Exergetic Analysis of Parabolic Trough Collectors Using Various Mono & Hybrid Nano Fluids

A Thesis Submitted

In partial fulfillment for the reward of the degree of

Master of technology

In Mechanical Engineering

SUBMITTED BY

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UNDER THE GUIDANCE OF

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STUDENT'S DECLARATION

I, RAUNAK KUMAR(Roll No. 2K19/THE/07), hereby certify that the work which is being presented in this thesis titled "Exergetic Analysis of Parabolic Trough Collectors using various Mono & Hybrid Nano Fluids" is submitted in the partial fulfilment of the requirement for degree of Master of Technology (Thermal Engineering) in Department of Mechanical Engineering at Delhi Technological University is an authentic record of my own work carried out under the supervision of Dr. Pushpendra Singh. The matter presented in this report has not been submitted in any other University/Institute for the award of Master of Technology Degree. Also, it has not been directly copied from any source without giving its proper reference.

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CERTIFICATE

This is to certify that this report titled, "Exergetic Analysis of Parabolic Trough Collector using Various Mono & Hybrid Nano Fluids" being submitted by Raunak Kumar (Roll No. 2K19/THE/07) at Delhi Technological University, Delhi for partial fulfilment of the Degree of Master of Technology as per academic curriculum. It is a record of bonafide research work carried outby the student under my supervision and guidance, towards partial fulfilment of the requirement for the award of Master of Technology degree in Computational Design. To the best of my knowledge this work is original as it has not been submitted earlier in part or full for any purpose before

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ACKNOWLEDGEMENT

I wish to express my profound gratitude and indebtedness to Dr. Pushpendra Singh, Department of Mechanical Engineering, Delhi Technological University, Delhi- 110042 for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout the project work.

I am also thankful to Prof Vipin, Head of Mechanical Engineering Department, Delhi Technological University, Delhi-110042 for his constant support and encouragement. I am also grateful to my seniors and classmates.

Lastly my sincere thanks to all my friends who has patiently extended all sorts of help for accomplishing this undertaking.

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M.Tech (THERMAL ENGINEERING)

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EXERGETIC ANALYSIS AND OPTIMISATION OF PARABOLIC TROUGH COLLECTOR USING VARIOUS NANO FLUIDS

ABSTRACT

Solar boasts itself to be most sustainable, employable and ecologically acceded renewable sources of energy due to its simplicity of usage and low environmental effect. Solar energy may be utilized for a variety of applications, including solar water heaters. Solar collectors are used for cooling and dehumidification in addition to room and water heating. Heat losses and fluid absorption characteristics, on the other hand, restrict the collector's efficiency. Alternative fluids, which are essentially the same as conventional fluids but include a specific quantity of suspension of metal or nonmetal particles, have been utilised to great success in solar collectors during the past several decades. Nanofluids are fluids that have microscopic particles suspended in them, thus the name. It has been established through numerous experiments and investigation that floating these nanoparticles enriches base fluid thermal properties, yielding better thermal conductivities than conventional fluids. As a consequence, nanofluids are more suited than traditional fluids for heat transfer enhancement applications.

It has been proved to be one among the most popular and promising ways for improving and enhancing the concentrating power collector performance . This work intents to investigate various thermal and energetic based efficiency optimization of parabolic through collector using various mono and hybrid Nano fluids. The goal of this study was to improve the LS-2 parabolic trough model and examine the enhancing effects of mono and hybrid Nano fluids. The methodology of heat transfer analysis is used in this study to construct a software using the Engineering Equation Solver for the numeric simulation of the parabolic trough collector. Solar irradiation, inlet fluid temperature, and volumetric flow rate of heat transfer fluid are the primary inputs to the proposed model, while the thermal and exergetic efficiency is the main output. The final result and findings clearly shows the optimized condition for exergetic efficiency in addition to the optimized conditions for thermal efficiency.

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CHAPTER 1

INTRODUCTION

1.1. Introduction

The use of energy increases at an alarmingly rapid rate as the world grows. Conventional energy sources are incapable of meeting the demands of the modern world. Historically, fossil fuels have served as the main source of conventional energy. The two main limitations of fossil fuels: their finite supply and environmental contamination, have prompted people all over the world to consider other sources of energy. Because of the limits of conventional energy sources, renewable energies are out of the question. However, owing to a lack of knowledge of these properties and the humongous cost accredited to the conversion mechanism, the use of such resources is restricted at this time Solar energy being the most probable renewable energy sources to meet current energy demands. The total solar energy available in the atmosphere on the world is 1017 watts [1] [source: National Geographic]. Solar radiation reaches 1016 watts, which is 1000 times the amount of energy required by the globe. Consequently, if just 5 percent of the available energy is used, the worldwide demand for energy is 50 times greater.

1.2 Solar radiations as baseline energy source

By fusion process, the Sun generates energy and transmits it as radiation. The sun has a very high temperature, therefore the sun's radiation has shorter wavelengths, as laid out in Wien's Law.

$\lambda \cdot T = \text{constant}(1)$ [1]

λ – Denotes the Radiation wavelength which corresponds to utmost energy T –Hot body temperature. Most of the energy that sun radiates belongs to visible and infrared region. A fraction of energy also lies in ultraviolet region as depicted in following figure.

When Earths top atmosphere was taken into consideration, the standard average sun ray intensity (SASA-based solar constant) was 1353 watts/square metre [1. Infrared radiation is absorbed by water vapour and carbon dioxide, whereas ultraviolet radiation is absorbed by the ozone layer. Even light dispersion happens as a result of dust particles, air particles, other gases, and other factors, and as a result, the strength of the radiation reaching the earth decreases. On the planet, there are two types of radiation:

i. Direct (beam) radiation

These radiations does not scatter or get soaked and reach Earth surface undeviated straight from sun.

ii. Diffuse radiation

These radiations before reaching the surface get scattered and their orientations are gelded as a cause of atmospheric reflection.

Additionally, on a clear day on an overcast day with little cloud cover, the quantum of direct radiations is considerably enhanced as compared to the quantity of diffuse radiations (10 to 20 percent of total radiation). The environment fluctuates as a consequence of changes in the quantity of solar radiation intercepted by the Earth's surface, resulting in variations in the quantum of solar radiation impinging the surface. The angle of incidence has an effect on the radiation drop on the surface as well (Angle between radiation incident and surface normal).

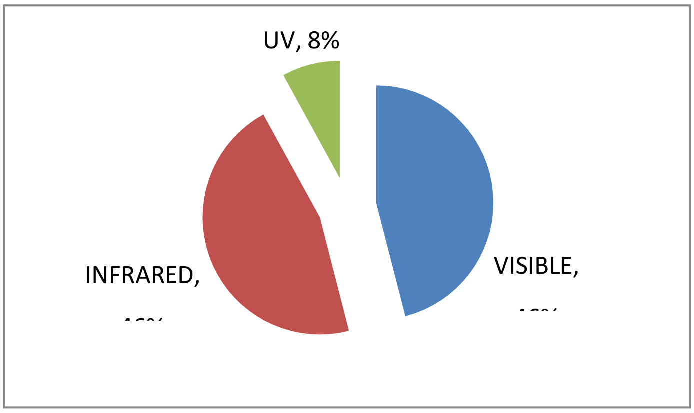


Figure1.1: Energy Distribution per Frequency Band

The average standard solar rays are measured at the top of the Earth's atmosphere (SASA-based solar constant) was 1353 watts/square metre [1. Infrared radiation is absorbed by water vapour and carbon dioxide, whereas ultraviolet radiation is absorbed by the ozone layer. Even light dispersion happens as a result of dust particles, air particles, other gases, and other factors, and as a result, the strength of the radiation reaching the earth decreases. On the planet, there are two types of radiation:

- Direct (beam) radiation

Solar radiation does not dissipate or absorb, and it travels directly from the sun to the earth's atmosphere.

- Diffuse radiation

Sunlight reaches the surface, but its orientation is altered via scattering and atmospheric reflection.

Additionally, on a clear day on an overcast day with little cloud cover, the amount of direct radiations is considerably higher than the quantity of diffuse radiations (10 to 20 percent of total radiation). The circumstances at places where solar radiation falls vary depending on the quantity of solar radiation that reaches the earth's surface.

1.3. Solar collectors

Sunlight collectors are the devices that are employed to transform solar energy into thermal energy by converting it to heat. When used in conjunction with the proper absorber, the solar collector gathers and transforms solar energy into thermal energy that is employed to fulfil a variety of purposes (absorb solars). The solar collector's functioning is shown in Fig.1.2 in terms of its operating principle.

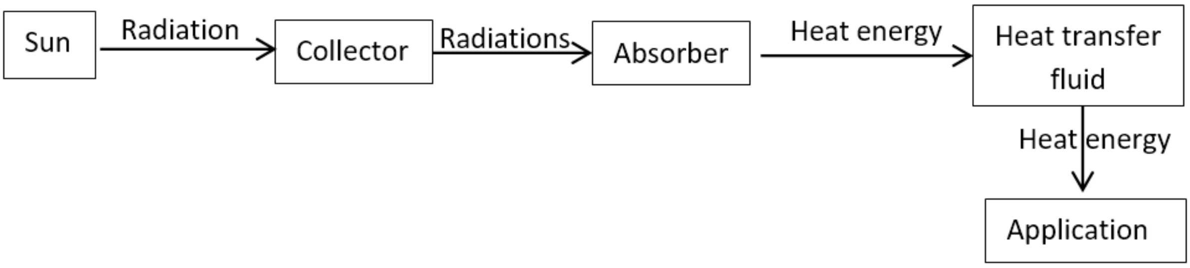


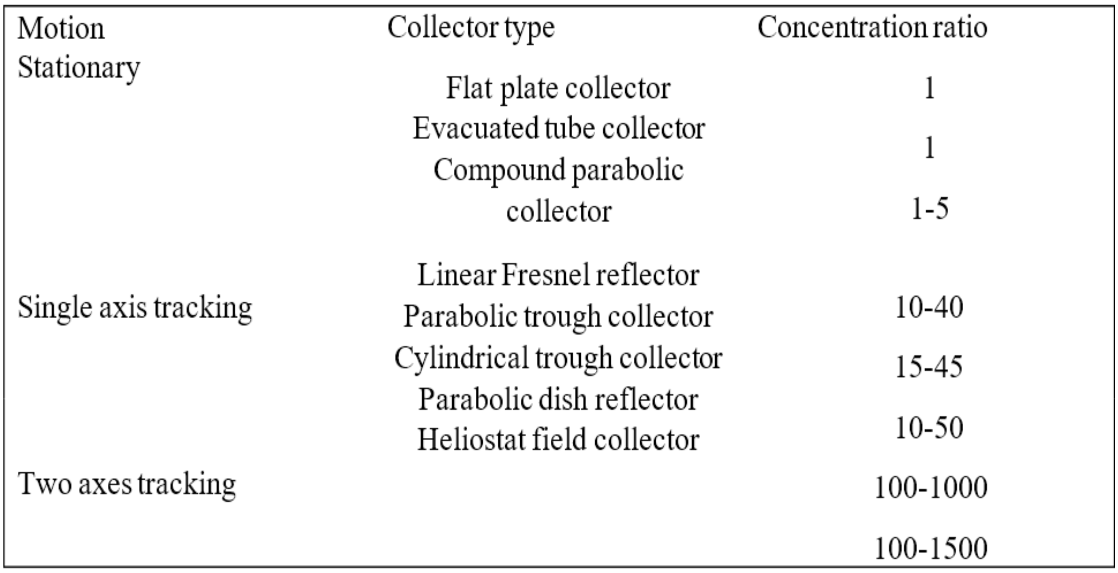
Figure 1.2: Solar Collector Governing Principle

Fig. 1.2 contains various collectors used to convert solar energy to thermal energy with its estimated temperature range.

1.4. Classification of solar collectors

Solar energy collectors vary in terms of their movement on the surface, namely in terms of their immobile single-axis tracking and two-axis tracking, as well as in terms of the temperature at which they operate[4]. Table 1.1 contains a long list of multihued varieties of solar collectors.

Table 1.1 Types of solar collectors [4]



Motion	Collector type	Concentration ratio
Stationary	Flat plate collector	1
	Evacuated tube collector	1
	Compound parabolic collector	1-5
Single axis tracking	Linear Fresnel reflector	10-40
	Parabolic trough collector	15-45
	Cylindrical trough collector	10-50
Two axes tracking	Parabolic dish reflector	100-1000
	Heliostat field collector	100-1500

The plate absorbs a considerable percentage of the solar radiation after going through a transparent pellucid cover and striking on a blackened surface of absorber with high absorptivity. It is subsequently moved the fluid tubes' transport medium and sent away for storage or usage. Using the clear cover, you may reduce the amount of stagnant air that accumulates between the glass and absorber plate, thus lowering the amount of convective losses that occurs from absorber plate. This is due to the fact that the short-wave radiation, glass is transparent. long-wave radiation, yet almost opaque to sun radiation, heat radiation generated by the absorber plate, which helps to cut down radiation losses from the collection (greenhouse effect). FPCs are usually placed permanently and do not need regular monitoring of the sun. In the northern hemisphere, collectors should be gazing to the south, while in the southern hemisphere, collectors should be looking to the south and to the north, as appropriate. The collectors should be oriented such that they face north.

With an active convection suppressor, the ETC's combined selective surface has been shown to be effective at high temperatures. The vacuum cover cuts down convection and plume loss, allowing collectors to function at temperatures beyond the FPC's temperature limit. Direct and diffuse radiation are gathered in the same way as with

FPC. Their efficiency, on the other hand, is higher at low incidence angles than at higher ones. ETC outperforms FPC throughout the course of a day's worth of competition To transmit heat at a high rate of efficiency, ETC uses fluid-vapor phase transfer materials. Because evaporation or condensation is not possible beyond the temperature of the phase transition, the heat pipe offers innate shielding against freezing and overheating. This automated control of temperature is a distinguishable feature pertaining to evacuated heat pipe collector that is not observed anywhere else.

It is essential to use a high-performance solar collector in direction to provide high temperatures while maintaining high efficiency. Lightweight structural solutions and low-cost systems that use parabolic collectors for procedure heat applications up to 400°C are possible to manufacture (PTCs). When operating at an effective temperature, PTCs may produce heat ranging from 50°C to 400°C. When facing the sun, the parabolic tube produces parallel rays on the indicator, which are imitated back to the observer. A single Sun axis tracking is sufficient for the construction of long-term collecting modules. If the collection is oriented east/west, and the sun is tracked from north to south, or north to south, the sun may be tracked from east to west, and the collector may be oriented east/west. The advantages of the prior tracking technique are that only a subtle amount of adaption of collector is imperative during the day and that the opening is always on the sun at noon; however, collective efficiency is significantly reduced during the early and late days because of high incidence angles during the early and late days

Using a series of linear mirror strips, the linear reflector method in Fresnel concentrates light on a stationary receiver that is mounted on a linear tower in a circular pattern. In some ways, the LFR field may be thought of as a broken-up reflecting parabola; however, unlike parabola troughs, the LFR field does not have to be parabolic in shape, This enables the creation of large absorbers that do not need to move. Reflectors which are flat or elastically curved, are inexpensive and affordable than parabolic glass reflectors but still offer enough light, are a benefit of this kind of system. In order to minimise the amount of structural support needed, they are likewise positioned near to the ground. It is more difficult to avoid shadowing and blocking adjacent reflectors because of the LFR technology, which results in a larger distance between reflectors. Although the blockage of the absorbing towers may be reduced, the cost of doing so increases.

A parabola is a concentrated reflector that monitors the sun in two directions and concentrates solar radiation on a receiver in the centre of the dish. A parabolic dish reflector is also known as a focus collector. In order for the beam to be reflected in the thermal receiver, the dish structure must follow the sun in its entirety. A similar technique, as described in the previous section, is employed in double the number of pickers, allowing the picker to be watched in two dimensions. The receiver intercepts and transfers radiant solar energy into a fluid, where it is transformed to thermal energy. Because the receivers are dispersed throughout the field, such as in a parabola plate, parabola plates are often referred to as scattered recipient systems in the scientific community.

In order to reflect direct solar radiation events on a common target with very high radiant power inputs, a large number of flat mirrors or heliostats may be used in combination. The field is referred to as the central collector field or the heliostat field in certain circles. With the use of heliostats with slightly concave segments of mirrors, A steam engine can produce large amounts of thermal energy while simultaneously generating high temperatures and pressurised steam. The heat energy received by the receiver is transformed into a fluid, which may subsequently be reposited and employed to generate electricity.

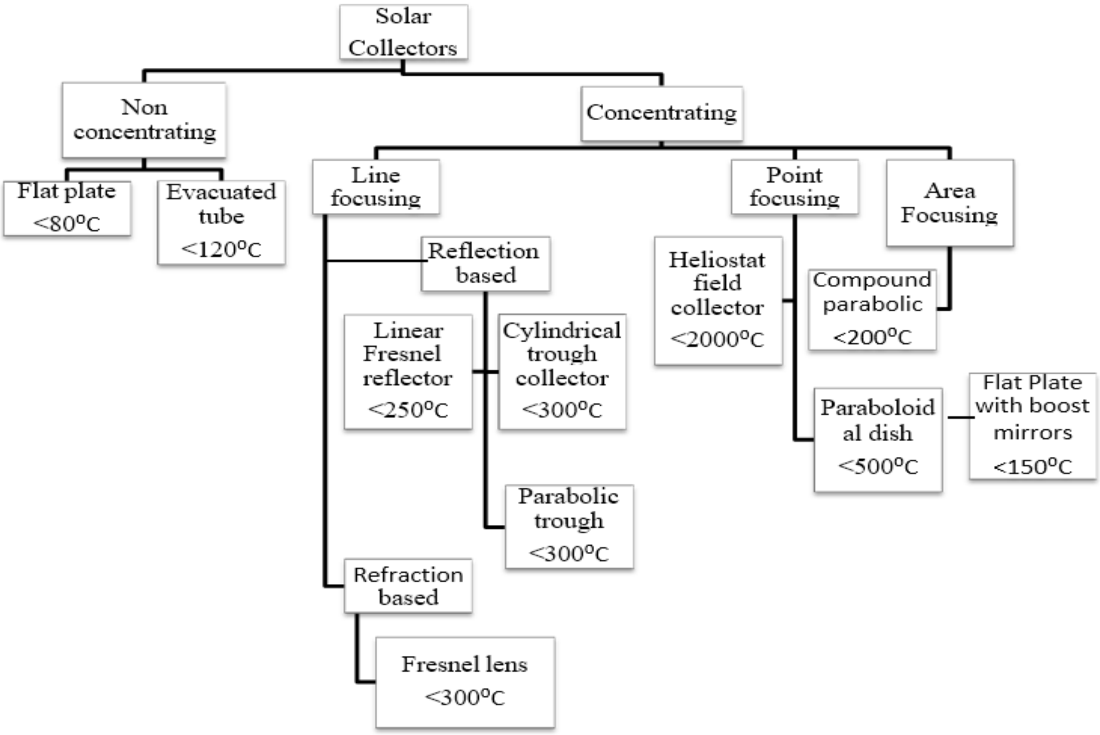


Figure 1.3: Classification of Solar Collector

1.4.1. Flat plate solar collectors

It is a collector of the kind that does not concentrate the collected material. This is used in low-temperature heating applications where high efficiency is required. The most common use for this technology is the home solar water heater. Because they are more reliable, they are also simpler to operate. They also need less maintenance. They are widely used all throughout the world, even in developing countries. In addition to pool heating, washing machines, space heating, agricultural products drying, and other applications, this collector collects data on the environment. Because of the low temperature requirement, unglazed collectors are used to heat swimming pools and spas. Flat plate sun collectors can be diversified into two types: liquid type flat plate solar collectors and solar air heaters, which are distinguished by the kind of fluid used for heat transfer. FIGURE 1.4 represents the various components of a flat plate solar collector employing flat plates.

Five main components comprise the FPLSC: the absorber, the cover transparent, the isolation system, flow tubes, and the cabinet. The absorber plate is responsible for absorbing solar radiation. Solar radiation absorption must be high on the absorbent plate to intercept the enormous potential quantity of solar energy. Utilizing selected surfaces, the absorber plate's absorption capacity may be enhanced. Selective coatings, directional selectiveness, and interference filters are all terms that apply to selective surfaces in a different way. Radiant energy that has been absorbed is converted to heat following absorption. The heat energy radiated by absorber plate is transferred to the flowing tubes via the tubes. Consequently, the heat conductivity of the system must be increased. Among the qualities that must be considered when selecting an absorber platform are its thermal, chemical, mechanical, and optical capabilities.

Figure 1.4: Flat plate liquid solar collector

1.4.2 Evacuated tube solar collector

The disposed tube, as illustrated in Fig. 1.5, is the non-concentrated collector The absorber tube is embedded in the glass tube. Spacing between the absorber and tube of glass being evacuated to bring and lower down heat loss to its minutest amount. Due to heating of the tubes of absorber, fluid is transformed into steam. The flow of the fluid in the manifold pushes high-temperature vapours upwards and cools down. Vapor heat is transmitted to the helpful liquid. This collector is intended for applications with low temperatures, such as home water heating, heating of space etc.

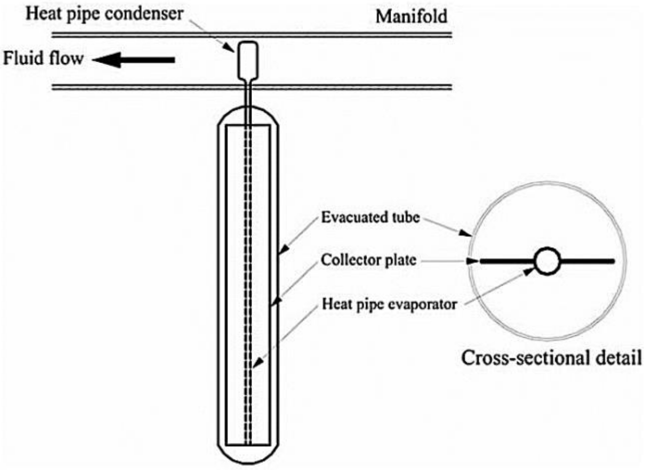


Figure 1.5: Evacuated tube collector

1.4.3 Parabolic trough

As seen in Fig. 1.6, the parabola is a collector line. It may be used to generate steam, electricity, and industrial process heat for applications requiring high temperatures, among other things. There are nine large solar power facilities in the California Mojave Desert[5]. Luz International Limited developed these plants and are referred to as solar power producing systems (SEGS). Each plant has a capacity of 354 MW and ranges in size from 14 to 80 MW. Two euro drilling models, the ET100 and ET150, have been forged coupled with an optical concentration of 82:1 and a temperature of 500^0C. [6].

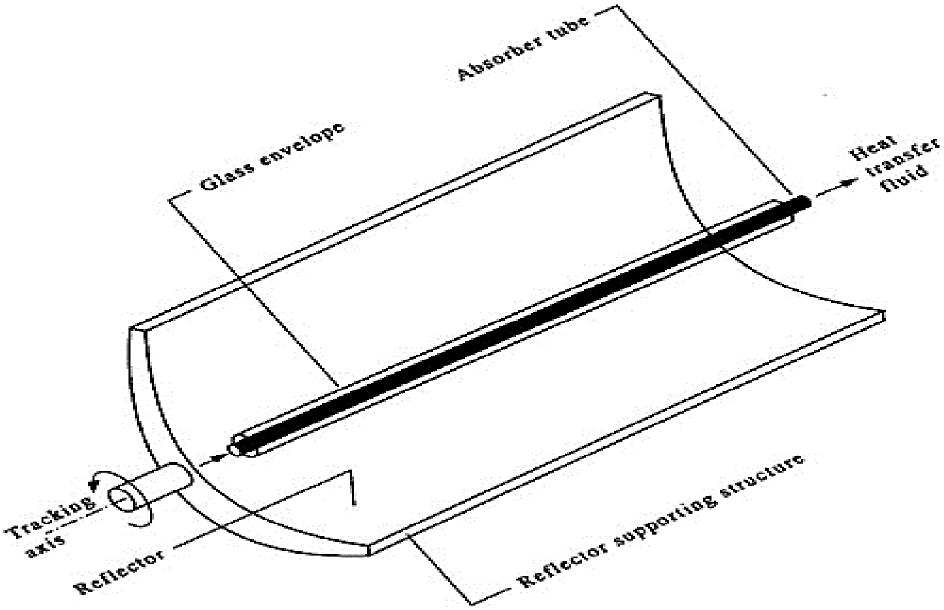


Figure 1.6: Parabolic Trough Collector System

1.5 Solar collectors Applications

- Solar water heaters mostly caters to the non-concentrated collectors. Solar water heaters are used for both hot water applications and at residents. The 100LPD flat-plate collecting system costs between Rs.22000 and Rs.26000. The 100LPD tube system is expected to cost between Rs. 15000 and Rs. 18000. The Ministry of New and Renewable Energy, GOI, provides a 30% subsidy on FPC systems, i.e. Rs.6600/-, and an ETC 100 LPD capacity system, i.e. Rs.4500/-. The Punjab Government has mandated the harnessing of water heating through solar systems in the following types of buildings: hot water processing enterprises.
- Government hospitals, hospitals, and nursing homes are all included.
- Hotels, motels, and banquet facilities
- Barracks in a prison, bars in a jail, bars in a jail, bars in a jail, bars in a jail
- The Punjab Urban Development Administration and Group Housing Societies have developed housing complexes.
- All residential buildings built on a 500 square metre plot are subject to the jurisdiction of the municipal/corporate and urban development authorities in Punjab.
- All public buildings, residential schools, schools, hostels, institutes of vocational training, district educational institutes, resorts and universities, etc.

- According to Punjab Energy Development Agency, solar water heaters in Punjab state are 16 lake capacity (PEDA).

1.6. Project Objective

There are three main objectives that must be achieved:

- Thermal Enhancement of collector.
- A approach for exergetic enhacement.
- A procedure for discovering the optimized conditions for thermal and exergetic enhancement.

1.7. Organization of Thesis

This classification of thesis has been done into 5 chapters as follows

CHAPTER-1

This chapter consist the framework of the research question, explaining the necessity for inexpensive and sustainable uses of solar water Heater and the objective of this study.

CHAPTER-2

This chapter comprises literature review, reviews the work that has been already completed in the field of solar collector and Solar heating system.

CHAPTER-3

This chapter consist the Methodology of experimental investigation of the analysis to investigate properties of solar radiation in solar collector.

CHAPTER-4

This chapter shows the modelling and design analysis of solar collector model using various techniques. This chapter consist results analysis and discussions on the better heat transfer rate of designed models of solar collector.

CHAPTER-5

Conclusion consists the key finding of this investigational analysis as well as possibilities for future.

CHAPTER 2

LITERATURE REVIEW

2.1. Literature Review

Nanofluid History

It was researchers at the University of Chicago's Argonne National Laboratory who were pioneer in coining the concept of nanofluids in 1995 as a novel group of heat transfer media that could be created by mixing metal and nonmetallic nanoparticles with base fluids such as water, ethylene glycol, and other solvents. According to many studies and investigations that have used nanofluids as fluids, the nanofluids thermal conductivity is evolved than that of regular fluids, suggesting a greater ability to efficiently transfer thermal fluids than ordinary fluids. Owing to the minute size of the particles, (10-30 nm), the wear rate is very low, but the temperature increases dramatically. There have been many efforts to improve system efficiency in different applications of nanofluids in sectors as diverse as microelectronics, the nuclear industry, automobiles, aeroplanes, and renewable energy sources, among others.

Nanofluids offer a number of benefits when it comes to improving heat transmission in a variety of applications. Because of their enhanced thermal characteristics for high heat transfer, many studies in the last decade have declared these fluids to be next generation fluids. The following factors contribute to improved heat transmission when nanofluids are used instead of traditional fluids.

- Nano particles added to base fluids result in a evolved and effective surface area of NP for heat transfer, increasing the quantity of heat transferred while occupying less space.
- Owing to the enhanced thermal conductivity of the fluid, adding Nano particles downsizes heat capacity of respective fluid.
- Turbulence is caused by NPs in the base fluid, which enhances rate of heat transfer .
- Brownian NP motion also contributes to heat transfer improvement.
- Nano fluid conductivity as the amount of nanoparticle rises and changes.

There was a focus on additional investigation of the above-mentioned nanofluid potentials. Hence In the fields of cars, solar energy, aerospace, medicinal, and electronics, usage of nanofluids has increased as technology progresses.

2.2. Literature Survey

Numerous research has been administered by academics on the computation of thermal performance in concentrating solar power systems. A large number of scientific articles have been published on their findings. In order to better recognize the features of nanofluids and anticipate their thermophysical properties, researchers have used a number of production techniques.

Evangelos Bellos et. al. [1] The research is pinpointed towards the meticulous and systematic examination of the thermal boom in parabolic trough collectors utilising nanofluid (Syltherm 800/Cu). Three different kinds of collectors were examined: the evacuated tube receiver, the non-evacuated tube receiver, and the non-covered tube. Variable values of the following factors are analysed in research: temperature, solar radiation, sun angle, wind speed, flow rate, temperature inlet, absorber emissions, and nanoparticle concentration. In addition, the study is conducted via the creation of an engineering equation solver mathematical model that is subsequently validated utilising experimental literature data. The results reveal that instances with the largest thermal losses have improved greatly and that the most effective use of nanofluids in the bare tube improves. Small flow rates and instances with increased emissions improve greatly. The greatest increase was 7,16 percent for the bare tube, 4,87 percent for the vacuum free receptor, and 4,06 percent for the removed receiver, with a flow rate of 25 L/min and a cermet cover. For 25L/min, the findings are 17.11 percent, 12.30 percent, and 12.24 percent, respectively, with a non-selective increase similar.

Evangelos Bellos et. al. [2] The aim of this research is to investigate the use of nanoparticles dispersed in thermal oil (Cu, CuO, Fe2O3, TiO2, Al2 O3, and SiO2) in the production of thermal oil (Syltherm 800). An intricate and meticulously dedicated analysis pertaining to flow rates ranging from 50 to 300 L min-1, for inlet temperatures ranging from 300 to 650 K, and for concentrations of nano particles ranging from 6 percent to 6 percent. The consequences of solar irradiation levels on the advancement in heat transfer efficiency have also been examined. In addition, a novel index for performance evaluation of working fluids in solar collectors is being created. In order to conduct the investigation, an engineering equation solver thermal model has been developed. According to the final findings, the Cu nanoparticle, along with CuO, Fe2O3, TiO2, Al2O3, and SiO2 are the most effective nanoparticles available. While the quantity of solar radiation varies, the amount of growth is greater for less flow, higher entrance temperatures, and higher concentrations of nanoparticles. However, the amount of rise is generally constant for the different quantities of flow.

Soteris A. Kalogiroue [3] The focused sunlight that reaches the receiver tube warms the solar energy liquid into usable thermal energy. The use of one axis is sufficient for monitoring the sun and hence the development of long collector modules. A comprehensive thermal model for a parabolic trough collector may be found in this article. Each thermal transfer method is considered in thermal analysis of the sensors: the convection to the tube, the ring between the tube, the glass cover and the glass overhead, a convection from the metal tube towards the ambient peripheral ventilation, and a radiation from the metal tube to the glass cover to the sky refractive pipe and the glasses surfaces. The model is developed in the Engineered Equation Solver (EES) and verified prior to the collector's evaluation of known collector performance.

Liu and Jordan et al. [4] Says that it is essential to priority the long-term performance of the collectors above the immediate rate of energy collection during construction of f collectors. A method has been progressive to determine the long-term presentation of collectors at various tilt levels and sites. This is a quick and easy method to calculate the results of a collector without having to do much study. Two of the most important measures used in these methods were the mean clearing index and the difference in the temperature of the air and the input water in the flat plate collector.

Xie et al. [5] Conductivity enhancement to optimise NPs mixed in the base fluid has been the focus of experimental study, and it has been discovered that adding Cu nano particulate matter to the basic fluid water has been a major role in improving water conductivity. The graphene nanofluid conductivity volume concentration of 0.5 percent increased by 7% to 8%, according to the findings.

Viskanta and Siebers et al. [6] In addition, it was discovered that flat plate collection operating at a constant temperature is less expensive than other platform collectors, which was previously unknown. For the same quantity of radiation the efficiency of the suggested radiator is more while maintaining constant temperature increases, which may be compromised by the advantage it provides.

Cooper et al. [6] The relationship between the change in heat loss and the angle of inclination of flat plate collectors has been experimentally proven. The speed of the wind, the slope of the plate, and the temperature of the surrounding air are all factors that contribute to the loss of heat from top surfaces. When plate collectors are angled below 55 degrees, the temperature and absorbance of the plates vary very little, and the temperature of the plate and absorption is not affected by the loss of heat.

Chiou et al. [7] His research looked at the impact of non-uniform flow delivery on the presentation of flat plate collectors, and the results were published. According to the results of the numerical research, in some other cases, the variation in flow efficiency hampered the distribution of the system by roughly 20% or more than 20%, depending on the case.

Lightstone and Hollands et al. [8] They found in their research that low-flow systems caused a rise in temperature that was about 18% – 25% higher than that generated by high-flow systems, according to their findings. Also discovered were lower costs and higher efficiency for low-flow systems, with low-flow collector systems outperforming their counterparts by an astounding 34 percent. Furthermore, the Low Flow Collector provides advantages in terms of handling and purification, as well as cost reductions that are considerable.

Enibe et al. [9] The solar heating system was designed and built, and then put through a series of tests to determine its efficiency. The whole system consisted of a glazed platform collector with a material in the phase change (PCM). In his investigational study, he collected information on the number of variables that were present and varied the temperature between 20°C and 55°C. The system's efficiency was found to be up to 56 percent when exposed to the maximum amount of incoming solar light.

Choi et al. [10] , Masuda et al. [9] and Lee et al. [10] They have shown in their research that solid metal and non-metal particles may be split into smaller sizes in order to be suspended more effectively in fluids. This resulted in additional advancements in the idea of microparticle suspension in water. Nanometric fluids are described as the nanoparticular suspension of a base fluid for a broad variety of applications. The creation of nonaluminum was accomplished via the use of nanoparticles of various materials, including metal oxides (AL2O3, TIO2, CuO), ceramic, and metal alloys (Al, Cu, Ti, Si, Mg...).

Wang et al. [11] Following his study, he discovered the thermal conductivity and flow resistance of nanofluids, in addition to the viscosity of nanofluids. According to the findings, the addition of NPC to nanofluids enhanced their conductivity as well as their flow resistance. The improvement in heat transmission has been shown in smaller particles more than in larger particles, according to the research. For nanofluids, the concentration of nanoparticles, as well as their size, shape, and operating temperature, as well as their stability in the base fluid, all have a significant effect on the thermal properties of the fluid. In his study, he discovered that the predicted nanofluid properties did not match up with his actual observations, and that temperature changes had an impact on nanoparticle stability in the base fluid.

Lee et al. [12] The following method is used to calculate the thermophysical properties of ethylene glycol and water particles Al2O3 and CuO when they are mixed. The conductivity of nanofluids was determined via an experimental research, which revealed that Nanofluid conductivity is higher than basic fluid conductivity.

Choi and Eastman et al. [13] They discovered that nanofluids based on Al2O3 and CuO enhanced the conductive mode of heat transfer by 22% for volume 2.5 percent and particle size by 30 nm for volume concentration in their research.

Xuan and Li et al.[14] According to their findings, elements smaller than 10 nm in size showed In the size of the base fluid greater stability than particles less than 10 nm. Researchers discovered that adding laurite salt to the base fluid in small quantities may enhance NP scatter capacity while simultaneously increasing conductivity in the base fluid, according to the study.

Das et al. [15] As a result of temperature changes, his study revealed that the effective conductance of CuO nanofluid increases between 15 and 54 degrees Celsius (Fahrenheit). For nanofluids made of ethylene glycol and water, the effective conductivity varied with temperature and the volume fractions of NPs in the base fluid varied with temperature and volume fractions in the base fluid.

Masuda et al. [16] He discovered that the TiO2 suspended nanofluid thermal conductivity of the Al2O3 was 31 percent and 11 percent greater for the NPC, respectively, than that of the basic fluid, with a 4.2 percent difference between the two.

Anoop et al. [17] Nanofluid based on al2O3 water with nanoparticles with sizes ranging from 40 nm to 90 nm was produced. Heat transfer for smaller particles was found to be increased, and the stability of the foundation fluid was found to be improved according to the results. The thermal properties of nanofluid on nanoparticles were the focus of his research, which was published in Nano Letters.

Murshed et al. [18] The conductivity improvements of TiO2 spherical and cylindrical nano-particles floating in water were 30% and 32%. respectively, at volume concentrations of 3% and 3.6%, respectively, when compared to the control.

Zhou and Gao et al. [19] The concept of differential media theory is introduced for the purpose of estimating effective nanofluid conductivity. After doing their research, they came to the conclusion that the thermal conductivities of nanofluid are enhanced when nanoparticles are produced; nevertheless, the stability of fluid nanoparticles is a concern.

Boungiorno et al. [20] Has performed an activity to evaluate the thermal conductivity by experimental techniques such as optical analysis, hot wire and stable state analysis of nanofluids, with samples obtained from about thirty different organisations. His research focused on the study of nano-particles of metal oxide in both aqueous and non-aqueous solutions, as well as the study of different types of nanoparticles suspended to varying NPC in base fluid. Detailed information on all nanoliquids has been collected, with results ranging from 5 percent to 15 percent of the total. Nanofluid thermal conductivity increases proportional to the number of the fluid nanoparticles. As a result of his research, he discovered that his experimental results were consistent with Maxwell's effective theory of the medium. He did not consider the effect of temperature on his study, and he used NPC values that were too low for his purposes.

Zhu et al. [21] It has been predicted that the Al2O3 water based nanofluid conductivity would have variable PH values. It was pointed out that the owners of nanofluid are very sensitive to the PH of the base fluid, and as a result, the PH of nanofluid stays within substantial limits. In the presence of chemical dispersants, nanofluid conductivity rose by 10 percent to 12 percent, while nanofluid conductivity was 0.25 percent.

Sundar et al. [22] The conductivity of nanofluids has been shown to rely on Nanoparticles volume and temperature. The findings of the experiments show that Fe3O4 water-based nanoparticle fluid with concentrations up to 2 percent improves in conductivity by 30 percent to 35 percent when the base fluid temperature is 55 degrees Celsius.

Wen et al. [23] Conductivity for water-based nanofluids was anticipated in his research. It incorporated stabilisers in base fluid and found that changes in nanofluid's thermo physical characteristics are minimal when comparing with the non-addition of stabilisers. In his experimental work he also found that, after a few hours of operation, the addition to a specific limit in basic fluid of nanoparticles triggered the separation phase. Nanoparticles based on water Al2O3 have been fully disconnected for concentration of 2.3 percent nanoparticles.

Das and Vajjha et al. [24] CuO-based In his experimental effort, he has recorded nano fluids, which include the base fluid, which is a mixture of water and ethylene glycol, and he has found thermal conductivities of al2O3 in the process. When he used nanofluids at 3-6 percent volumetric concentration and a temperature range of between 300 K and 355 K, he saw an increase in conductivity of between 20 and 24 percent, indicating that the nanofluids were more conductive.

Otanicar et al. [25] His study on nanofluid-based direct sunlight absorption FPCs was published in Nature. The effective conductivity of nanofluid is increased by 20 to 25 percent at nanoparticle concentrations ranging from 0.5 percent to 2 percent. The effectiveness of flat plate collectors in solar radiation may be improved by up to ten percent.

Ghoneim et al. [26] The effectiveness of solar flat plate collection was discovered to be affected by forced and natural convective heat transfer processes. Air on the ground and on top of the plate collector creates a barrier to heat transfer, reducing the effectiveness of the collecting system. In the case of forced and natural convection, it has been demonstrated that calculating the coefficients of bottom and top thermal transfer for each of the two modes of convection results in less resistance to heat transmission flow and greater coefficients of loss for an optimal thickness of 3 mm air layer.

Sughanti et al. [27] In his study, he found an improvement in heat transmission for ZnO particles floating in water, which he saw experimentally. According to the findings of his research, the viscosity of nanofluids increases by 7 to 8% at temperatures below 38°C when particles are not in direct contact with the fluid. If the maximum nano-fluid particle concentration is 2.7 percent or higher and the maximum nano-fluid particle concentration is raised, system performance at pumping power and flux resistance is reduced.

Goudarzi et al. [28] His experimental research showed that CuO nanoparticles floating in water increased their efficiency as a result of the random fluctuating movement of NPs in the base fluid, as shown by the results of the study. The fluctuating random motion of the NPs is referred to as the Brownian motion in certain circles.

Yousefi et al. [29] The efficiency of an Al2O3-based solar direct absorption system. nanofluid-based water has been studied, and it has been discovered that the efficiency of flat platform collectors improves with increasing absorptions of NPs in the base fluid (base fluid NPs). The rate of heat transfer decreases as the size of the nanoparticles increases. The effective nanofluid conductance may be improved by up to 4 percent -9 percent for nanoparticle volume fractions ranging from 0.2 percent to 0.4 percent.

Reddy and Rao et al. [30] Various combinations of water, ethylene glycol, and TiO2 were used to evaluate three different kinds of Nanofluids.

- The first nanoparticles of water suspended in suspension
- A second solution containing water and ethylene nanoparticles
- Ethylene glycol nanoparticles are used in a third combination.

The greatest conductivity improvement is obtained in the water-TiO2 nanofluid. The effective conductivity of nanofluid, which consists of a mixture of water and ethylene glycol at concentrations ranging from 0.2% to 5%, is substantially elevated. In ethylene glycol, NPs showed the least amount of conductivity improvement in three different combinations. It has been shown that NP stability is best in water.

REFERENCE	YEAR	REMARKS
[1]	2020	The maximum enhancement attained by employing nano particles in the parabolic collector was obtained for the bare receiver tube case followed by non-evacuated and evacuated type receivers. Maximum thermal losses were there for bare type receiver which provided a greater margin for the enhancement.
[2]	2018	The most effective nano fluids for thermal enhancements of evacuated receiver parabolic collector are copper, copper oxide, aluminium oxide and silicon oxide. The work carried in this paper are employed for non-evacuated type receiver with air being trapped owing to convection as well as radiative losses.
[3]	2012	The thermal modelling of the examined parabolic collector is done considering all the convective and radiative losses from receiver to heat transfer fluid as well as from glass cover to the ambient and losses taking place between glass cover and receiver.
[16]	2019	The enhancement in the heat transfer properties were better when Ti02& Al203 based nano fluid was implemented.

2.2 Thermophysical Properties of Nanofluids

2.2.1 Models of Thermal Conductivity

A variety of mathematical models developed to certain the credibility of thermal conductivity of nano-base fluids, which is due to the fact that nano-base fluids have a higher thermal conductivity than base fluids. Several scientists established enhancment in effective nanofluid thermal conductivity, while others have argued that the rise is more consistent with the average effective theory of an increase in thermal conductivity than with the experimental evidence. Several models have yielded results that are comparable to those obtained via experimental investigations, but more research is needed to determine precisely how high the thermal conductivity of nanofluids may be increased. The models that are offered may be divided into two categories: static and dynamic.

Static Models

Form, size, concentration of nanoparticles, and stability of nanoparticles are all taken into account in these models, which are created on the foundation that heat transfer is diffused in both solid NP and liquid base fluids.

Dynamic Models

When determining the effective thermal properties of nanofluids, the dynamic model takes into consideration the movement of nanoparticles, while the static model does not take into consideration nanoparticle mobility at all. Because of this, it is imperative to consummate that the random mobility of nanoparticles produces an even greater enhancement in effective nanofluid conductivity than previously thought.

Below are a number of enhanced models produced by scientists for calculating the effective conduction of nanofluids.

Maxwell et al. [31] The model was the first model to be developed for estimating the conductivity of nanofluids. He looked at scattering spherical particles of small sizes while dismissing the possibility of interactions with nanoparticles. In the presence of an NP concentration of %, the Maxwell equation estimates the efficacy of those spherical particles with a knp and the suspended thermal conductivity of the base liquid kb:

$$\mathrm{kn}F = \mathrm{kp}+2\mathrm{kb}-2ø(\mathrm{kb}-\mathrm{kp}) \qquad (2.1)$$

$$kb \qquad kp+2kb+ø(kb-kp) \qquad (2.1)$$

Bruggemen et al. [32] Present a model for the random motion and dispersion of nanoparticles mixed in fluids that takes a wide range of factors into consideration for the homogenous nanoparticular blending of the spherical shape while also taking the random motion and dispersion of nanoparticles mixed into the base fluids into consideration. For low concentrations of nanoparticles up to 1.5 percent, the findings obtained with this model are similar to the findings obtained with the maxwell model; however, the findings obtained with the two models are substantially different for higher concentrations of nanoparticles. For higher concentrations of nanoparticles, the Bruggemen model performs better than the other models in terms of agreement with experimental results.

Yu and Choi et al. [34] They shared their model for computing nanofluid thermal conductivity, which includes molecules with a layer-style structure that interact with solid nanoparticles. They also shared their model for computing nanofluid thermal conductivity. Although this layer is very thin, it has an impact on thermal efficacy.

2.2.2 Specific Heat Capacity of Nanofluid

It is the quantity of energy needed to increase object temperature per unit. In the energy equation, it is extremely essential that the thermal capacity of nanofluids be calculated properly, so that thermal performance analyses of nanofluid are conducted.

Pak and Cho et al. [35] Following their research, they came up with an equation to regulate the specific heat of nanofluids, which is

$$Cpnf = ØCpnp + (1 - \varphi)Cpbf \qquad (2.7)$$

Xuan and Roetzl et al. [36 They have produced an equation after their study to establish the specific thermal value of nanofluids.

$$(pC\ ) \quad = Ø(pC\ ) \quad + (1 - \varphi)(pC\ ) \quad (2.8)$$

These two theories are in excellent agreement with experimental findings.

The researchers made the following findings after completing their study on estimating the specific heat of nanofluids

- Because nanomaterials have a greater conductance than liquids, the specific thermal energy of the nano-fluid is lower than those of the particular thermal energy of the basic fluids.
- A reduction in the specific nanofluid heat is seen with an increase in NPC.
- Specific nanofluid heat fluctuates insignificantly as a function of temperature variations.
- Because of the large thermal capacity of the fluid, the variation in the size of the nanoparticles has a very little consequences on the change in specific heat owing to the fluctuation in particle size.

2.2.3 Density of Nanofluid

When applied to energy and momentum equations, the mass of the fluid is characterised by its thermo-physical qualities as well as other thermo-physical characteristics. Because of this, when free convection is present, it is essential that the boosting force and density differential of the fluid work properly for the system to be successful. Increased nanofluid density differential has an effect on natural convection processes, This has consequences on the performance of nanofluid heat transfer. The density of nanofluids is affected by temperature.

The density of the solid particles added to the liquid density is enhanced as compared to the density of the regular fluid. If the number of NPs in the base fluid is larger, the nanofluid density enhances as well.

Nanofluid density can be calculated by mixture theory is given by

$$\mathrm{pnf} = \varphi \mathrm{pnp} + (1 - \varphi)\mathrm{pbf} \qquad (2.9)$$

The following observations regarding nanofluid density fluctuation may be made based on existing literature:

- The density of nanofluids is greater than the density of the fluid basis.
- As the concentration of nanoparticles rises, the density of nanofluid increases as a result of the high density of NPs.
- Due to the decreased intermolecular interactions between base fluid molecules as a result of increased temperature, the nanofluid density falls with temperature rise, and the overall fluid density change is mostly dependent on the property of base fluid.

2.2.4 Viscosity of Nanofluid

In the early stages of nanofluid viscosity calculations, it was discovered that all of the theoretical equations available for determining viscosity were derived from Einstein's study, which was established on ground of assumption that a diluted linear viscous fluid contained spherical nanoparticles. This was confirmed by subsequent investigations. Initial estimates of the viscosity of spherical nanofluid-containing particles were made by Einstein et al. utilising hydrodynamic phenomenon equations[37] to determine their size. Regarding the movements of particles in the surrounding fluid, the equation is illustrated in relation to the motions of particles in the surrounding fluid

$$\mu\mathrm{eff} = (1 + 2.5\varphi)\mu\mathrm{bf} \qquad (2.10)$$

After that, Brinkman et al. [38] presented the expanded Einstein equation for medium concentration in his research.

$$\mu\mathrm{b}F\ (1-\varphi) \qquad 2.5$$

Batchelor et al. [39] The following equation was presented in his study, which incorporated the impact of Brown's random motion on the mass movement of spherical particulate suspension into nanofluids:

$$\mu\mathrm{eff} = (1 + 2.5\varphi + 6.5\varphi 2)\mu\mathrm{bf} \qquad (2.12)$$

2.2.5 Consequences pertaining to Nanoparticle Size on Nanofluid Thermophysical Properties

Xie et al. [40] During the course of the investigation, SiC-based nanofluid was generated with particle sizes ranging from 25 to 400 nm in order to investigate the impacts of particle size on effective nanofluid conductivity.

Kim et al. [41] In his research, nanofluids based on Al, Zn and $TiO2$ used water and ethylene glycol as base flubids at volume concentrations of nPs of as high as 3 percent were modified in their thermal conductivity. In his works, he demonstrated that nano fluids attain maximum efficient conductivity via the addition of 25-60nm particles to the base fluid.

Teng et al. [42] When it comes to particle size NPC and temperature, the effect on the conductivity of $Al2O3$ water-based nanofluid was shown in its publication.

Wang et al. [43] In his research, he discovered that the usage of very small particles at constant volume concentrations of nanoparticles resulted in a reduction in the specific heat capacity of nanofluids.

Diverse research have shown that a decrease in nanoparticle size, when coupled with a base fluide and a drop in specific heat, results in an increase in conductance.

CHAPTER 3

MATHEMATICAL MODELLING OF SOLAR PARABOLIC COLLECTOR

3.1. Overview

A physical model of the compound parabolic collector, as well as a mathematical model of efficiency, are required for a thorough investigation of the collector's function in light of the objectives of this work. It is explained in detail in this chapter how the physical model used for the study was developed, as well as all the formulations that were used to achieve the goal of the present work.

3.2 Modelling of the Solar Parabolic Collector

The Parabolic collector module developed for this study includes a complex cylindrical-parabolic reflecting surface as well as a copper tube with a diameter of about 15 mm. The schematic diagram is shown in Fig 3.1.

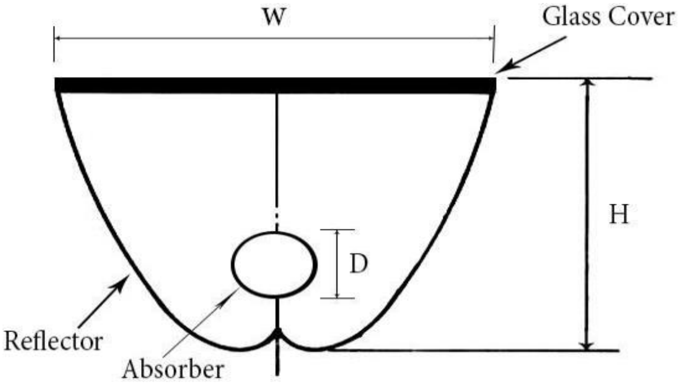


Figure 3.1: Schematic Diagram of the parabolic collector

The sun energy is converted into heat by the pipe collector. The pipe absorber is coated with a variety of colours that are both highly absorbing and low in emissivity (r). The reflector area has a high refraction coefficient (m). In between the pipe absorber and the reflector, there is a gap (hole) that prevents heat from being transmitted from the tube to the reflector. When syltherm 800 is used as the working liquid, it is circulated through the collecting pipe in a turbulent fashion. The collector's apparatus is protected by a transparent cover layer of glass, which prevents the formation of a reflecting zone and allows the amount of heat loss from the surrounding tubing pipe absorber to be decreased significantly.

Aluminum was used in the construction of the reflector. Physical properties of solid materials were taken into account while determining their temperature. Perfect gas, which cannot be compressed, is used to represent the air trapped in the hole. The thickness of the aluminium reflector should be measured in millimetres (mm). The top of the glass cover has a thickness of 4 mm. The reflector has a length of 1 m when seen in the axial direction. In this study, a concentration ratio of 2 was used. The circular receiver was split into two halves by a radius derived from the angle of 1 mm between the receiver and the bottom of the box, and the two parts were then connected together. Tilt-angle values of 45°, as measured by the ground, have been chosen. Copper is utilised as a material absorber in this application. The copper tube has a thickness of one millimetre (mm).

3.4 System description

In this investigation, the turbulent flow through the absorber is taken into account. In the current investigation. In the absorber pipe, there is a presence of solar radiation. Solar rays pass through the transparent glass cover of the collecting device and into the gadget itself. After passing through the transparent cover of the pipe, a part of the solar energy falls directly onto the absorber. After being reflected by the reflector and falling at the pipe absorber, a part of the solar energy travels through the transparent pipe cover layer to reach the receiver.

3.5 Convection and radiation heat transfer formulations of the model

Many different ways of heat transfer in the CPC model, as previously stated, have been explored in this area. Generally speaking, the primary modes of heat transfer are radiation and convection. In this particular case, performance is inconsequential.

3.5.1 Receiver – aperture

Eq (3.5) describes the heat transmission between the receiver and the opening through convection. [2]

$$q_{Cr \rightarrow a} = h_{Cr \rightarrow a}(T_r - T_{ap})$$

$$\text{Where, } h_{Cr \rightarrow a} = \frac{Nu_{r \rightarrow a} k_{air,a}}{D_e} \qquad (3.5)$$

In order to better understand convective heat transfer correlations for CPCs, Many research and hypothesis investigations were conducted [2, 3, 4]. It was indicated in each of the studies that there was a relationship between the numbers Nusselt and Grash. A heat transfer correlation that takes the acceptance angle into consideration and angular inclination has been developed by Eames and Norton[4]. [citation needed] The form of the relationship was the relationship itself:

$$Nu_{r\rightarrow a} = 0.398\left(\frac{H}{W}\right)^{0.365} \times \frac{Gr_{r\rightarrow a}^{(0.1825+0.0736+\cos(\theta-45))}}{1.24+0.066054\cos(\theta-45)} \tag{3.6}$$

Where, $Gr_{r\rightarrow a}$ evaluated from

$$Gr_{r\rightarrow a} = \frac{g\beta(T_r - T_a)}{\nu^2} \tag{3.7}$$

The findings of Eames and Norton[4] provide a linear plot across the range of interest for the angle dependent Nu-Gr correlations. The system that Eames and Norton (1993) have studied more carefully than any other system corresponds to the modelling of the CPC system. Rabl[6] has been parameterised for conductivity and kinematic viscosity from the terms:

$k_{air} = k_o T_a^{0.7}$ (3.8)

Where, $k_o = 4.86\times10^{-4}\ Wm^{-1}K^{-0.7}$ (3.9)

And $\nu_e = \nu_o T_e^{1.7}$ (3.10)

Where, $\nu_o = 9.76\times10^{-10}\ m^2s^{-1}K^{-1.7}$ (3.11)

3.6. Collector Dimensions And Selective Coating

In this study the thermal and exergetic performance of LS-2 parabolic collector operating with syltherm_800 as base fluid and other nano particles infused in it are done.

DESIGN DATA OF LS-2 COLLECTOR

- D_2(absorber inner dia)=0.066m
- D_3(absorber outer dia)=0.070m
- D_4(glass envelope inner dia)=0.109m

- D_5(glass envelope outer dia)=0.0115m
- W(collector aperure width)=4.8235m
- L(collector length)=7.8m
- Collector reflectance=0.935
- Cover transmittance=0.95
- Inserted pipe dia=0.0528m
- Geometry accuracy of collector=0.98
- Shadowing error=0.974
- Selective absorber coating=luz cermet

This section presents the thermal equations used in modeling the parabolic through collector. The thermophysical properties of all fluids were extracted from the EES library. After the thermal model or code is written out on the EES program, the program takes a few seconds to run. The LS2 module is modeled by feeding its physical dimensions of the collector listed in Table 1 into the equation

3.7. Heat transfer analysis

The present work uses a thermodynamic model based on the mathematical approach presented in ref [53]. The details of the model and physical interpretation for each term used have been discussed in [54,55]. Temperature-dependent characteristics of all liquids and the temperature changes are accounted for using the EES program. The sources used by the EES program to evaluate the properties of Therminol VP1, ,Syltherm 800, can be found in ref. [56–63] respectively. In the

model, The usable temperature absorbed by the PTC work fluid should be determined accordingly:

$$Q_u = \dot{m}_r C_{pr} (T_{ro} - T_{ri})$$

Where $\acute{U}_{rr}$ is a PTC work fluid mass flow rate, C_{pr} is a fluid specific heat, T_{ro} and T_{ri} are the PTC leaving and entering fluid temperatures correspondingly Tri . The usable energy (Qu), produced by the PTC, may be defined in accordance with the convective heat transfer between absorber and heat transfer fluid.:

$$Q\_u ,Conv = hf*Ac* [T2 – T1]$$

$T_{fm} = \frac{\text{Tinlet} - \text{Toutlet}}{2}$

Where mean fluid temperature of the fluid is defined as the average of inlet and the outlet temperature of heat transfer fluid and hf , A_c are the heat convection coefficient of fluid and effective area of the absorber pipe respectively which established contact with heat transfer fluids for convection heat transfer mechanism.

Depending on the external diameter of the receiver tube (Dro, Dri, hfi, and kr), the internal diameter of the recipient tube, the inner coefficient of heat transfer inside the receptor tube, and the thermally conductive heat transfer of the recipient tube are calculated, as well as their respective values. The convective coefficient of heat transmission (hf) is calculated:

$$Nu = \frac{h_f \cdot D_{ri}}{k}$$

where Nu is the working fluid Nusselt number.

The parabolic trough collector uses the thermal efficiency:

$$\eta_{th} = \frac{Q_u - W_{pump}}{G \times A_{ap}}$$

where G is the solar radiation in W/m^2

The pump work in the PTC could be calculated as follows:

$$W_{pump} = \Delta P \times Vf/\eta_{elect}$$

3.8 Exergy efficiency

The exergy efficiency of the PTC could be calculated as follows:

$$\eta_{ex} = \frac{E_u}{E_s}$$

The useful exergy Eu and solar exergy Es is obtained as follows:

$$E_u = Q_u - \dot{m} \cdot C_p \cdot T_0 \cdot \ln\left(\frac{T_{out}}{T_{in}}\right) - \dot{m} \cdot T_0 \cdot \frac{\Delta P}{\rho_{fm} \cdot T_{fm}}$$

$$E_s = A_c \cdot G \cdot [1 - \frac{4}{3} \cdot \left(\frac{T_0}{T_{sun}}\right) + \frac{1}{3} \cdot \left(\frac{T_0}{T_{sun}}\right)^4]$$

where $T0$, Tfm and $Tsun$ are the ambient temperature, the mean fluid temperature in PTC, and sun temperature, respectively.

The exergy destruction can also be calculated using the following equations:

$$E_{d,\Delta P} = T_0 \cdot \dot{m} \cdot \frac{\Delta P}{\rho} \frac{\ln\left(\frac{T_{out}}{T_{in}}\right)}{T_{out} - T_{in}}$$

$$E_{d,s-r} = \eta_{opt} \cdot E_s - Q_{abs} \cdot (1 - \frac{T_{am}}{T_r})$$

$$E_{d,r-f} = Q_u \cdot \left(1 - \frac{T_{am}}{T_r}\right) - E_u$$

Where

$E_{d,\Delta P}$, $E_{d,s-r}$ and $E_{d,r-f}$ are the exergy destruction due to fluid friction, the exergy destruction due to finite temperature difference heat transfer from the sun to the receiver, and exergy destruction from the fluid in the receiver. Qabs is the absolute solar energy intercepted from the sun and ηopt is the reflector efficiency. The entire devastation of exergy by PTC is the sum of the value and is derived as follows:

$$E_d = E_{d,\Delta P} + E_{d,s-r} + E_{d,r-f}$$

3.9 Thermal properties of the examined nanofluids

Three different nanofluids consisting of copper nanoparticles are compared used in this study. The base fluids used are syltherm800 and therminolVP1, and used nanoparticles. The nanoparticles volume concentration used in this study ranges between 0 and 6%, and the equations used in This research is aimed at determining nanofluid thermophysical characteristics do not account for the size of the nanoparticles which should range between 10 – 100 nm [26]. The density of the nanofluids (nf) can be calculated from the nanoparticles volume fraction (φ) as follows [27]:

$$\rho\text{nf} = \rho bf . (1 - \varphi) + \rho np . \varphi$$

The specific heat capacity of nanofluids may be determined using

$$c_{p,nf} = \frac{\rho_{bf}.(1-\varphi)}{\rho_{nf}} . c_{p,bf} + \frac{\rho_{np}.\varphi}{\rho_{nf}} . c_{p,np}$$

This work presents a comparative and parametric thermal performance investigation of various mono and hybrid fluids operating in the PTC. The nanofluids used are Cu0/Syltherm800, Cu/Syltherm 800, Fe2O3/Syltherm800,Al2o3/Syltherm800 and SiO2/Syltherm800 while hybrid nano fluids investigated where Ag-Mgo/Syltherm800,Ag-Zno/Syltherm800,Ag-Ti02/Syltherm800 and Al2O3-Ti02/syltherm800. The reason behind employing these hybrid and mono nano particles were their earlier examination done in literature which propelled us to do a comparative study as no results were available were for their comparative study and impact of these nano particles on exegetic enhancement of the examined collector.

Furthermore, the result of adding copper nanoparticles on the thermal performance of , Therminol VP-1, Syltherm 800 are also investigated, and an optimization is performed to ascertain the optimum condition of nanoparticle concentration, volume flow rate, and input temperature to give the maximum thermal and exergetic efficiency for most efficient mono and hybrid nano fluid used in the study. The nanofluids used are Cu0/Syltherm800, Cu/Syltherm 800, Fe2O3/Syltherm800,Al2o3/Syltherm800 and SiO2/Syltherm800, and the results of the study are summarized as follow:

- The thermal efficiency of the collector increases with the growth in the flow rate of the working fluid.
- The effect of the inlet temperature on PTC thermal efficiency is much higher than the effect of flow rate.
- The use of nanofluids in the PTC is relevant only in the case of thermal oils while it is not relevant in the case of liquid sodium and pressurized water due to the high thermal properties of those fluids.
- The exergy efficiency for all working fluids increases with an increase in nanoparticle
- concentration, this is due to the improved convection heat transfer coefficient in the absorber as a result of nanoparticle loading.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

Parabolic Solar Collector are utilized and caters to various applications in few domestic and many industrial domains for medium to high temperature heating applications. The simple design and excellent dependability of these collectors worldwide are extensively utilised. A system performance can be described as an amalgamation of its respective constituents and the harmony pertaining to these constituents. Parabolic solar collector systems are need to be certain with the variations in thermal conditions, ambient conditions and chemically occurring reactions. These characteristics are achieved by the amalgamation of its constituents. The absorber plate, insulation, transparent cover, flow tube, and box are the main constituents of a parabolic solar receiver. Other minor components include the flow tube and box. The optical properties of the absorber effect are used to evaluate the thermal presentation of the Parabolic Solar Collector. The performance of the parabolic solar collector is also used to evaluate the absorber's design parameters and parameters. The consequences of enhancement in heat transfer properties due to inclusion of nano particles in heat transfer fluid is being examined. According to the research, the thermal performance of the system is influenced by volumetric flow rate, inlet temperature and concentrations of the nano particle in the base fluid. By examining the optical and design features of the system, it is possible to determine its thermal performance. This is accomplished via the use of the transparent cover effect. The contact between the absorber plate and the device's glass cover affects the device's thermal performance. The type of insulating material used to keep a system warm has an impact on its thermal performance.

4.2. Model Validation Analysis

- In this the results from the developed model are related with the outcomes from the literature.
- It is very well evident that there is minimal amount of deviation between the data of model and literature with respect to the thermal efficiency.
- Hence this model could be considered to be validated.

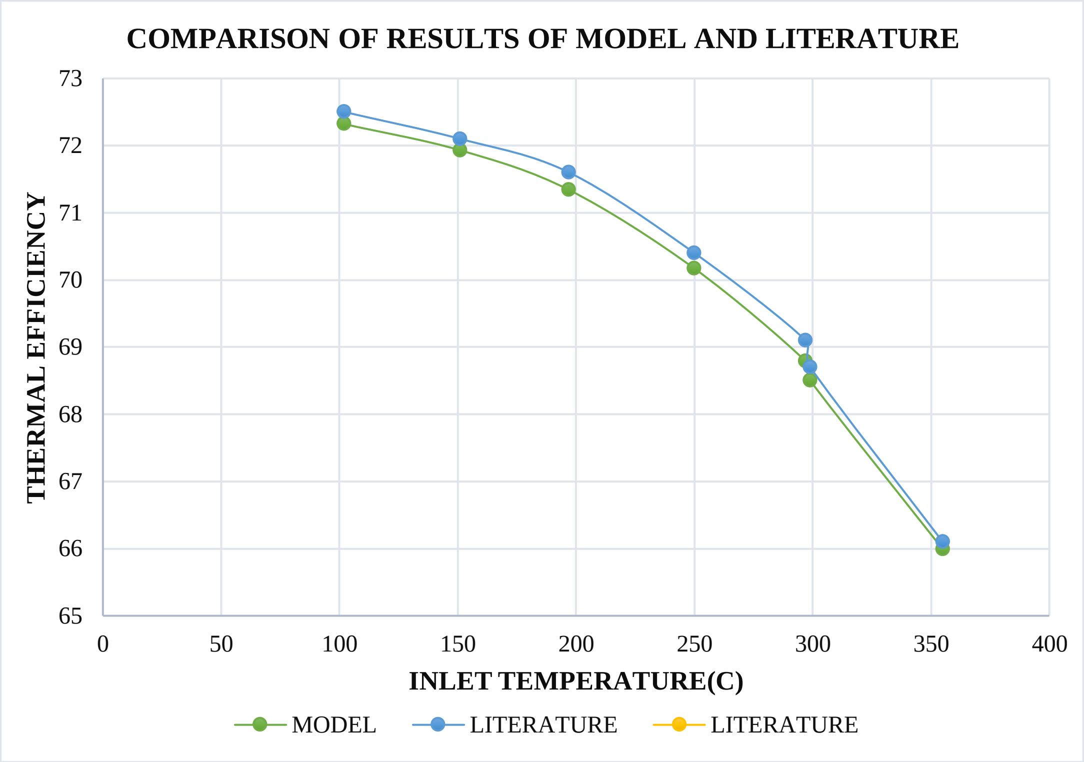


Figure 4.1: Comparison developed model results of Literature model

4.3.Thermal Efficiency Variations With The Inlet Temperature

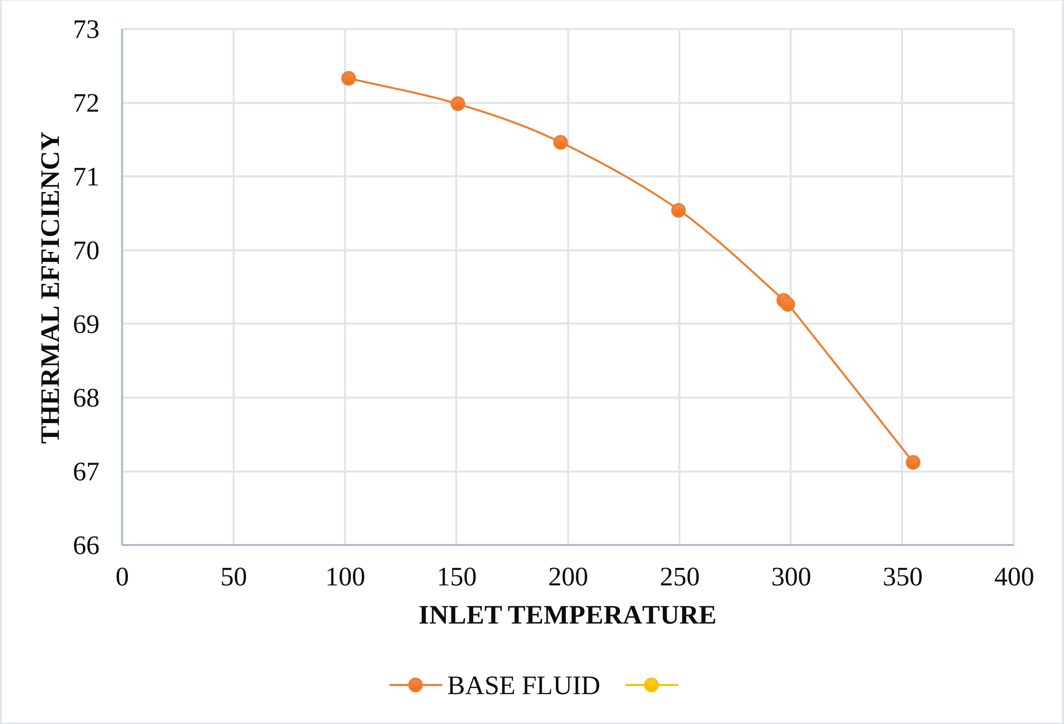


Figure 4.2: Variations of Thermal Efficiency as per Inlet Temperature using Base Fluid

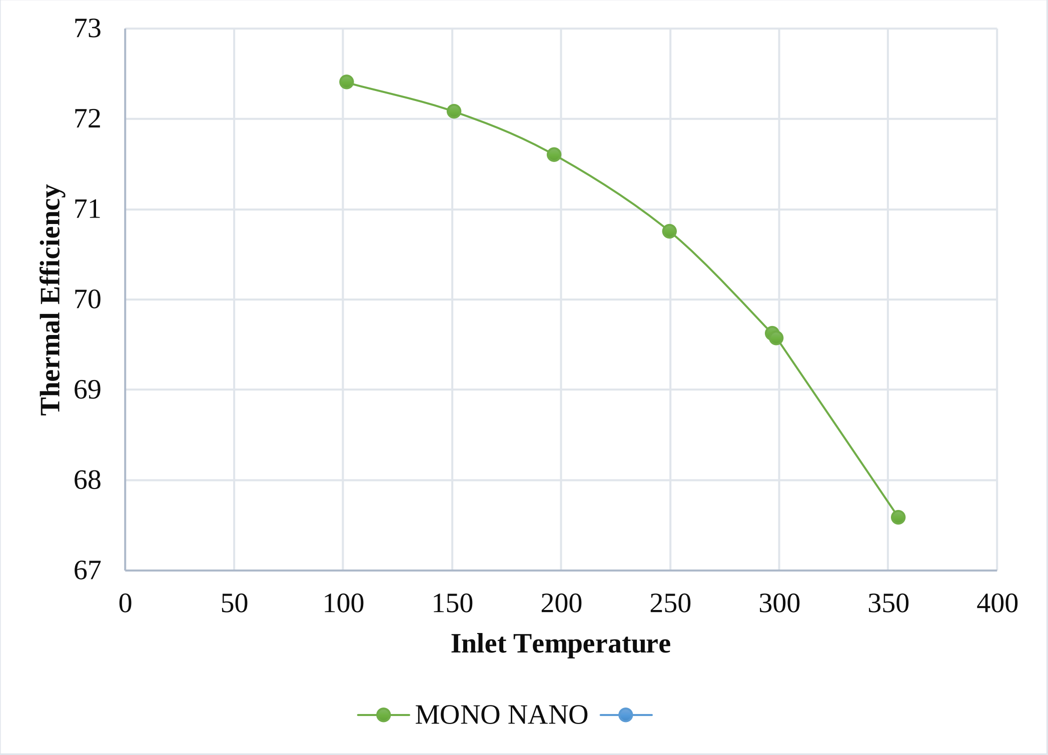


Figure 4.3: Variations of Thermal Efficiency as per Inlet Temperature using Mono Nano Fluid

- As inferred from the graph 4.2 it is clearly visible that thermal efficiency is decreasing owing to the increment employed in heat transfer fluid intake temperature.
- It is due to the fact that at high inlet temperatures there is greater radiation and convection losses due to high temperature diff between fluid and absorber and absorber and atmosphere.
- The same trend is observed for the nano fluids also.

Parametric study with the volumetric flow rate of the base fluid.

This segment graphically investigates heat performance and heat performance improvement by volumetric rate of flow. Initially, the geometrical investigation is applied using purified thermal oil. Figure 4.4 demonstrates the variation in thermal performance for 3 distinct volumetric rates of flow at a given set of input temperatures of approximately L/min, 75 L/min, & 100 L/min. At certain inlet temperatures, the pattern demonstrates that a greater volumetric rate of flow leads to improved thermal performance. Since a enhanced and evolved volumetric flow rate of heat transfer fluids results from a enhanced volume rate of flow, the usable heat gain of the examined collector increases. Moreover, at greater input temperatures, thermal performance varies significantly with the volumetric rate of flow. As a consequence, a better thermal performance may be attained with a potentially lower temperature as well as a higher volumetric rate of flow.

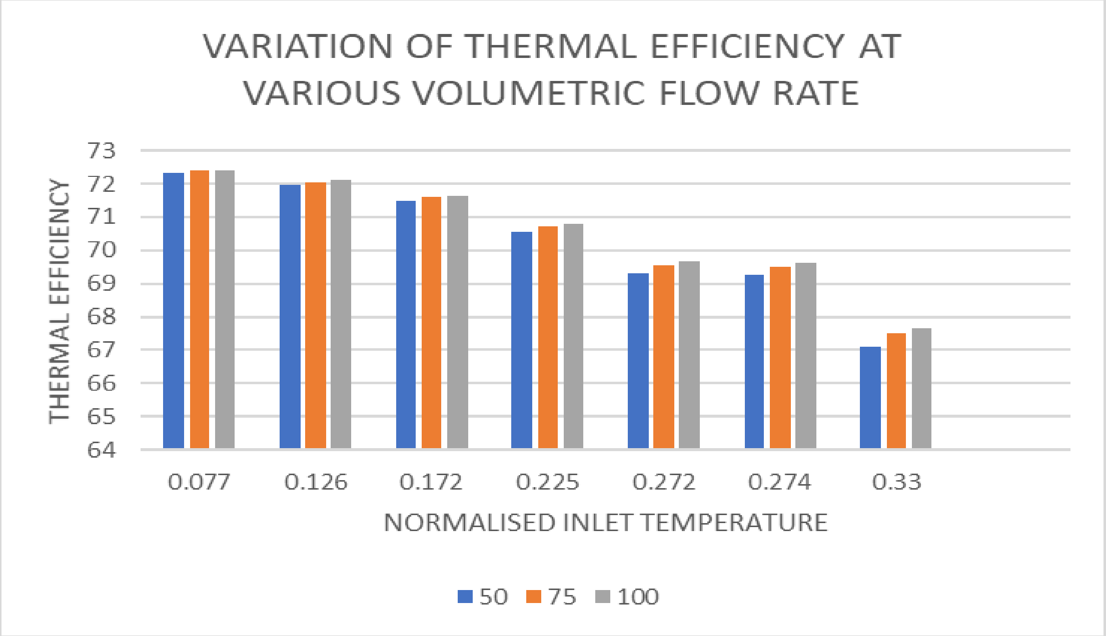


Figure 4.4: Thermal efficiency as per Normalised inlet Temperature

4.4. Comparative Study Of Thermal Efficiency With And Without Utilization Of Nano Particle

In this section, an investigation into thermal enhancement is carried out. Figure 4.5 depicts the thermal efficiency of the examined collector while utilizing pure thermal oil in one case, while nanoparticles infused thermal oil in the second case, at a particular inlet temperature being examined at various flow rates. It has been determined that the thermal performance improvement due to the proliferation of nanoparticles in the heat transfer fluid is considerably more pronounced at reduced volumetric rate of flow than at greater volumetric rate of flow. It is due to the reality that the thermal performance of purified thermal oil is substantially greater at a larger volumetric rate of flow. As a result, the potential for additional improvement is reduced.

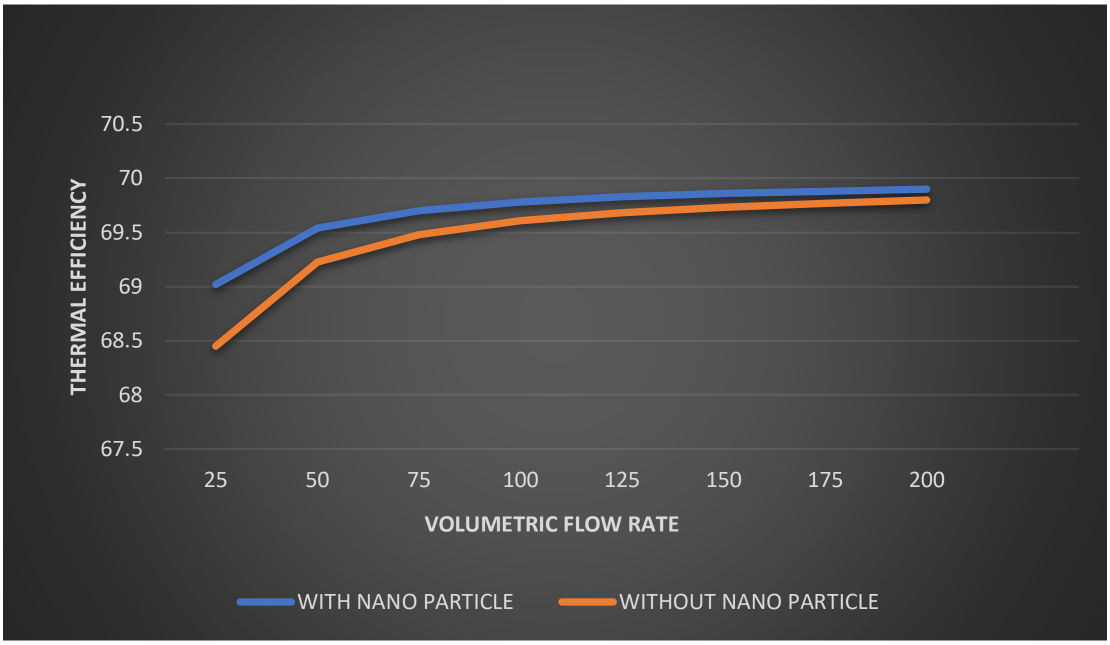


Figure 4.5: Comparison of Thermal efficiency b/w with nano particle and without nano particle

4.5 Thermal Enhancement Variation With Volumetric Flow Rate And Inlet Temperature

Figure 4.6 shows that a larger value of thermal improvement is achieved at a reduced volumetric rate of flow, but the significant increase is reached at a given rate of flow at a higher intake temperature of the transfer of heat fluid. The following variation is credited to the fact that the thermal efficiency of pure thermal oil-based collectors decreases as the inlet temperature of pure thermal oil increases. This leaves a better margin for improvement. Hence, maximum thermal enhancement is obtained at higher inlet temperatures and lower volumetric flow rates.

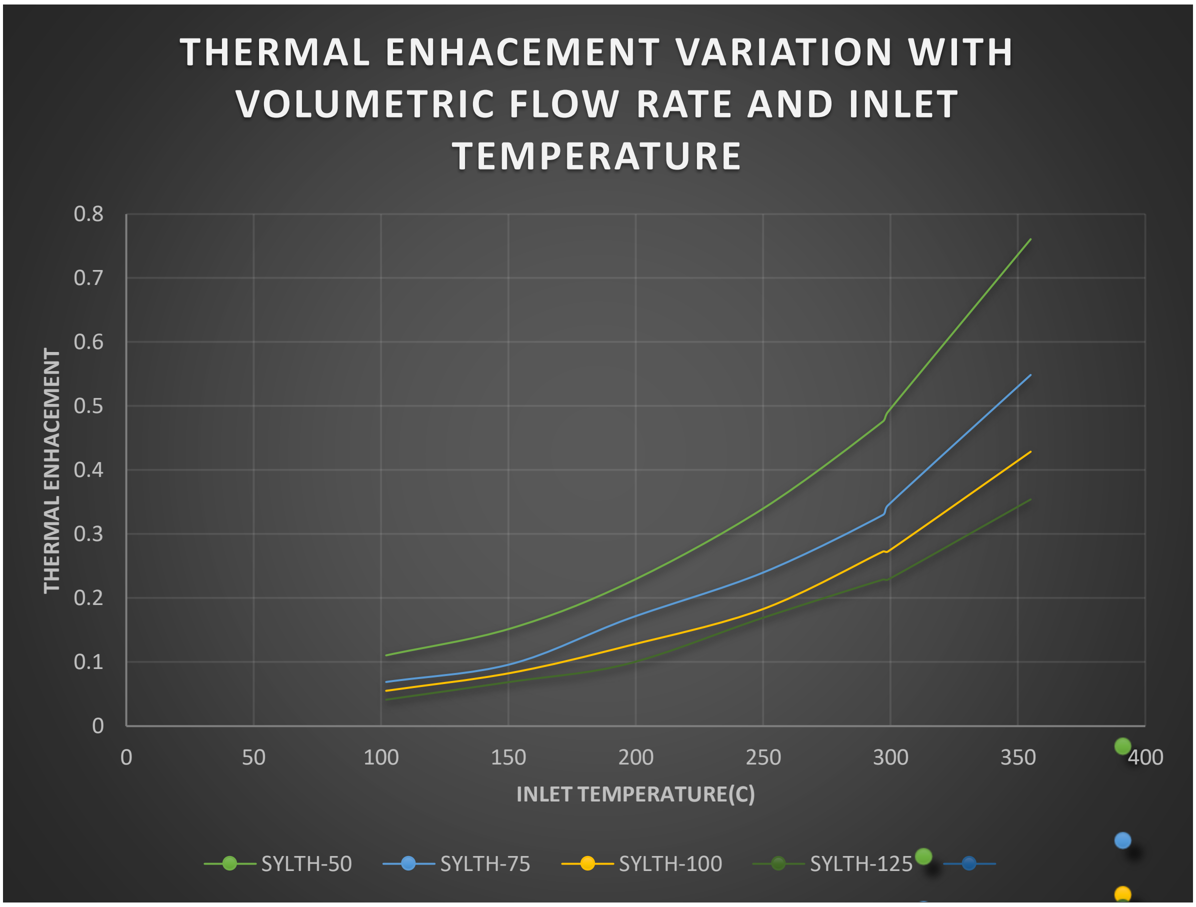


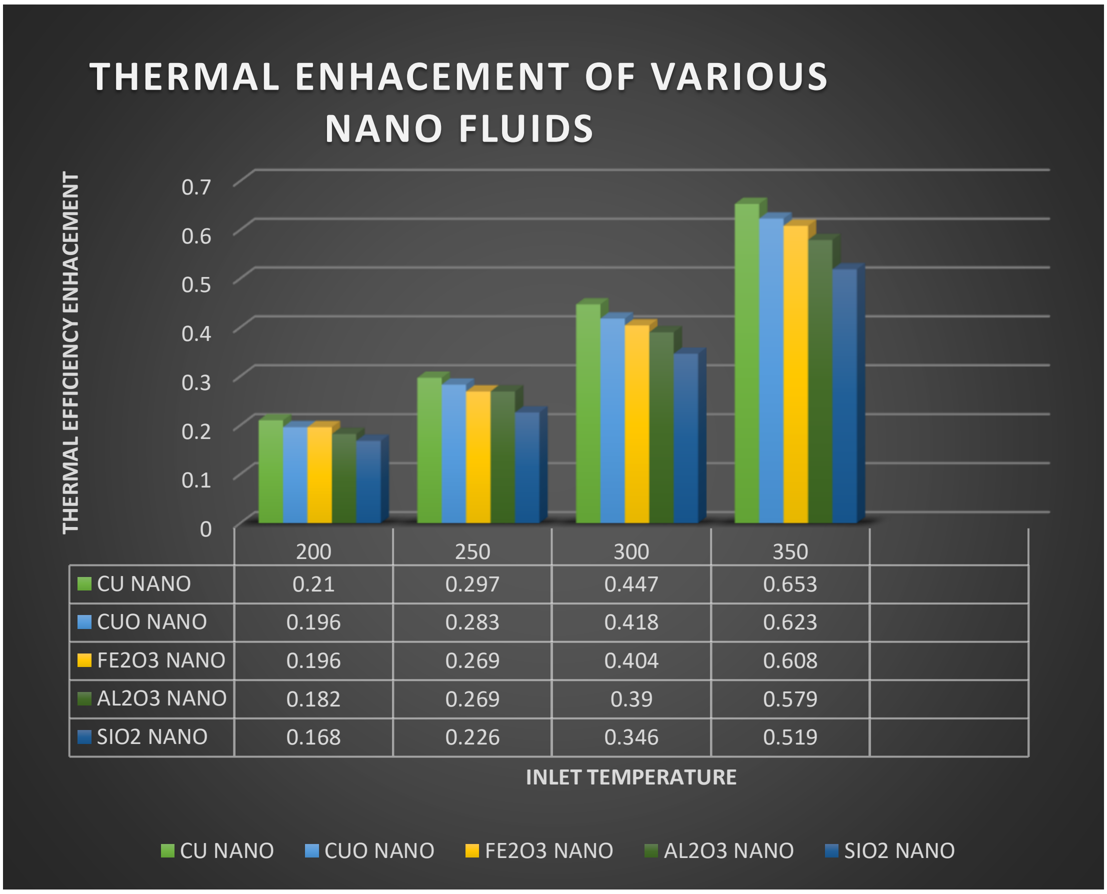
Figure 4.6: Thermal Enhancement Variation With Volumetric Flow Rate

4.6. Thermal Efficiency Enhancement Variation Of Different Nano Fluids

This section of the presented work examines the thermal enhancement obtained by the inclusion of various nanoparticles in Syltherm so as the base fluid. The examined nanoparticles Copper (Cu), Copper oxide (CuO), Aluminum Oxide (Al_2O_3), Iron oxide (Fe_2O_3), and Silicon Oxide (SiO_2). All the examined nanoparticles were infused with Syltherm 800, which was our base fluid or pure thermal oil. Equal concentrations of all the nanoparticles were taken.

The thermal efficiency calculations were made for pure thermal oil at the same inlet temperature and other conditions, and thermal efficiency calculations for the respective nanofluids were also done at the same conditions.

Figure 4.7 establishes the fact that maximum enhancement at all inlet temperatures is obtained for copper nanoparticles. The maximum enhancement obtained was 0.65% for the Cu/Syltherm – 800 nanofluids at 350°C inlet temperature as well as a volumetric rate of flow of 5 L/min at a 4% concentration of copper nanoparticles. It is because the proliferation of nanoparticles to the heat transfer fluid improves the effective heat generation. The inclusion of nanoparticles leads to better heat transfer properties. The maximum enhancement for the copper nanoparticle was credited to its altitudinous value of thermal conductivity in comparison to other nanoparticles.



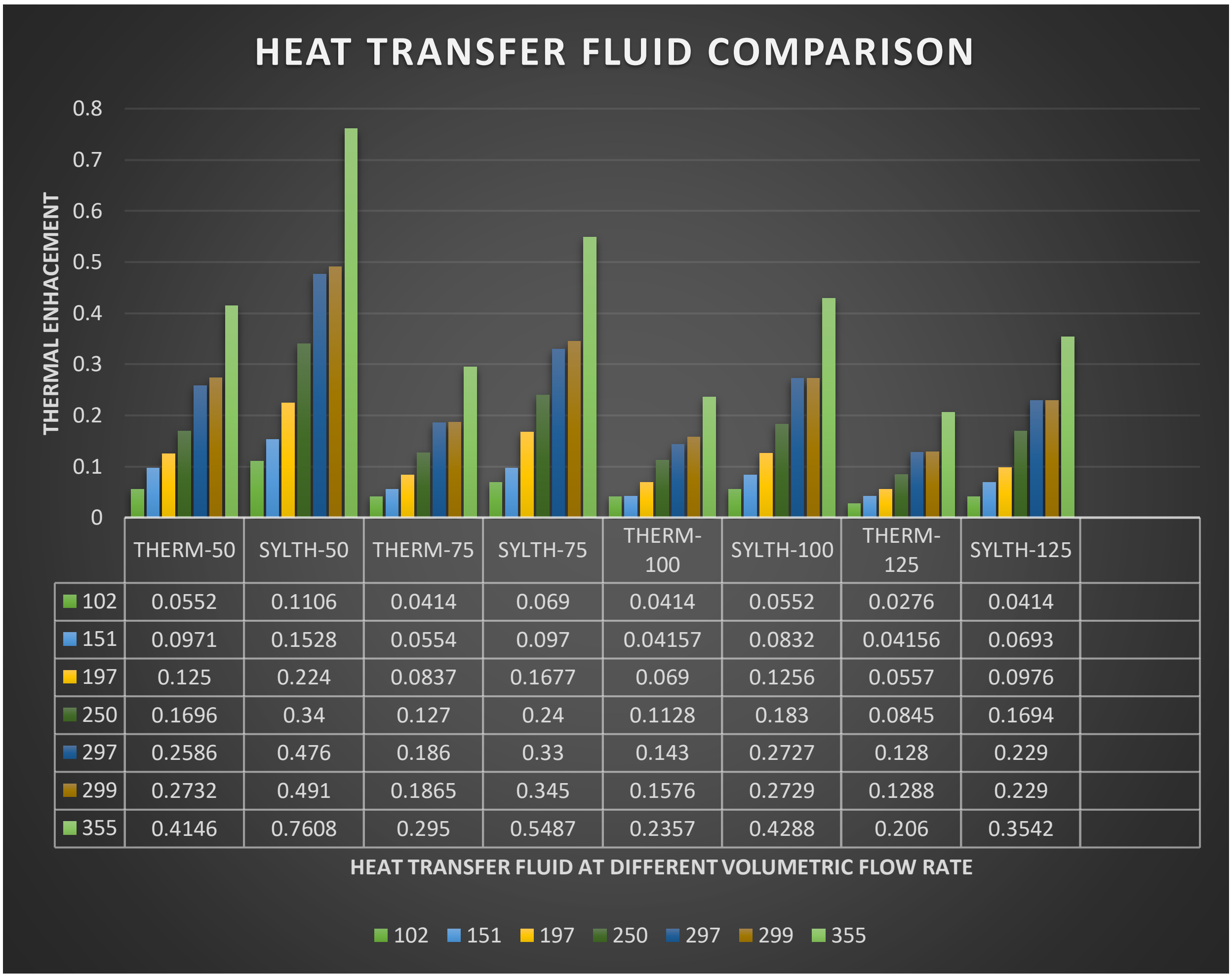
	200	250	300	350
🟩 CU NANO	0.21	0.297	0.447	0.653
🟦 CUO NANO	0.196	0.283	0.418	0.623
🟨 FE2O3 NANO	0.196	0.269	0.404	0.608
🟩 AL2O3 NANO	0.182	0.269	0.39	0.579
🟦 SIO2 NANO	0.168	0.226	0.346	0.519

Figure 4.7: Thermal Efficiency Enhancement Variation Of Different Nano Fluids

4.7. Comparison of Copper nano particle in two different heat transfer fluid.

In this section of the present work, copper nanoparticles are infused with two different base fluids and the thermal enhancements results are compared. The two different base fluids to be taken are Syltherm 800 and therminol VP-1. The comparative study was done at various volumetric flow rates and at various inlet temperatures. The comparison is made at four different volumetric flow rates that are 50L/min, 75L/min, 100L/min, 125L/min and at various inlet temperatures of 102°C, 151°C, 197°C, 250°C, 297°C, 299°C, and 355°C.

Under all the examined conditions, the Cu/Syltherm–800 based Nanofluids provided a better value for thermal enhancement as compared to the Cu/Therminol–VP-1 based nanofluids. Hence, the maximum enhancement is obtained for copper nanoparticles infused into the Syltherm 800 as the base fluid.



	THERM-50	SYLTH-50	THERM-75	SYLTH-75	THERM-100	SYLTH-100	THERM-125	SYLTH-125
🟩 102	0.0552	0.1106	0.0414	0.069	0.0414	0.0552	0.0276	0.0414
🟦 151	0.0971	0.1528	0.0554	0.097	0.04157	0.0832	0.04156	0.0693
🟨 197	0.125	0.224	0.0837	0.1677	0.069	0.1256	0.0557	0.0976
🟩 250	0.1696	0.34	0.127	0.24	0.1128	0.183	0.0845	0.1694
🟦 297	0.2586	0.476	0.186	0.33	0.143	0.2727	0.128	0.229
🟫 299	0.2732	0.491	0.1865	0.345	0.1576	0.2729	0.1288	0.229
🟩 355	0.4146	0.7608	0.295	0.5487	0.2357	0.4288	0.206	0.3542

Figure 4.8: Comparison Of Cu Nano Particle In Two Different Heat Transfer Fluid.

4.8. Investigation of Thermal Enhancement With The Nano Particle Concentration

This section investigates the impact of nanoparticle concentration on thermal enhancement. The copper nanoparticles at 4 different concentrations of 1%, 2%, 3%, and 4% are examined at a flow rate of 50L/min at various inlet temperatures.

The trend suggests that higher enhancement values are obtained at higher concentrations of nanoparticles. The maximum thermal enhancement was obtained at a 4% concentration of copper nanoparticles in Syltherm 800 base fluid.

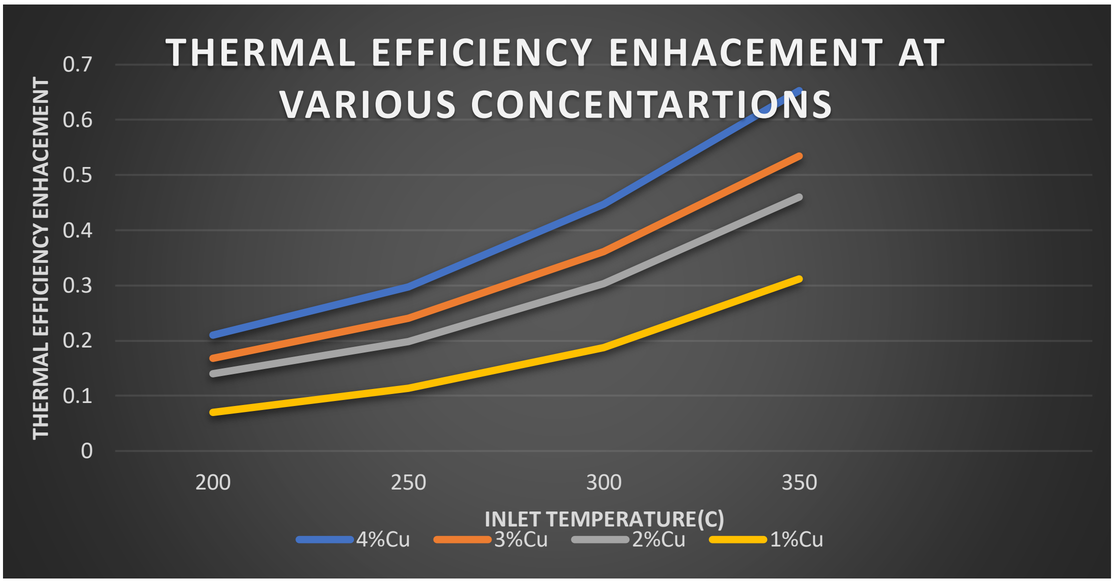


Figure 4.9: Thermal Enhancement Variations With The Concentration of Nano Particle

4.9. Exergy Analysis

- This section of the present work is dedicated to the investigation of exergetic efficiency and enhancement of the examined parabolic collector.
- The consequences of intake temperature and volumetric flow rate on the exergetic efficiency is investigated.
- As the Figure 4.10 suggests that exergetic efficiency of parabolic collector utilizing pure thermal oil as base fluid increases as the inlet temperature increases.

- Besides, exergetic efficiency at a particular temperature is higher at the lower volumetric flow rate. The trend observed here is opposite to that of thermal efficiency.
- In the further section the reason for such behaviour is explained meticulously.

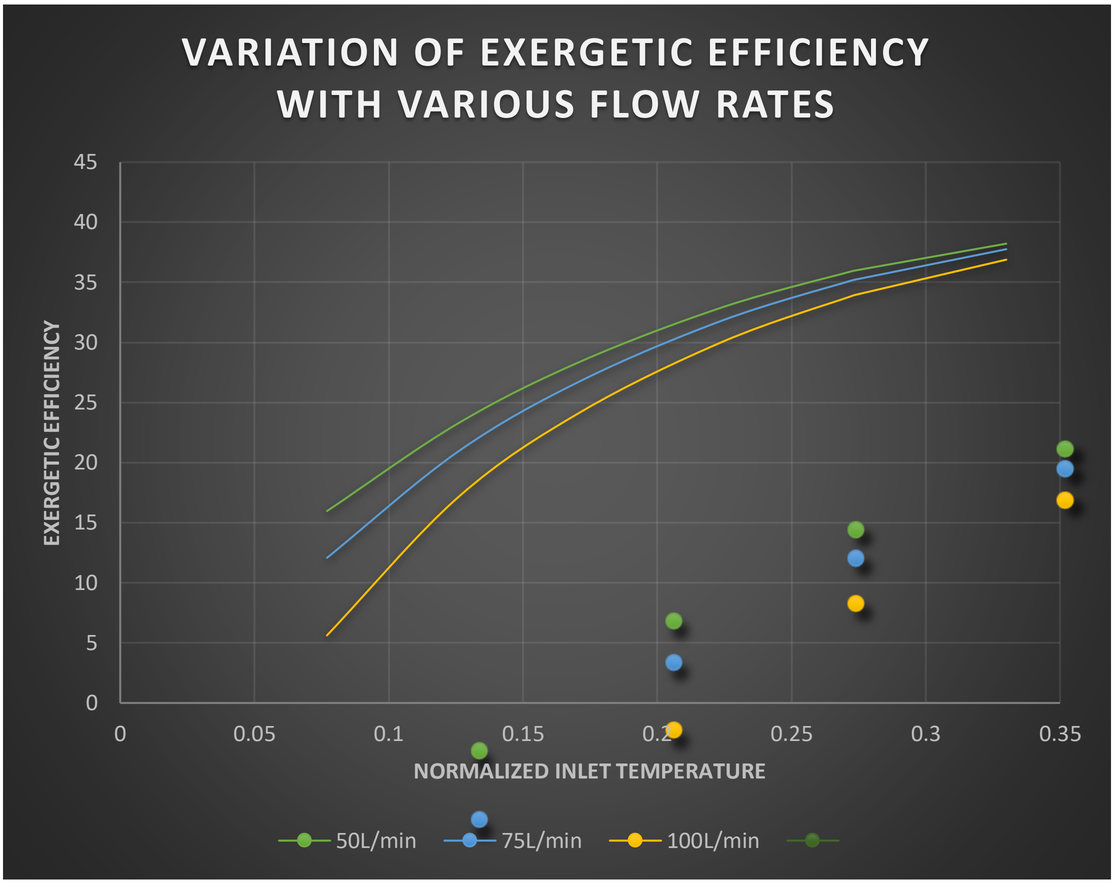


Figure 4.10: Variation Of Exergetic Efficiency With Various Flow Rates

4.10. Absolute Rate of Exergy Destruction

The exergetic efficiency of the examined collector depends upon the absolute rate of exergy destruction which is due to inevitable irreversibilities present in the examined system and the exergy lost due to various heat losses.

Figure 4.11 suggests that absolute rate of exergy destruction of the examined collector which is due to the inevitable irreversibility present in the examined collector are decreasing as the inlet temperature increases.

Besides at a particular inlet temperature total exergy destruction rate is more prominent at higher volumetric flow rates.

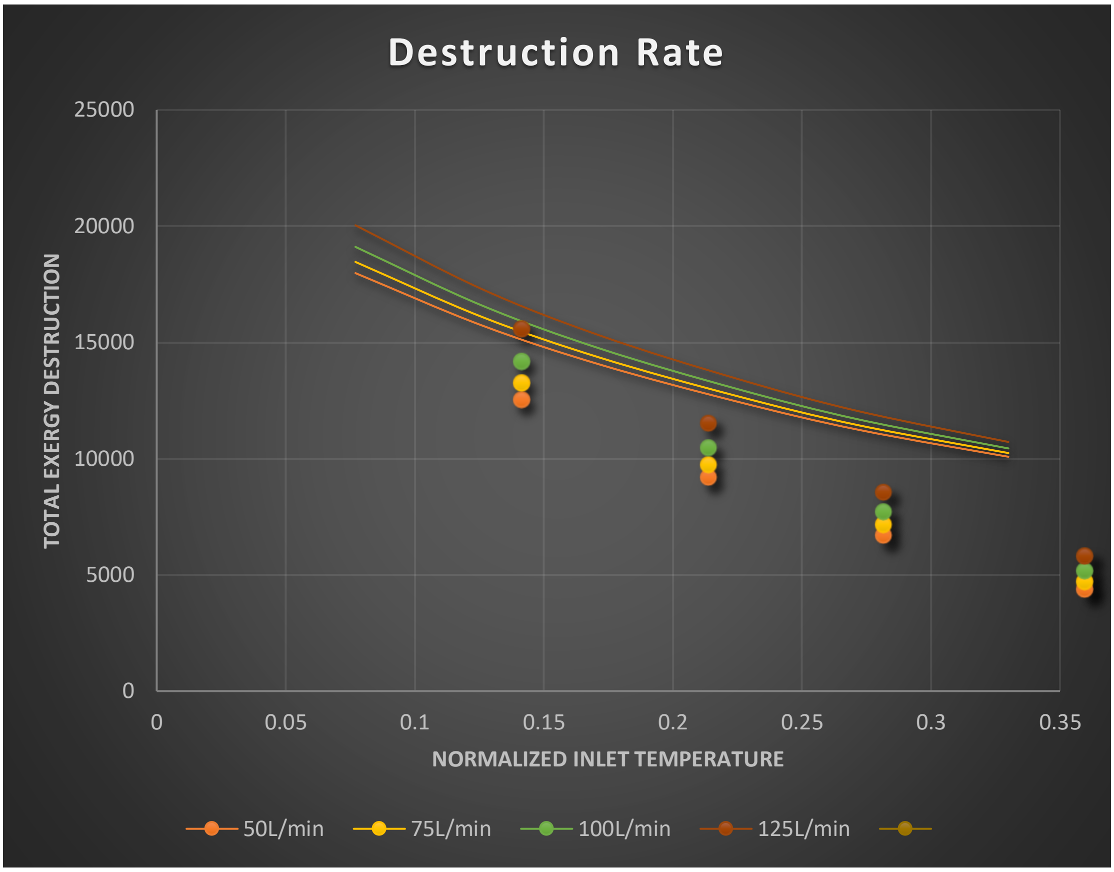


Figure 4.11: Absolute Rate of Exergy Destruction

4.11. Total Exergetic Loss Variation

Figure 4.13 establishes the fact that exergetic loss increases as the inlet temperature increases . At a particular inlet temperature total exergetic loss are higher at lower volumetric flow rate. The trend of total exergetic loss variation can be very well explained by the trend by exergetic thermal loses as depicted in figure 4.12.

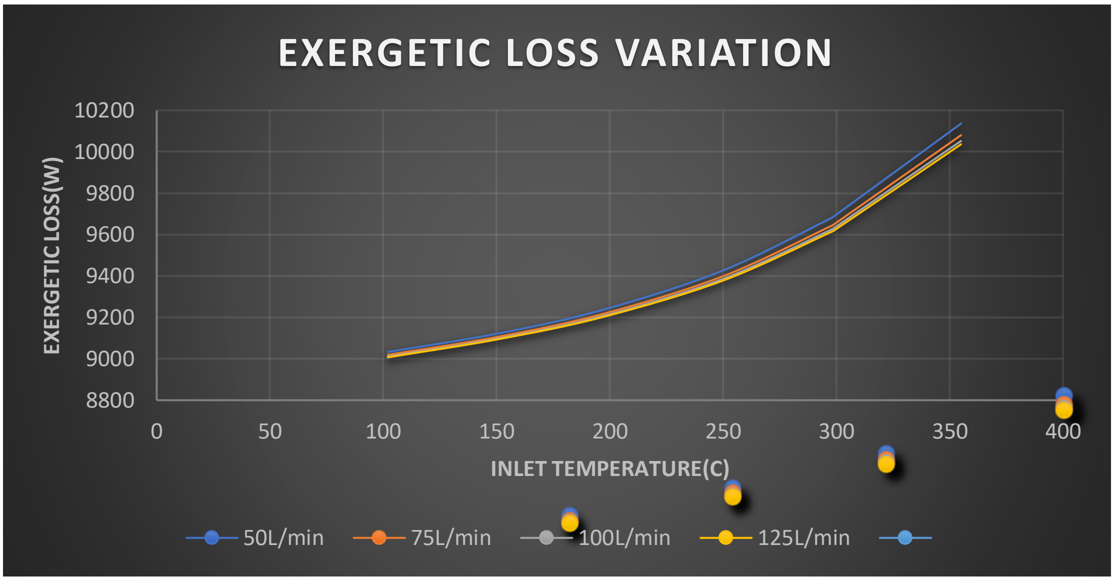


Figure 4.12: Total Exergetic Loss Variation

4.12. Exergetic Thermal Loss Variation

- The exergetic thermal loses being the major component of the total exergetic loss dominates the trend to be in similar manner.
- Moreover the exergy destruction due to irreversibility's were a bit higher as compared to total exergetic loss at same inlet and volumetric flow rate.
- The exergy destruction due to irreversibility's and total exergy lost with the lost heat energy , both impacts the exergetic efficiency of examined system.
- However the trend of exergetic efficiency is governed by the total exergy destruction rate as it has more dominating effect.

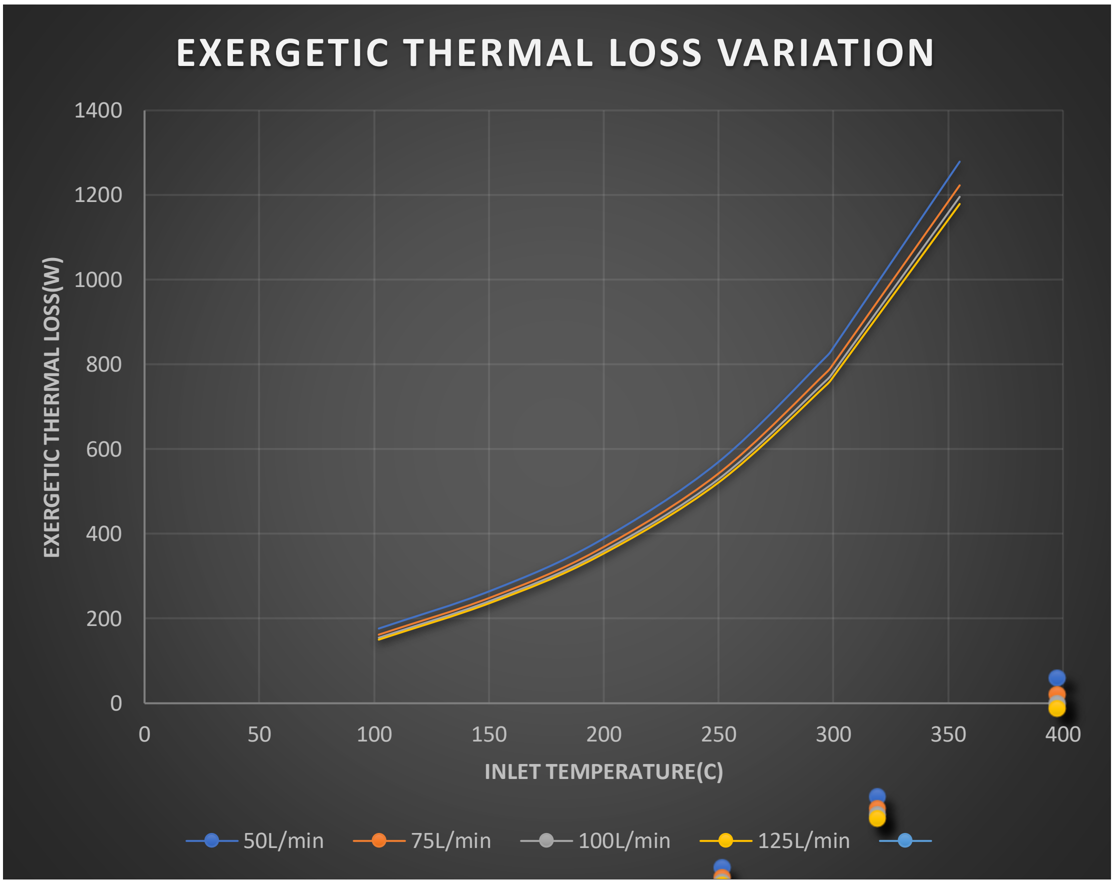


Figure 4.13: Exergetic Thermal Loss Variation

4.13. **Impact of Introducing Nanoparticles on the Exergetic Efficiency**

The goal of this section of research is to see how the proliferation of nanoparticles in the base fluid affects the collector exergetic performance. The best results for thermal enhancement were obtained for Cu/Syltherm 800 nanofluid. The same nanofluid is being examined for its impact on exergetic efficiency.

Figure 13 suggests that exergetic efficiency enhancement by the Nanofluid is higher at higher volumetric flow rates. It can also be deduced that enhancement due to nanofluids is much more prominent at higher intake temperatures as compared to lower inlet temperatures. The maximum enhancement obtained is 0.807% at an inlet temperature of 355oC with a volumetric flow rate of 50 L/min for Cu/Syltherm 800 as nanofluid. The aforementioned findings are due to the fact that at lower volumetric rates of flow and higher temperatures, the collector has greater exergetic performance.

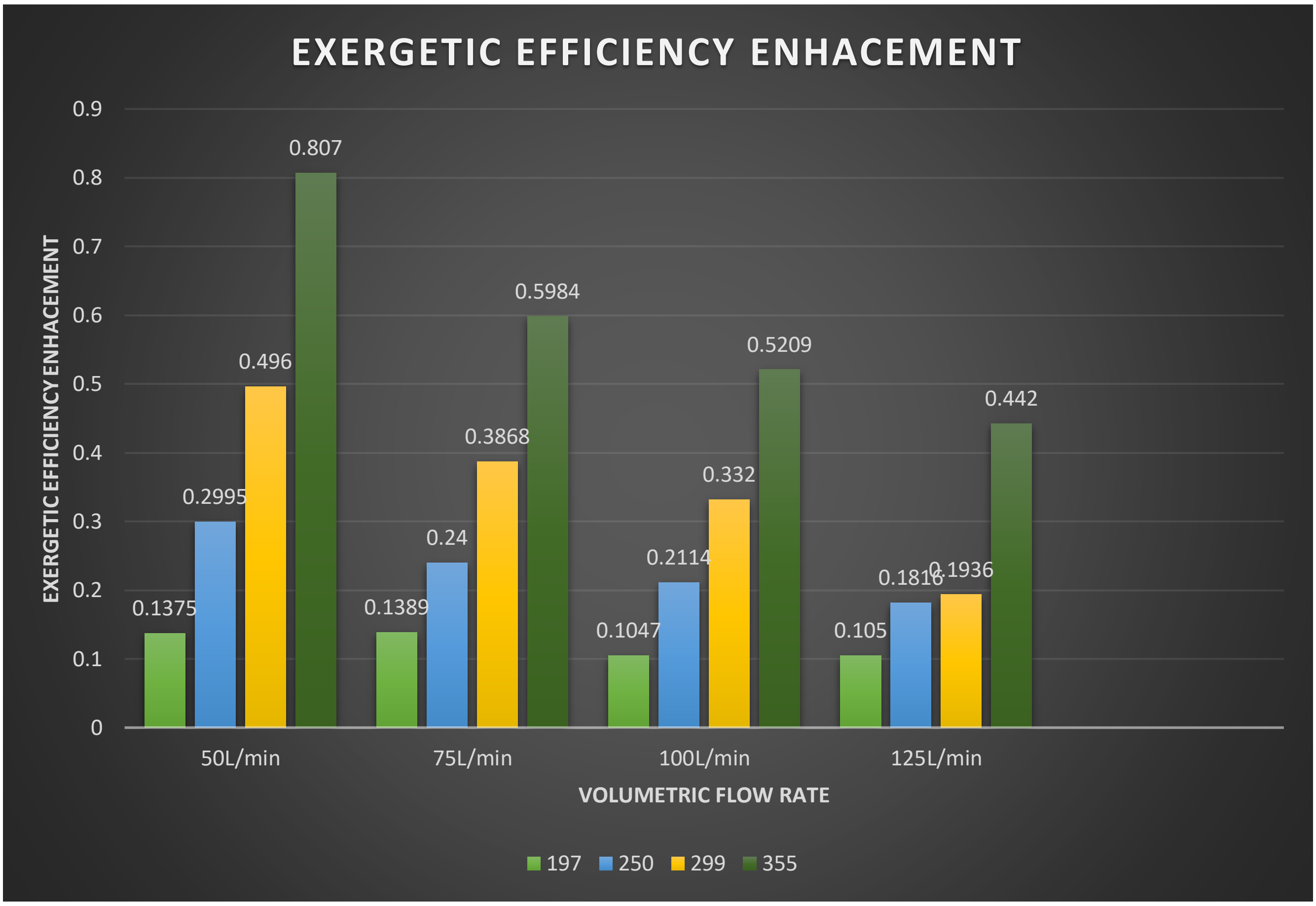


Figure 4.14: Exergetic efficiency enhancement

4.14. Impact of Nano Particle Concentration on Exergetic Efficiency

This Section of examined work evaluates the impact of Nano particle concentration. The Nano particle taken here is Copper infused in Syltherm 800.

There is slight increase in exergetic efficiency at 4% concentration of copper Nano particles.

The exergetic efficiency at 4% concentration was 36.46% while it was 36.45% and 3.42% at 3% and 2% concentration of copper nanoparticle respectively.

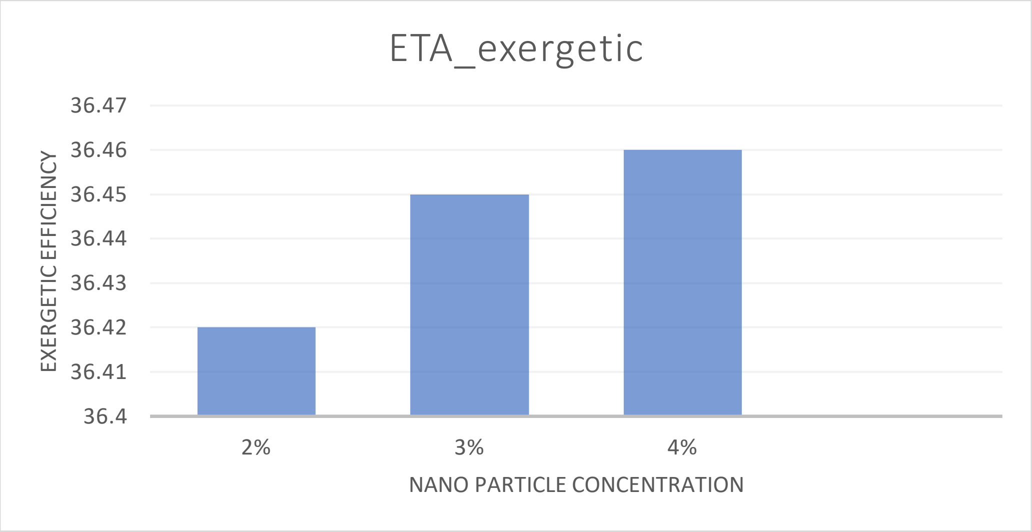


Figure 4.15: Variation With The Nano Particle Concentration

4.15. Explanation of exergetic efficiency variation with nano particle concentration.

The following section attempts to explain the behaviour of exergetic efficiency with the concentration of the nano particles in the base fluid.

The reason for such behavior is due to fact that at lower concentration the exergy destruction between receiver and heat transfer fluids increases depicted by Figure 4.16..

While exergy destruction between solar radiation coming from sun and receiver decreases at the lower concentration of nano particles established by Figure 4.17.

However the total exergetic losses were higher at lower Nano particles concentration Depicted by Figure 4.18

All these factors lead to slight increase in exergetic efficiency as Nano particle concentration is increased.

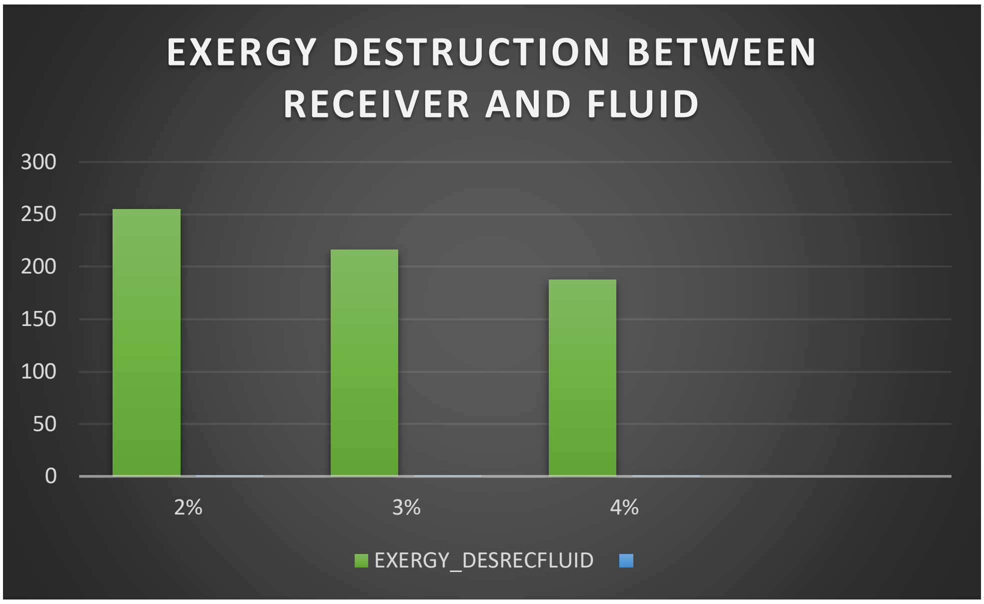


Figure 4.16: Exergy destruction between receiver and fluid

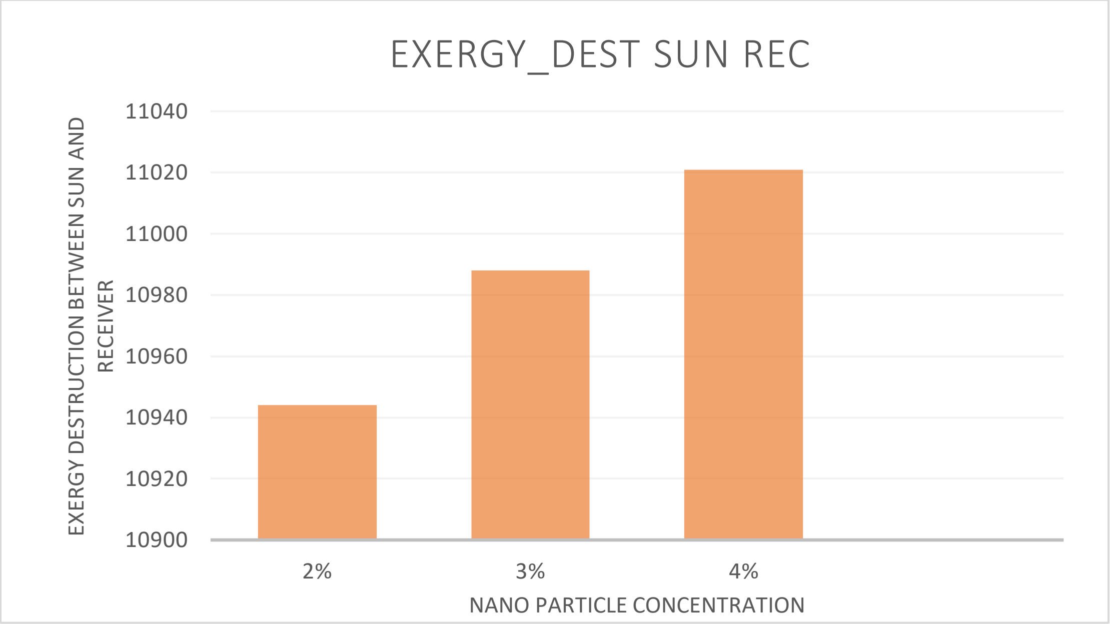


Figure 4.17: Exergy Destruction Between Receiver and Sun

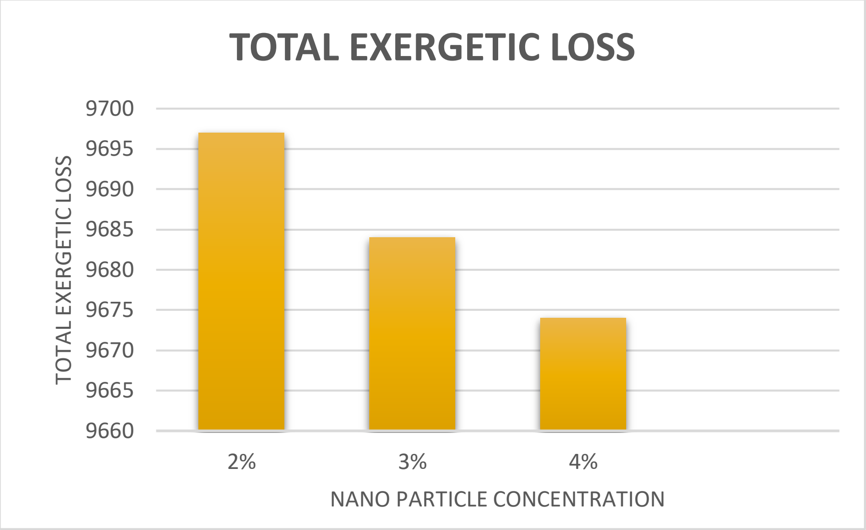
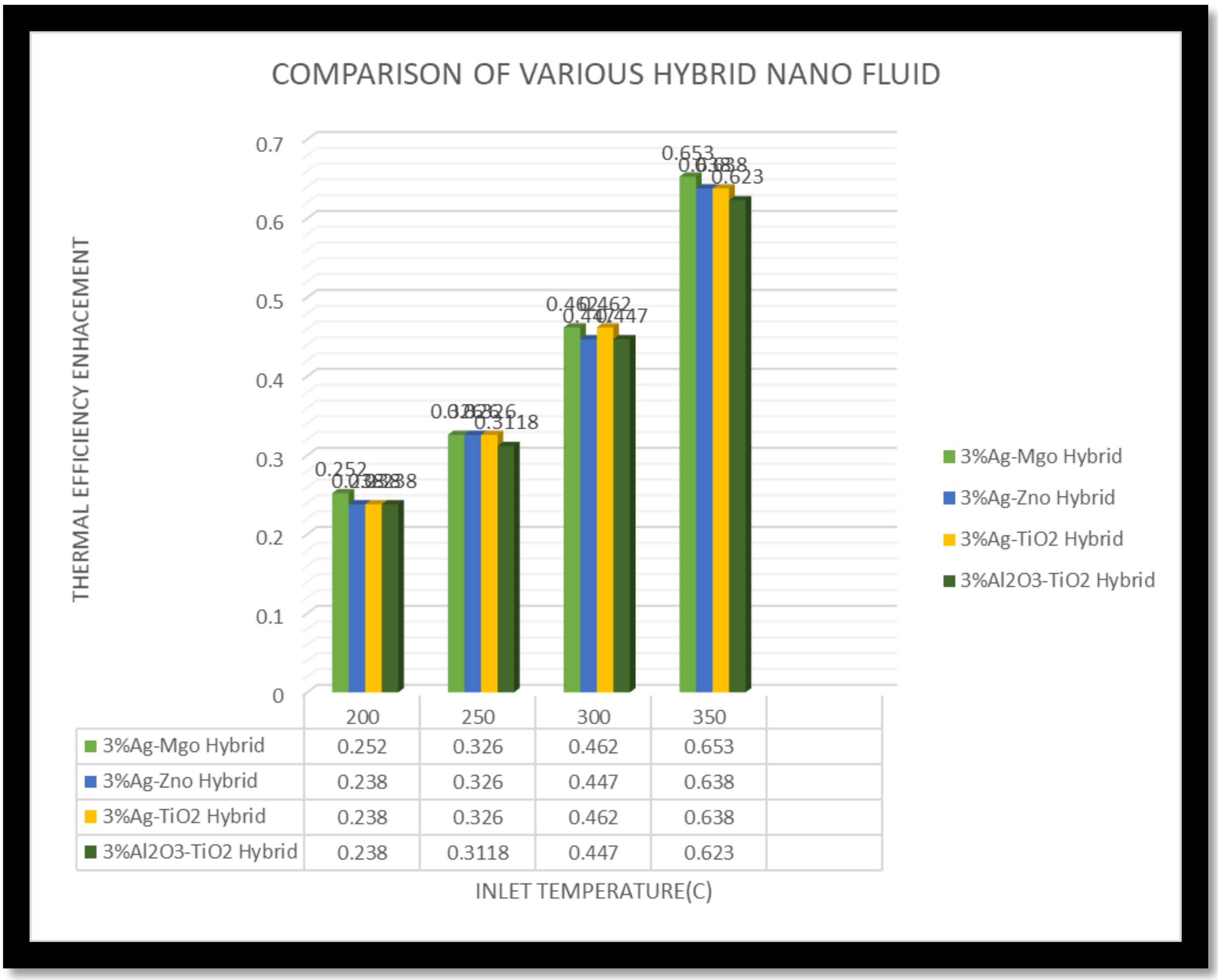


Figure 4.18: Total Exergetic Loss

Concentration.

4.18. Impact of Hybrid Nano Fluid on Thermal Enhacement

This section of present work evaluates the impact of introducing hybrid Nanofluids to the examined collector. The hybrid nanofluids that were taken are Ag – MgO/Stltherm 800, Ag – ZnO/Syltherm 800, Ag – TiO2/Syltherm 800, Al_2O_3 – TiO_2/Syltherm 800. All these hybrid nanoparticles were taken at a 3% concentration. The reason for the selection of such a hybrid nanofluid was their previous work done in literature, which prompted us to do a comparative study. Figure 4.19 suggests that silver-based hybrid nanofluid performed better and gave better values for the thermal enhancement as compared to Al_2O_3 based nanofluid. At an inlet temperature of 350^oC, the Ag–MgO based hybrid nanofluid showed the greatest enhancement. It was concluded that silver-based hybrid nanofluids were superior to aluminum oxide-based hybrid nanofluids.



	200	250	300	350
🟩 3%Ag-Mgo Hybrid	0.252	0.326	0.462	0.653
🟦 3%Ag-Zno Hybrid	0.238	0.326	0.447	0.638
🟨 3%Ag-TiO2 Hybrid	0.238	0.326	0.462	0.638
🟩 3%Al2O3-TiO2 Hybrid	0.238	0.3118	0.447	0.623

Figure 4.19: Impact of Hybrid Nano Fluids on Thermal Enhacement

4.19 Comparative Study Between Most Promising Mono Nano Fluids And Most Efficient Hybrid Nano Fluid

This section of the work aims to have a look at the performance of Cu/Syltherm 800 and Ag-MgO/Syltherm 800 under similar conditions of inlet temperature as well as the volumetric rate of flow. The comparison is made at four different inlet temperatures and for four different volumetric flow rates. At a particular inlet temperature under all conditions of volumetric flow rate, Ag-MgO/Syltherm 800 provided a better thermal enhancement. Under the conditions of low volumetric flow rate, the hybrid nanofluid and the mono nanofluid had the maximum difference in thermal enhancement values at all inlet temperatures. Besides that, the hybrid nanofluids followed the same trend of providing better thermal enhancement at lower volumetric flow rate and higher intake temperature.

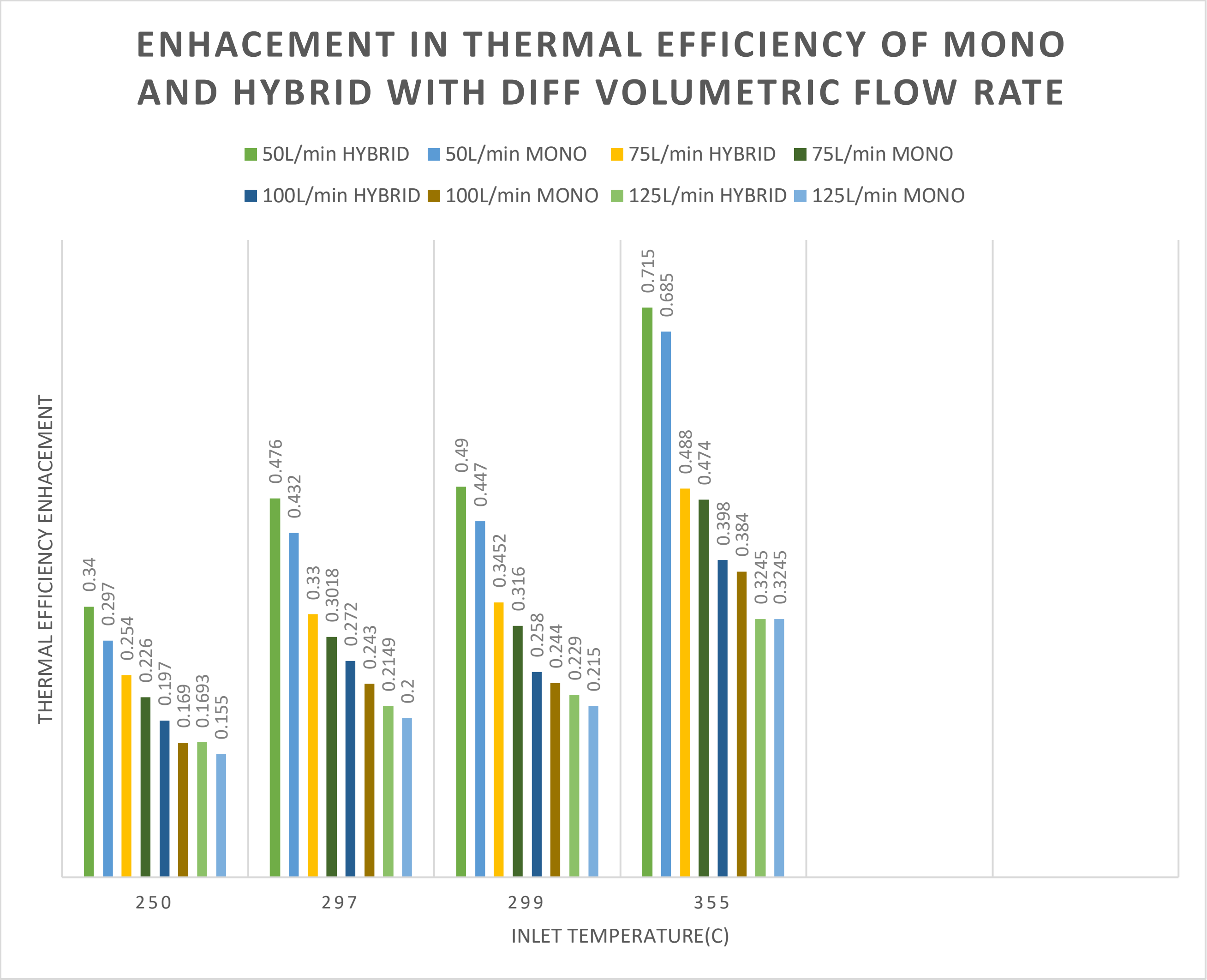


Figure 4.20: Comparative Study between Mono Nano Fluid and Hybrid Nano Fluid

4.20. Variation in Exergetic Efficiency of Hybrid Nano Fluids

- This section of the present work determine the exergetic efficiency of examined collector employing hybrid Nano fluid.
- Figure 18 shows that exergetic efficiency is higher at increasing inlet temperature of the Nano fluid.
- At a particular inlet temperature exergetic efficiency is higher at lower volumetric flow rate.
- The reason for such a trend is higher exergy destruction rate at higher volumetric flow rate and lower inlet temperature.

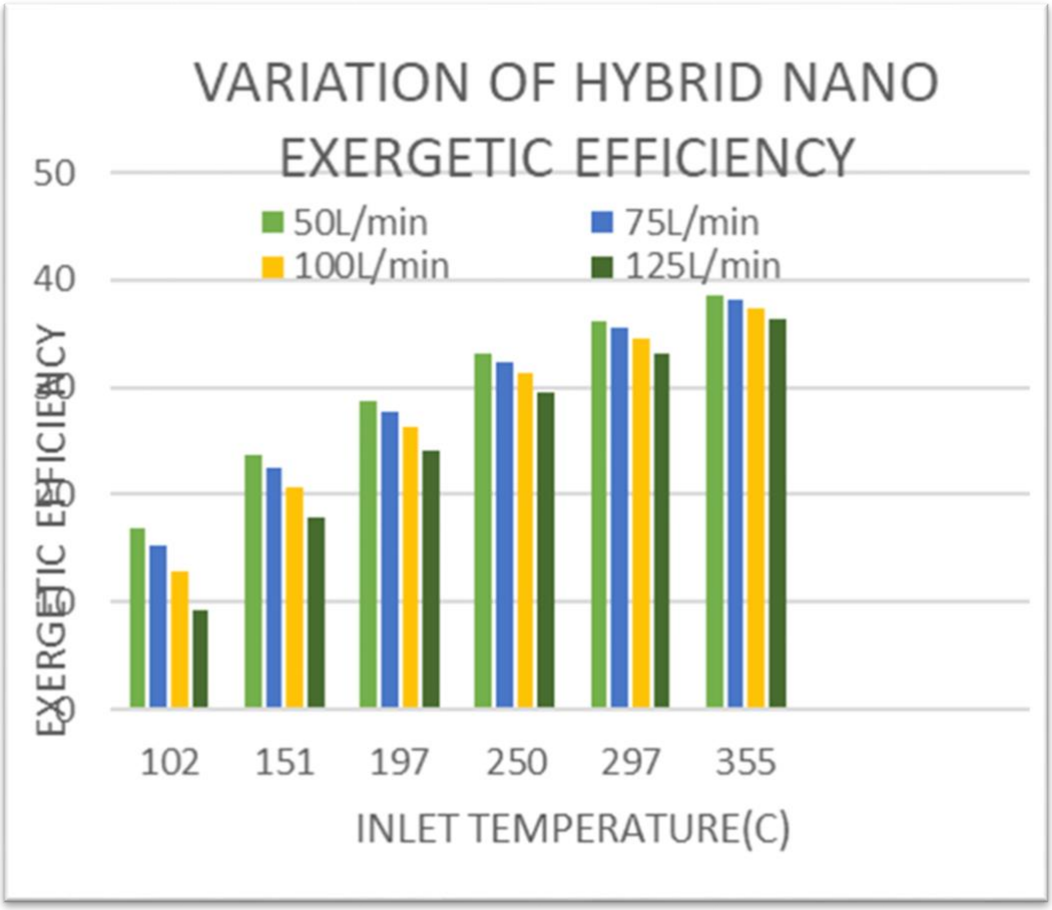


Figure:4.21 Variation of Hybrid Nano Fluid Exergetic Efficiency

4.21 Exergetic Efficiency Variation with Concentration Of Hybrid Nano Fluids

No appreciable variation in the exergetic efficiency of collector utilizing hybrid Nano fluids was observed at various concentrations of the hybrid Nano particles in the base fluid. This is established by the result of Figure 4.23

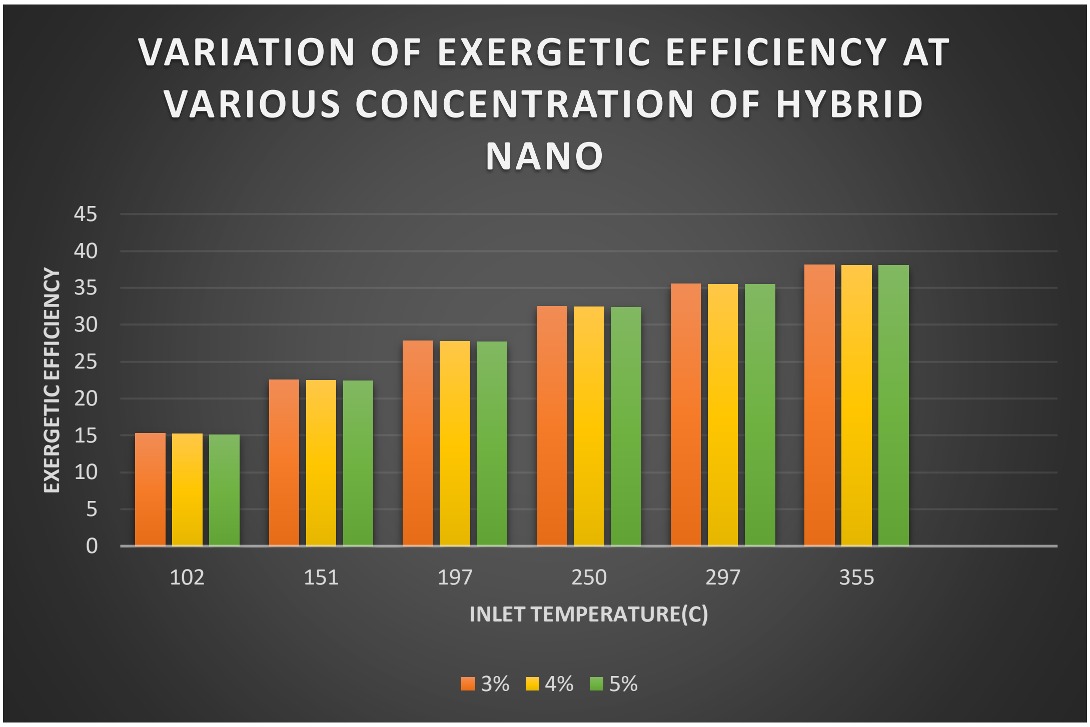


Figure 4.22: Exergetic Efficiency Variations with Concentration Of Hybrid Nano Fluid

CHAPTER 5

CONCLUSION

5.1. Conclusion

Copper nanoparticles infused in Syltherm 800 base fluid gave the best thermal efficiency enhancement results for mono nanofluid. For the case of hybrid nanofluid, the best results for thermal efficiency enhancement were for silver magnesium oxide based hybrid Nanoparticles infused in Syltherm 800 base fluid. Hybrid nanofluids, on the other hand, had a better thermal enhancement than mono-nanofluids under the same operating conditions. For both the hybrid and mono-nanofluid-based heat transfer fluids, the thermal enhancement gave better results for higher inlet temperature and lower volumetric flow rate. The thermal performance of a system diminishes as the inlet temperature rises. Higher mono nanoparticle concentrations in base fluids gave slightly better thermal enhancement values. As the inlet temperature rises, the exergetic performance rises as well. At the very same input temperature, the decreased volumetric rate of flow produced exceptional results. Exergetic efficiency enhancement results at the highest level in the case of mono-nano and hybrid nanofluids, and was obtained at higher inlet temperatures and lower volumetric flow rates. A slightly higher value for exergetic efficiency enhancement was obtained at higher nanoparticle concentrations. With the concentration of hybrid nanoparticles, there was little variation in exergetic efficiency.

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