Heat Transfer Enhancement in Notched Finn Array Coated with Nanomaterial

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Abstract - **This paper aims study under natural mode of heat convection. It is a mechanism in which the motion of fluid is not generated through external source external source like blower, pump etc. but only due to the density differences in the fluid occurring because of the change in temperature. Natural convection cannot perform in inertial environments where other heat transfer mechanisms are required to stop the overheating of the heating component. Fins are the extended surfaces from an object so as to increase the rate of heat transfer by increasing convection. In addition to fins, nanomaterial coating has been provided in this paper which enhances the rate of heat transfer. Nanomaterials are materials which have nanoscale dimensions in case the surface or interface properties dominate the bulk properties. A nanoparticle is a small particle ranging 1-100 nanometers in size. There unique properties like small size, high surface area to volume ratios make them excel in our research area.**

The experimental setup consisted of a base plate, cartridge heater and notched fins. We took 3 different kinds of notched fin surfaces for experimentation purpose that is the plain fins, triangular fins and semi-circular fins, while choosing the dimensions in a way that the surface area of all the types of fins is kept constant, for better experimental study. The fin material is Aluminum and the nanomaterial selected for coating purpose is graphene. Results were analyzed for two cases, one for fins with nanomaterial coating and the other for fins without coating. The CFD analysis is done on ANSYS FLUENT software, which showed that without coating of fins the maximum temperature reached at tip for extreme outside fins is around 64.20C ,the fins placed exactly above the (two) heaters, shows higher temperatures around 64.80C,the fin which at middle position also shows the higher temperature of 64.80C, the average HTC found on Fin surface is 7 W/m2K and in case when the fins were coated with nanomaterial - the maximum temperature reached at tip for extreme outside fins is around 64.50C ,the fins placed exactly above the (two) heaters, shows higher temperatures around 65.10C,the fin which at middle position also shows the higher temperature of 650C, and the average HTC found on Fin surface is 8W/m2K.Similar results were found with experimental study also. There is heat transfer enhancement in fins with nanocoating as compared to fins without nanocoating. The average HTC varied by 1 W/m2K.This concluded that the heat transfer is increased with use of nanomaterial, which enables more vast and efficient use in vivid areas.

In this paper the analysis and experimentation were done using aluminium as a material, for future research, copper or any heat conducting material can be used in the experimentation. A setup of inverted fin arrays or different combination such as plain-square, square-triangular and so on, can be carried out.

Index Terms - **convection; fins; CFD; nanomaterial; HTC-Heat Transfer Coefficient.**

1.INTRODUCTION

In a fluid layer natural convection heat transfer confined in a very closed space with segments like fins is encountered in a very large choice of applications of engineering of passive cooling of electronic devices like moveable computers, compact power provides and telecommunications confined areas. For planning packets of equipment, there are a unit robust incentive to mount the maximum amount electronic elements the maximum amount potential as given enclosure. This results in high power generation density which could raise the temperature of the packages on the far side the permissible vary. so as to induce obviate this downside the warmth transfer rate from the packages must be most. Finned surfaces area unit the foremost common technique to extend the warmth transfer rate. The issue on that sweetening magnitude relation of warmth transfer depends area unit the fin orientations, geometric parameters of arrays of fins. the foremost necessary arrangement of fins array in heat sinks is

horizontal or vertical over surface plate on that fins array area unit connected. It is a mechanism during which the motion of fluid isn't generated through external supply external supply like blower, pump etc. however solely thanks to the density variations within the fluid occurring as a result of the amendment in temperature. In natural convection, heat supply coated all around by fluid receives the warmth. thanks to this the thermal enlargement settle down dense and thus rises. it's replaced by the encircling that acts as a cooler fluid This cooler fluid is thenceforth heated that forms the convection current. during this method energy is transferred from rock bottom to prime of the convection cell. Buoyancy is that the drive for natural convection, that may be a result of variations within the density of fluid. thanks to this, the presence of a correct acceleration like arising from resistance to gravity, or a similar force like that arising from acceleration, force (known as Coriolis effect), is crucial for natural convection. Natural convection cannot perform in mechanical phenomenon environments, (e.g.: -orbiting international area Station) wherever different heat transfer mechanisms area unit needed to prevent the warming of the heating element. Fins area unit the extended surfaces from AN object thus on increase the speed of warmth transfer by increasing convection. Thereby, adding a fin to AN object, will increase the extent and may generally be a cheap answer to heat transfer issues like warming in digital equipment's. Additionally, to fins, nanomaterial coating has been provided during this paper which boosts the speed of warmth transfer. Materials that have nanoscale dimensions area unit known as nanomaterials whose surface or interface dominate the majority properties. A nanoparticle may be a little particle locomote 1-100 nanometers in size. There distinctive properties like little size, high {surface space|area|expanse|extent} to volume ratios create them stand out in our analysis area. Incorporation of nanoparticles will increase the thermal and electrical conduction. Graphene chemical compound nanoparticles shows ultra-high electrical still as thermal conduction.

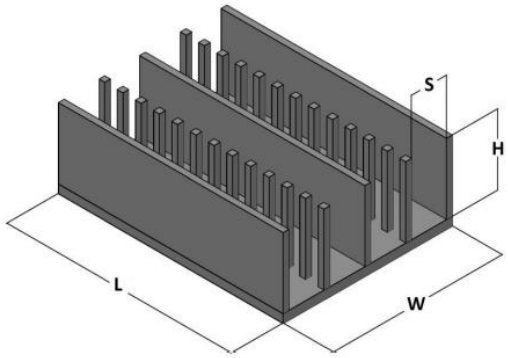
2. LITERATURE REVIEW

Suhil Kiwan et al : During this paper, we have a tendency to encounter that the thermal impact of mistreatment doughnut-shaped porous fins connected to the outer surface of a suspended heated vertical cylinder with constant heat flux was through an experiment investigated. 3 Al cylinders with 2 totally different quite porous material area unit utilized in fins arrangement which permit North American nation to pick thickness of fin and range of fins.[1]

Payam Shams Ghahfarokhi et al: This paper represents the thermal study that defines the appropriate correlations. it's allowed the deciding of the convective heat transfer constant for giant parallel rectangular fins for a static magnet synchronous generator coil. A comparison is created between the experimental results and analytical methodology, supported correlations projected inside the literature, that area unit restricted for a touch vary of warmth sinks.[2]

L.EI Moutaouakil et al: During this paper, we have a tendency to encounter that the finite volume methodology gets combined with the separate ordinate methodology for learning the natural convection that is coupled to surface radiation throughout a cooled sq. finned cavity. The fin array created of N skinny fins area unit organized throughout one horizontal row for this study.[3]

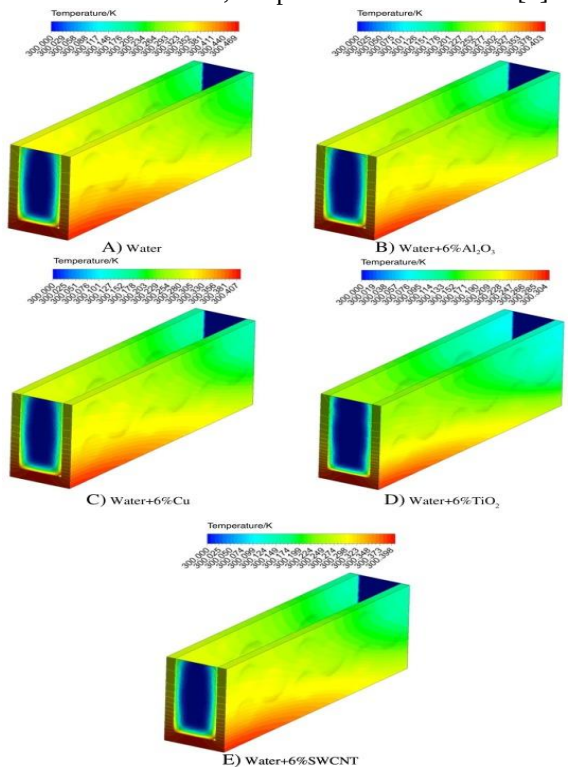
S.Sadrabadi Haghighi et al: The paper had AN methodology to live the convective heat transfer constant and thermal performance of plate cuboid pin-fins heat sinks and plate fins, below natural convection regime. it had been conducted.[4]



Shitole Pankaj et al: The most objective is to quantify and compare the natural convection HT improvement of perforated fin array with numerous fin spacing, heater inputs and perforation diameter. For this natural convection cooling simply just in case of finned

surfaces the variables are orientation and pure mathematics. This study tells concerning optimization of fin setup and numerous parameters of fin pure mathematics and their impact on heat transfer results. it's over that the warmth transfer rate for the perforated fins with constant pitch and four millimeters of diameter with forty-five-degree pure mathematics of perforation is most optimum fin and so the array of this fin with ten millimeters of spacing is best suited horizontal rectangular fin array.[5]

Milad Gholami et al: During this numerical study, we tend to encounter the natural flow and heat transfer of nanofluids with Al2O3, TiO2 and CNT nanoparticles for a vertical channel with mark fins at Lord Rayleigh number. TiO2 nanoparticle's use options a superb impact on alphabetic character range improvement. simply simply just in case of solid nanoparticles in base fluid causes additional uniform distribution of warmth transfer, particularly in areas on the brink of hot surface and by addition of additional volume fraction in base fluid, temperature level reduces.[6]

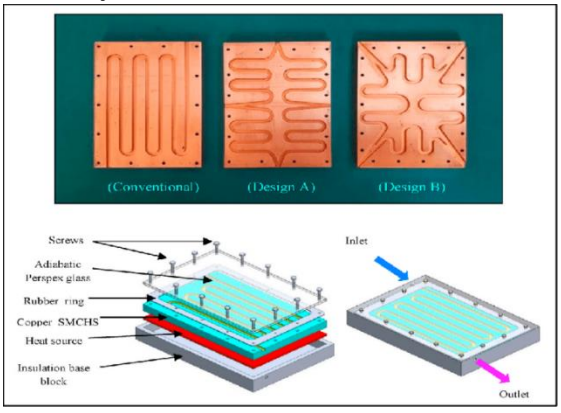


Sebastian Unger et al: The natural convection heat transfer of finned oval tubes was studied for numerous tube tilt angles starting from zero degree to forty-degree, fin spacing starting from six millimeter to sixteen millimeter and Lord Rayleigh numbers from 11000 to 130000. temperature measurements on the fin surface and gradient calculations were wont to verify fin potency. Nusselt range and meter heat flux is chosen as parameters for the thermal performance.[7]

J.Vogel, M.Johnson: Natural convection will have immense impact on the melting method throughout charging in heat of transformation storage kind system. Heat transfer improvement by natural convection depends strictly on the fabric properties, dimensions and boundary conditions of the storage system. In complicated acknowledged like shell-and-tube storage systems having extended fins, approximation of the impact of natural convection for the melting method becomes terribly tough.[8]

Majid Siavashi et al: During this analysis study, natural convection of Cu-H2O nanofluid throughout a cavity with AN array of porous fins on its hot wall has been analyzed numerically with the employment of two-phase approach. Porous fins, rather than solid ones, improves physical phenomenon and will have terribly less impact on convection as flow will endure it. Hence, the results obtained on the number and length of fins, and heat transfer and entropy generation are inspected.[9]

Sayedeh Sahar Hosseini et al: The paper showed a detail numerical study on natural convection in star air heaters with completely different fins. impact of fin form - rectangular, elliptical and triangular, the inclination angle starting from forty-five to ninety degree on mass flow temperature and performance was noted down by considering the impact of shadow created by fins.[10]



Y Si, H Zhu: Carbon nanomaterials (CNMs) have recently been used to type superhydrophobic coatings on metals, artificial polymers or textiles. Here we tend to investigate the probability of victimization C (CB), graphene (Gr) and carbon nanotubes (CNTs), as water repellent agents on naturally deliquescent wood. we tend to show that it's doable to create uniform CNM coatings on any quite wood via easy strategies of drop casting and dip coating, victimization CNMs distributed in organic solvents or water. it absolutely was found that the contact angle measurements of wood coated with solely zero.05 g/m2 CNTs and zero.25 g/m2 Gr gave the results exceptional 130°, that indicates apparent property. Yet, high adhesion of the droplets was discovered that indicate that “rose petal” is of superhydrophobic nature.[11]

JOHN T SIMPSON, TOLGA ATYUG: Over the past few years within the scientific community the world's coatings trade has seen the introduction of oxide/polymer-based superhydrophobic surfaces and coatings with further normal water repellency. this text makes an attempt to elucidate the basics of this behavior and to discussion and make a case for the foremost recent superhydrophobic technological breakthroughs. Since superhydrophobic surfaces and coatings will have an effect on the interaction of water with completely different surfaces, thus it is over that earth might even be a water world as a result of this technology has the potential to vary the world.[12]

Phuong Nguyen Tri et al: With the recent progress in applied science and material engineering, nano-based coatings became multifunctional, smarter, efficient, versatile and durable. Superhydrophobic coatings are an important category of the good coating family, that has gained recognition in coating science over the last few years. the event of superhydrophobic nanocoating is foretold to grow over the decades. By planning a double-scale structure by victimization applied science, followed by the addition of water repellent compounds, we can get fin spacing and numbers are varied between 5 to 12 mm and 5 to 9mm, respectively. Low thermal resistance is caused with increasing fin spaces altogether kinds of studied heat sinks. But, increasing fin numbers doesn't necessarily have better heat transfer. the only conductor design was acknowledged to be plate cubic pin–fin conductor with 7 fins and fin spacing of 8.5 mm. superhydrophobic surfaces. During this attitude article, various fundamental aspects of wettability and related phenomena are discussed. We present and compare the prevailing methods for the preparation of superhydrophobic coatings. Properties of superhydrophobic coatings like self-cleaning, anti-icing, anti-fouling, and anti-bacterial features were also induced. The review also put light on various superhydrophobic technologies breakthroughs and future trends within application of those materials.[13]

Wenjing Zhang et al: In this paper nano hierarchical structure Cu/Ni multilayer coating was made by a two-step method combined with electroless and electro deposition. Structure and morphology of the as-prepared Cu/Ni multilayer coating were analyzed by X-ray diffractometer and emission scanning microscopy. Final result show that micro-nano Cu/Ni coating is well-crystallized and also exhibits sea cucumber-like microstructure with Ni nano cone arrays which are uniformly dispersed perpendicular to the circular conical surface of Cu cone. Static contact angles were measured to research the surfaces' wettability. The result reveals that the Cu/Ni multilayer coating is super-hydrophobic, of which the static contact angle with test liquid (water) was 156°.Due to its super-hydrophobic property and unique shape, Cu/Ni multilayer coating is predicted to possess extensive practical applications.[14]

Sheikholeslami et al: A brief discussion on the articles on various fluids and nanoparticles were presented. The results show that the paraffin was the foremost used PCM within the studies, and thus the foremost typical unit was shell and tube device. Results also indicate that addition of longitudinal fin is that the foremost well-liked technique in TES units. Additionally, to the present, heat transfer enhancement using extended surfaces, encapsulation, other ways of augmenting the thermal features, and applying of multiple PCMs were also scrutinized.[15]

Trung Nguyen-Thoi et al: For developing the energy output of the buildings, heat storage mixed with phase transition material becomes an efficient technique. For enhancing the productivity, one among the techniques applied is storing heat whilst the time of great solar intensity and releasing it through the already dark. Enhancement within the thermal conductivity leads

the discharging time of PCM through the solidification to scale back. So, nanoparticles are dispersed into paraffin during this text. additionally, considering wavy surface for the inner duct is taken under consideration as second way which is combined with first technique. Numerical approach was successfully verified for various cases. The obtained results showed that entropy generation is a function of amplitude of wavy surface and it's reducing function of concentration of nanomaterial. Also, dispersing nanomaterial is simpler when sinusoidal surface has been employed.[16]

Aygun, Aysenur et al: This is an excerpt from journal of pharmaceutical and biomedical analysis. Under this study, silver nanoparticles (Ag NPs) were synthesized using mushroom (Ganoderma lucidum)'s extract. Different analytical techniques including X-ray Photoelectron Spectroscopy (XPS), X-ray diffraction (XRD), transmission microscopy (TEM), UV-vis spectroscopy, and Fourier Transform Infrared Spectrophotometer (FTIR) were used for the characterization of Ag NPs.[17]

Xie, Hongtao et al: Producing NH3 through the Haber process has caused huge energy-consumption and heavy emission of CO2. Electrochemical N2 reduction offers an alternative to understand N2 fixation under ambient conditions. In this paper, PdP2 nanomaterial decreases to graphene oxide which is suggest as an efficient electrocatalyst for the N2 reduction reaction.[18]

Khan, Ibrahim et al: This paper provides a thorough overview of synthesis, properties and applications of nanoparticles (NPs) in various forms. NPs size ranges from 1 to 100 nm. They're getting to be classified into different classes supported their properties, shapes or sizes. NPs possess unique physical and chemical properties because of their high area and nanoscale size. Their optical properties are accurate to the dimensions, which imparts different color due to absorption within the visible region. Their reactivity, toughness and other properties also are enthusiastic to their unique size, shape and structure.[19]

Zhu, Xiaojuan et al: Titanium-based catalysts are needed to know electrocatalytic N-2 reduction to NH3 with an outsized NH3 yield and a high Faradaic efficiency (FE). Iron is one among the foremost cost effective and most abundant metals on earth, and is an efficient dopant for greatly improving the nitrogen reduction reaction (NRR) performance of TiO2 nanoparticles in ambient N-2-to-NH3 conversion. The catalytic mechanism is further proved with theoretical calculations.[20]

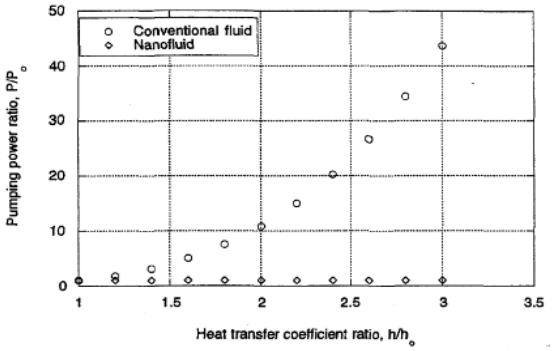


Figure 3. POTENTIAL PUMPING POWER SAVINGS WITH NANOFLUIDS

Milad Gholami et al: In this paper, the study of natural flow and warmth transfer of nanofluids with Al2O3, TiO2 and CNT nanoparticles along a vertical channel with dimpled fins with Rayleigh number (Ra) of Ra = 3.25 × 107 to Ra = 1 × 108 are investigated with the help of tactic of finite volume. The obtained results showed that, using CNT in volume fractions of twenty-two and 4% cause significant heat transfer and at φ = 6%, using TiO2 nanoparticles creates great effect on Nu number enhancement. Using solid nanoparticles in base fluid causes more uniform heat transfer distribution, especially in areas on the brink of heated surface and by adding more volume fraction in base fluid, temperature level reduces. generally, consistent with temperature contours, reduction of wall temperature depends on the rise of Ra and volume fraction and therefore the sort of solid nanoparticles.[21]

E. M. Sparrow et al: The effect of a buoyant phenomenon spawned by a heated vertical plate on the natural convection heat transfer from an upper colinear vertical plate has been determined analytically. The interpolate spacing, relative temperatures and lengths of two plates were varied parametrically, the Prandtl number was around to 0.7 for all cases. The upper-plate heat transfer was compared thereto of an otherwise identical vertical plate, but with the lower

plate absent. When the temperatures of the upper and lower plates are an equivalent, the general upper-plate heat transfer could also be a smaller amount than that of its single-plate counterpart for little interplate spacings, with the other relationship at larger spacings. On the. other hand, heat transfer enhancement generally occurs when the upper plate is comparatively hot. generally, the warmth transfer from relatively short upper plates is extremely sensitive to the presence of the lower plate, with a lessening sensitivity with increasing plate length. The computed temperature and velocity profiles demonstrated that near the vanguard of the upper plate, a replacement phenomenon develops within the already existing phenomenon spawned by the primary plate.[22]

Senthil Kumar Pongiannan et al: In this paper, aluminium nanocoating was employed to a conductor to test the heat transfer performance under natural-convection conditions. The nanocoating was done using electronic beam method. Also, the characteristics of nanocoated surfaces were analyzed using SEM which is an energy dispersive X-ray spectroscopy. Study was also done to analyze the heat dissipation from conductor both ways i.e. with and without nanocoating and that too under natural-convection at different surrounding temperatures. a uniform increase within the surface roughness by the nanocoating was seen altogether cases. The conclusion from the experimentation was drawn that the rate of heat transfer increases by the application of nanoparticles.[23]

Argonne, Illinois et al: In this paper measurement of effective thermal conductivity of mixtures of fluids and nanomaterials was done. The method used is parallel plate method. Experimental results indicate that the thermal conductivities of nanoparticle–fluid mixtures are above those of rock bottom fluids. it had been observed using theoretical models that the thermal conductivity of nanoparticle and fluid mixture are much but the experimental data which indicates the deficiency within existing models.[24]

Mohamad I. Al-Widyan et al: In this research paper a rectangular fin with following specifications- uniform cross-section, circular perforations were taken under consideration and it was attached to a surface at a constant temperature. The perforated fin was then analyzed for natural convection using the computational fluid dynamics i.e., FLUENT ANSYS. It was matched with the solid fin. Different levels of Grashof number were considered. Also, the spacing between holes and hole diameters was considered. It was observed that as we decrease the spacing between holes, rate of heat transfer increased. Almost all cases represent an increase in rate of heat transfer excluding for the case of high Grashof number (1x106) and high spacing ratio, ε. [25]

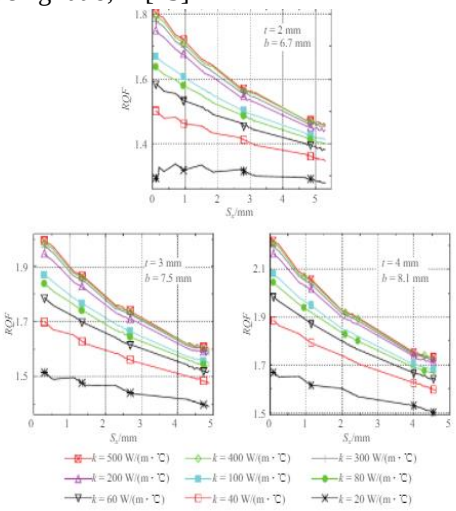


Fig. 7 Ratio of heat dissipation rate RQF vs. longitudinal spacing S_x with variable fin thickness and thermal conductivity

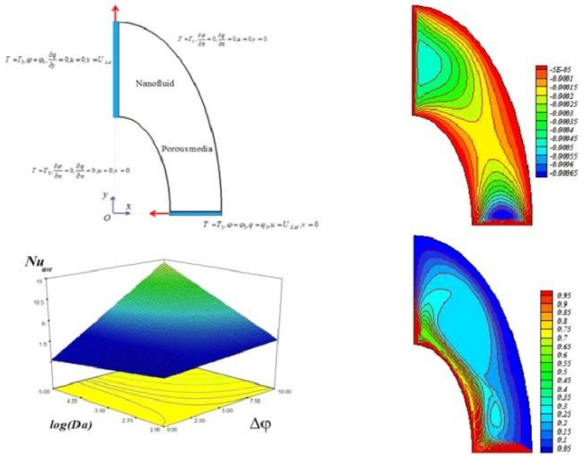
Jaeseon Lee et al: This experiment discovered the micro-channel cooling blessings of water which is primarily based totally nanofluids containing small concentrations of Al2O3. The excessive thermal conductivity of nanoparticles is proven to beautify the single-section warmth switch coefficient, mainly for laminar flow. Higher warmth switch coefficients have been completed more often than not withinside the front location of micro-channels. However, the enhancement changed into weaker withinside the completely evolved location, proving that nanoparticles have a considerable impact on thermal boundary layer development. Higher concentrations additionally produced more sensitivity to warmth flux. Despite this enhancement, the general cooling effectiveness of nanoparticles changed into pretty miniscule due to the big axial temperature upward thrust related to the reduced particular warmth for the nanofluid as compared to the bottom fluid. For two-section cooling, nanoparticles precipitated catastrophic failure via way of means of depositing

into big clusters close to the channel go out because of localized evaporation as soon as boiling commenced. These and different realistic risks convey into query the general benefit of the usage of nanofluids in micro-channel warmth sinks.[26]

M. Alipanah et al: In this paper enhancement of buoyancy-pushed convection warmness switch inside vertical cavities containing nanofluids subjected to one of a kind aspect wall temperatures and numerous factor ratios is investigated. The computations are primarily based totally on an iterative, finite volume numerical procedure that carries the Boussinesq approximation to simulate the buoyancy term. With the bottom fluid being water, 3 one-of-a-kind nanoparticles (Cu, TiO2, and Al2O3) are taken into consideration because the nanofluids. This take a look at has been performed for the pertinent parameters withinside the following ranges: the Rayleigh number, Raf = 105 –107 and the volumetric fraction of nanoparticle among zero and five percent. The outcomes are offered for one of a kind length-to-peak ratios various from 0.1 to 1.0. The comparisons display that the imply Nusselt numbers and pace magnitudes growth with quantity fraction for the complete variety of the Rayleigh numbers. The predictions display a substantial warmness switch enhancement in comparison to natural fluid. It is likewise determined that the warmth switch enhancement using nanofluid is extra said at low factor ratios than excessive factor ratios. Moreover, the outcomes depict that the addition of nanoparticles to the natural fluid has extra results at decrease Rayleigh numbers.[27]

Mohammad Parsazadeh et al: Energy garage is severely crucial for intermittent renewable reassets including sun or wind. This paper affords a numerical have a look at on a shell and tube thermal power garage unit the use of a not unusual place natural section alternate material (PCM) – paraffin wax. To triumph over the trouble of gradual charging because of low thermal conductivity of paraffin wax, this study applies a multiscale warmth switch enhancement technique, with round plate fins on outer floor of the warmth switch fluid (HTF) tube and quite conductive nanoparticles (Al2O3) dispersed withinside the PCM at the shell side. The novelty of this studies is that via way of means of simultaneous utility of enhancement methods, we're capping a position to investigate the interactions among the , which became now no longer viable in preceding research on separate technique. A computational fluid dynamics (CFD) version is advanced to simulate melting of the PCM with the subsequent parameters: nanoparticle attention ϕ from zero to four vol.%; fin perspective α from - 450 to 450, and pitch p from fourty five to sixty-five mm. The acquired numerical information became analysed with a conventional approach and a statistical reaction floor approach (RSM). The latter represents every other novelty of this studies. The RSM evaluation indicates that fin perspective and nanoparticle attention are extensive parameters in affecting the PCM melting, however pitch of the fins does now no longer display sizeable impact. Numerical outcomes show that including nanoparticles withinside the PCM does now no longer boost up the charging process; at the opposite it ends in longer charging time and decrease basic warmth switch fee because of discount of herbal convection withinside the melted PCM. A sturdy interplay is likewise observed among those extensive parameters, for instance the charging time notably will increase whilst nanoparticles are delivered at α = 1.[28]

Xinwei Wang and Xianfan Xu et al: Effective thermal conductivity of combinations of fluids and nanometer-length debris is measured with the aid of using a steady-country parallel-plate method. Experimental consequences display that the thermal conductivities of nanoparticle fluid combinations are better than the ones of the base fluids. Using theoretical fashions of powerful thermal conductivity of a mixture, we've got proven that the expected thermal conductivities of nanoparticle fluid combinations are plenty decrease than our measured data, indicating the deficiency with inside the current fashions while used for nanoparticle fluid combinations. Possible mechanisms contributing to enhancement of the thermal conductivity of the combinations are discussed. An extra complete principle is wanted to absolutely provide an explanation for the conduct of nanoparticle fluid combinations.[29]



Sheikholeslami et al: Nowadays, the upward push withinside the human populace and therefore growing call for electricity in distinct fields, have triggered critical hassle for societies. Increasing electricity call for necessitates the want to supply extra electricity, thus, the intake of fossil fuels which might be a shape of non-renewable electricity might be increased. Phase alternate substances as environments for storing warmness have huge programs in storing sun electricity. This electricity supply is clean, inexhaustible, and accessible. Its utilization with the aid of using human beings varies primarily based totally on instances along with geographical conditions, terrain, time variations, and cloud cover. Current article reviews a complete evaluation of TES technology the usage of PCM in the course of discharging and charging. The motive of cutting-edge studies is to scrutinize the used strategies for augmenting overall performance of TES for non-strength plant life and PCM programs. In addition, warmness switch enhancement the usage of prolonged surfaces, encapsulation, distinct approaches of augmenting the thermal features, and making use of more than one PCMs had been scrutinized. Furthermore, a quick dialogue at the current articles on diverse fluids and nanoparticles has been presented. The effects display that the paraffin turned into the maximum used PCM withinside the studies, and the maximum not unusual place unit turned into shell and tube warmness exchanger. Results additionally suggest that addition of longitudinal fin is the maximum famous approach in TES units.[30]

3. CONCLUSION

From the above we conclude that to prevent overheating, heat transfer enhancement using nanomaterial coating is beneficial. Natural Convection mode opted adds to the economy factor as well as saving extra redundant parts to achieve heat transfer. The CFD Analysis made us reach to a numerical result for our fixed configuration. We also conclude here that the addition of nanomaterial in cavity with an array of porous fins on the hot side increases the HTC. The parameters such as fin spacing, boundary conditions, nanomaterial coating thickness are some of the important aspects to be taken care of.

REFERENCES

[1] Suhil Kiwan,Hamzeh Alwan &Nisrin Abdelal, “An experimental investigation of the natural convection heat transfer from a vertical cylinder using porous fins” 2020.

[2] Payam Shams Ghahfarokhi , AntsKallaste &Toomas Vaimann, “ Determination of natural convection heat transfer coefficient over the fin side just just in case of a coil system” 2018

[3] L.EI Moutaouakil , M.Boukendil , Z.Zrikem, “Natural convection and surface radiation heat transfer during a cavity with vertically oriented fins” 2020

[4] S.Sadrabadi Haghighi, H.R.Goshayeshi & Mohammad Reza Safaei, “ Natural convection heat transfer enhancement in new designs of plate-fin based heat sinks” 2018

[5] Shitole Pankaj, Bhosle Santosh, Kulkarni Kishore & Joshi sarang, “Experimental Investigation of heat Transfer by Natural Convection with Perforated Pin Fin Array” 2018

[6] Milad Gholami , Mohammad Reza Nazari, Mohammad Hossien Talebi, “Natural convection heat transfer enhancement of varied nanofluid by adding dimple fins on a vertical channel wall” 2019

[7] Sebastian Unger , Matthias Beyer, Johanna Thiele, “Experimental study of the natural convection heat transfer performance for finned oval tubes at different tube tilt angles” 2019

[8] J.Vogel,M.Johnson, “Natural convection during melting in vertical finned tube latent thermal energy storage systems” 2019

[9] Majid Siavashi , Reve Yousofv and ,Saeed Rezanejad, “Effect of nanofluid and porous fins

on natural convection and generation of entropy of flow inside a cavity" 2017

[10] Sayedeh Sahar Hosseini, Abas Ramiar , Ali Akabar Ranjbar, "The effect of fins shadow on natural convection solar air heater"2019

[11] Y Si, H Zhu, L Chen, T Jiang, "Towards the event of superhydrophobic carbon nanomaterial coatings on wood"

[12] JOHN T SIMPSON, TOLGA ATYUG, "Superhydrophobic materials and coatings"

[13] Phuong Nguyen Tri, Hai Nguyen Tran, A.K. Bajpai, Sonil Nanda, "Recent progress within the preparation, properties and applications of superhydrophobic nano-based coatings and surfaces"

[14] Wenjing Zhang, Zheyin Yu, Zhuo Chen, "Preparation of super-hydrophobic Cu/Ni coating with micro-nano hierarchical structure"

[15] Sheikholeslami, M (Sheikholeslami, M.); Keshteli, AN (Keshteli, A. Nematpour) ; Babazadeh, H (Babazadeh, Houman), "Nanoparticles favorable effects on performance of thermal storage units"

[16] Ma, XJ (Ma, Xiaojie) ; Sheikholeslami, M (Sheikholeslami, M.), "Solidification inside a clean energy storage unit utilizing phase transition material with oxide nanoparticles"

[17] Aygun, A (Aygun, Aysenur); Ozdemir, S (Ozdemir, Sadin), "Synthesis and characterization of Reishi mushroom-mediated green synthesis of silver nanoparticles for the biochemical applications"

[18] Xie, HT (Xie, Hongtao) ; Geng, Q (Geng, Qin), "PdP2 nanoparticles-reduced graphene oxide for electrocatalytic N-2 conversion to NH3 under ambient conditions"

[19] Khan, I (Khan, Ibrahim); Saeed, K (Saeed, Khalid) ; Khan, I (Khan, Idrees), "Nanoparticles: Properties, applications and toxicities"

[20] Wu, TW (Wu, Tongwei); Zhu, XJ (Zhu, Xiaojuan), "Greatly Improving Electrochemical N-2 Reduction over TiO2 Nanoparticles by Iron Doping"

[21] Milad Gholami , Mohammad Reza Nazari , Mohammad Hossien Talebi , Farzad Pourfattah , Omid Ali Akbari , Davood Toghraie, "Natural convection heat transfer enhancement of different nanofluids by adding dimple fins on a vertical channel wall"

[22] E. M. Sparrow, M. Faghr, "Natural Confection Heat Transfer' from the Upper Plate of a Colinear, Separated Pair of Vertical Plates"

[23] Senthil Kumar Pongiannan, Velraj Ramalingam, Latha Nagendran, "NATURAL CONVECTION HEAT TRANSFER ENHANCEMENT OF ALUMINUM HEAT SINK USING NANOCOATING BY ELECTRON BEAM ME THOD"

[24] Xinwei Wang and Xianfan Xu Purdue University, West Lafayette, Indiana ,Stephen U. S. Choi Argonne National Laboratory, Argonne, Illinois, "Thermal Conductivity of Nanoparticle–Fluid Mixture"

[25] Mohamad I. Al-Widyan, Amjad Al-Shaarawi, "Numerical Investigation of Heat Transfer Enhancement for a Perforated Fin in Natural Convection"

[26] Jaeseon Lee, Issam Mudawar, "Assessment of the effectiveness of nanofluids for single-phase and two-phase heat transfer in micro-channels" 2006

[27] M. Alipanah, A. A. Ranjbar, A. Zahmatkesh, "Numerical Study of Natural Convection in Vertical Enclosures Utilizing Nanofluid"

[28] Mohammad Parsazadeh, Xili Duan, "Numerical Study on the Effects of Fins and Nanoparticles in a Shell and Tube Phase Change Thermal Energy Storage Unit"

[29] Xinwei Wang and Xianfan Xu, "Thermal Conductivity of Nanoparticle–Fluid Mixture"1999.

[30] Sheikholeslami, M (Sheikholeslami, Keshteli, AN (Keshteli, A. Nematpour) , Babazadeh, H (Babazadeh, Houman), "Nanoparticles favorable effects on performance of thermal storage units"2020.