eng. 2014;63(1):11-22.
16. Zeng R, Wang X, Chen B, et al. Heat transfer characteristics of microencapsulated phase change material slurry in laminar flow under constant heat flux. Appl Energy. 2009;86(12):2661-2670.
17. Sabbah R, Seyed-Yagoobi J, Al-Hallaj S. Heat transfer characteristics of liquid flow with micro-encapsulated phase change material: numerical study. J Heat Transf. 2011;133(2):121702.
18. Lenert A, Nam Y, Yilbas BS, Wang EN. Focusing of phase change microparticles for local heat transfer enhancement in laminar flows. Int J Heat Mass Transf. 2013;56(1):380-389.
19. Song SH, Liao Q, Shen WD, Ruan Y, Xu JF. Numerical study on laminar convective heat transfer enhancement of microencapsulated phase change material slurry using liquid metal with low melting point as carrying fluid. Int J Heat Mass Transf. 2013;62:286-294.
20. Emanuel G. Analytical Fluid Dynamics. 2nd. CRC Press; 2000.
21. Maddah H, Alizadeh M, Ghasemi N, Wan Alwi SR. Experimental study of Al2O3/water nanofluid turbulent heat transfer enhancement in the horizontal double pipes fitted with modified twisted tapes. Int J Heat Mass Transf. 2014;78:1042-1054.
22. Garg HP, Mullick SC, Bhargava AK, "Solar thermal energy storage", D.Reidel Publishing Co; 1985
23. Project Report, "Energy conservation through thermal energy storage", An AICTE project
24. Atul Sharma, V.V. Tyagi, C.R. Chen, D. Buddhi "Review on thermal energy storage with phase change materials and applications", Renewable and Sustainable Energy Reviews 13 (2009) 318–345, 2009
25. Belen Zalba, Jose Ma Marın, Luisa F. Cabeza, Harald Mehling, "Review on thermal energy storage with phase change: materials, heat transfer analysis and applications", Applied Thermal Engineering 23 (2223) 251 -283,2003
26. Muruganantham K, "Application of Phase Change Material in Buildings: Field Data vs. EnergyPlus Simulation", Master Thesis Approved by the Graduate Supervisory Committee: Phelan P, Lee T, Reddy A, ARIZONA STATE UNIVERSITY, December 2010
27. Baylin F. Low temperature thermal energy storage: a state of the art survey. Report no. SERI/RR/-54-164. Golden, Colorado, USA: Solar Energy Research Institute; 1979
28. Pillai KK, Brinkwarth BJ, "The storage of low grade thermal energy using phase change materials" Appl Energy, 1976;2:205–16
29. Abhat A. "Low temperature latent heat thermal energy storage" In: Beghi C, editor. Thermal energy storage. Dordrect, Holland: D. Reidel Publication Co.; 1981
30. Abhat A. "Low temperature latent heat thermal energy storage: heat storage materials", Solar Energy 1981;30(4):313–32