Study Experiential And Numerical For Investigation The Efficiency Inside Building Structure

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Abstract:

In this paper, the thermal efficiency for system horizontal solar concrete collector is studied. Consisted of four models of horizontal concrete solar collector at area 0.6m². In addition, the operating conditions were three radiation values of 400W/m², 700W/m² and 1000W/m² with three fluid inlet temperatures of 15, 20 and 25°C. Models were represented in the Ansys Software 18-workbench with suitable boundary condition according to case model. The models are designed to give the best efficiency at Reynold 900.The case stet up was validated with of the previous work and the results showed a good agreement with error than 6%.The results show that, the best type of tube section was rectangular section are where the thermal efficiency enhancement about 36 % compared to those in the solar collector that contains circular tubes.

Keywords: Building Structure, Experiential and Numerical, Efficiency.

1. INTRODUCTION

With the growing concerns that the global demand for energy is ever increasing while the traditional natural resources that are harnessed to provide energy are diminishing, a significant amount of focus has been given to green/clean sources of power like the sun, wind, current and tidal power. The former has especially been lucrative due to the ease with which it can be tapped and harnessed to power domestic as well as industrial processes. Solar energy is derived from the sun: a huge sphere of made up of extremely hot gases with an actual blackbody temperature of about 5762 K [1]. The burning reactions in the sun—analogous to the reactions in a fusion reactor—involve the conversion of hydrogen into helium, a process that releases incredibly huge amounts of energy that radiate away from the sun in every direction and strike the earth after about 8.333 minutes. The entire power yield from the sun ranges from 3.8 to 1020 MW, an output that is equivalent to 63MW/m^2 [1]. Standing in the way of the radiations, the earth intercepts and absorbs some of the energy [1]. Even though the quantity of energy from the sun that the earth intercepts and absorbs is a very tiny portion of the entire energy output from the burning sphere (1.7 to 1014 KW), researchers have established that just half an hour of uninterrupted sunlight beams hitting the earth's mainland is enough to provide energy enough to supply the annual global energy demand [1].

It is widely believed that this form of green energy should harness ahead of all the other sources of energy. Therefore, this research study will investigate how solar energy can be effectively harnessed using advanced low cost technology.

Concrete Solar Collectors: As the sun shines upon the surface of the earth, concrete structures like building walls and pavements tend to capture the radiations from the sun and heat up. The thermal power in such concrete structures can be harvested through an appropriate heat exchange system. The normal heat exchange systems that have been developed to harvest the energy absorbed by various concrete structures consist of pipes containing the conveying fluid. These pipes are embedded in the concrete structures and are often known as concrete solar collectors CSCs. The conveying fluid acts as a coolant to the concrete structure, absorbing heat energy from the structure in the process of cooling it [2].

(Nayak et al, 1989) [3] the authors conducted several experiments to investigate the performance of varnished concrete roof solar energy collector mostly used to heat water and supply the hot water to various households for domestic purposes. In the experiments, the authors used black PVC tubes located approximately 10 mm underneath the layer of concrete.

(Bopshetty et al, 1992) [4] studied increased the amount of concrete between adjacent tubes from 0.06m to 0.15m in order assesses factors that influence thermal storage of concrete solar energy collectors. From the parametric investigation, they established that increasing the amount of concrete between the adjacent tubes through which the operating fluid flow results in improved thermal storage for the concrete solar energy collectors. **(Reshef and Sokolov, 1992) [5]** the authors designed a one dimensional transient model of a concrete solar collector. The model was considerably wide, of a circular cross-sectional area, and the concrete was reinforced by glass. The operating fluid in this case was water and the temperature gradient in the direction of the working fluid was much smaller in comparison to the temperature gradient in the direction incident to the flow, also the temperature downstream was neglected. **(Jubran et al., 1994) [6]**purposed to reduce the amount of energy lost by a concrete solar collector during the cold seasons. To realize this aim, they opted to used glass to cover the concrete solar during cold seasons. They developed several designs by using readily available window pane glass. **(Chaurasia, 2000)[7]** achieved a study about the solar concrete collectors which supplied the domestic hot water with aluminum tubes embedded over slab concrete without insulation at the back and without glazing on the upper surface. The area of absorbing surface was $1.06m^2$. The diameters of aluminum tubes were (12, 19, 25) mm. The better results were gotten at 19 mm. It was concluded the output hot water temperature gotten from the concrete collector was raised by 2^0C to 5^0C. **(Bilgen et al., 2002)[8]** used horizontal slab concrete system in the solar energy collection device. they conducted an experimental assessment of heat transfer mechanisms in the horizontal slab concrete system. The experimental investigation of free convection heat transfer mechanism over the horizontal slab concrete system also resulted in the derivation of an experiential correlation between the variables involved. Also, the results obtained the amount of heat absorbed by the slab did not significantly depend on the angle of radiation. Heat losses by radiation and free convection accounted for all the energy loss from the slab (60% and 40% respectively). **(Sullivan et al., 2007) [9]** Connected concrete-based solar energy collectors to typical heat pumps utilized for the heating and cooling of buildings and homes. Afterwards, different assessments were conducted in order to investigate the potential damaging impacts of embedded tubes on the life of pavements as well as to establish how compaction operations affect plastic pipes used in these solar collection devices. **(Majdi Hazami et al., 2010)[10]** presented an experimental analysis of a cheap integrated solar storage collector ISSC with entire area of aperture was 2 m^2, which was used in order to supply domestic hot water. An absorber matrix fabricated of a thin cement concrete slab which achieved the function for the two absorbing and storing of the solar thermal energy so that the ISSC could be characterized. A copper tubes network was embedded into the concrete absorber. The results showed that integrated solar storage collector had energetic efficiencies of 32%, which could supply acceptable stored thermal heat rate by providing about 80% in domestic hot water for a family includes 5 persons. **(Zhiyong Yang et al., 2011)[11]** achieved a design for a solar heat pump SAHP that used in solar collector especially in the integrated roof as the evaporator. To predict the space heating load, a building energy simulation was used besides 3D theoretical model to analyze the performance of the solar roof collector. In order to decrease the energy demand, a floor radiant heating unit was done. The results showed that through the winter the system could supply a comfortable living space, when the average temperature of the room about 18.9%. The average COP for the system was 2.97 with peak around 4.16. **(Rangsitarachittia et al., 2011)[12]** studied the thermal performance for two rooms, the first room with roof-integrated solar concrete collector with PVC tubes embedded in it while the second room with reinforced cement concrete slab, with no insulation and no glazing on the top. The results illustrated that the room with concrete solar collector slab produced up to 40 litres of hot water for every day at temperature varied from 40 to 50^{o}C, also the heat gain to the house decreased and the economic study showed that the payback period was swift.

(P. BLECICH et al., **2012) [13]** investigated the domestic hot water heating system with solar concrete collector. The serpentine tubes could be put into roof slabs, walls and concrete pavements. a numerical model according to the finite volume approach has been improved. It could be noticed that the serpentine tube could heat water up to 40-50ºC during the summer season when the temperature reached to 30-40ºC. The average efficiency (i.e. solar fraction) is 50-70% in Rijeka (Croatia) during the period from May to September, in other words less than half of the required energy was provided by using the auxiliary heating source. The efficiency of solar concrete collector systems were effected by many parameters such as; tilt angle of the concrete, tube depth, tube spacing, tube length and solar absorbance. The results concluded that the 40% to 70% of the required energy for DHW heating in the summer season could be provided by the solar concrete collector. **(A. A. Keste et al., 2012) [14]** The proposed work is concerned with the experimental setup of a cheaper and economical 2m X 1m solar concrete collector and analysis of its performance. The objective of present work is to find out daily efficiency and average temperature of the output hot water. Metal fiber reinforced concrete, Storage capacitance, Thermal conductivity Hot water at moderate temperature (up to 54°C) can be obtained in buildings during the daytime in winter by using reinforced cement concrete slabs or by slightly modifying the roof structure and laying down a network of copper pipes over it which can offer a low cost passive solar water heating system in the building itself. This passive solar water heating technique is easy to fabricate and the mason or skilled person can do this type of job after a little training for it. Solar collector with dimple surface can be used for the further enhancement in heat transfer rate. **(D'Antoni et al., 2013) [15]**The aim of this work is to investigate the energy potential of using exposed concrete structures as solar energy absorbers during the heating period and in particular the design of a Concrete Solar Collector is then presented. Numerical models and simulation factors were used to establish the energy potential of the CSC design in diverse climatic conditions experienced across regions in Europe. The models determined that, for the climate of Stuttgart, Germany, the winter heat flux rate was about 93.07W/m^2, yielding energy of 460.77kWh/m^2. This yield resulted from an operating fluid flow rate of 45kg/h/m^2 and entry temperature of 5^{0}C. (**Richard O'Hegarty et al., 2017) [16] The** numerical results showed that the performance of the system was affected by several factors such as flow rate, tube length, collector area and the solar absorptance. By using a façade integrated concrete solar collector for a small house, the annual solar fractions were 24% (Dublin), 30 % (Sofia) and 20% (Helsinki). **(A. Chiarelli et al., 2017**)[17] presented in this study which was achieved by the experimental tests with computational fluid dynamics (CFD) simulations in order to calculate how to optimize the design so that to decrease a high temperature of the urban pavement. The results showed that the tubes should be put in an individual row beneath the pavement wearing course for an entire optimal performance. The aim of this study is to improve the thermal efficiency of the horizontal concrete solar collector by the effect of changing the section area shape tube of the HCSC on enhancing the heat transfer

Mathematical and Numerical Solutions

Heat Flux of Solar Radiation

The short-wave solar radiation absorbed by the surface of the pavement can be computed from the equation below (1.1).

$q_{absorbed} = \propto * q_{solar}$ (1.1)

From the equation, surface absorptivity (α) can be defined as the portion of energy from the sun that is absorbed by the surface of the HCSC. The value of α usually depends on factors such as the mean temperature and colour of the surface, inbound radiation's wavelength, and the time of life of the absorption surface [18]. Absorptivity of concrete surfaces, α, tend to commonly reduce during with the age of the concrete and with the fading away of the colour of the surface [19]. The typical values of surface absorptivity for common absorption surfaces made of concrete are shown in the table below. **α**= 0.6 -.72 [20]

Heat Flux of Thermal Radiation

The other characteristic radiation present in the HCSC is the long-wave thermal radiation. The thermal radiation results in a heat flux between the absorption surfaces (HCSC) and the environment (other objects and/or buildings, lower atmosphere etc.) whose value can be computed as [20]:

$Q_{thermal} = \varepsilon\sigma\ (T^4_{surr} - T^4_o)$ (1.2)

Where T_{surr} is the temperature of the surrounding in kelvin (K) whereas T_o is the temperature of the absorption surface in kelvin (K); ε is the emissivity of the surface whose value is dependent on

wavelength of radiation, temperature of surface, and type of materials present in the concrete. Some typical values of ε are indicated in the table below. **Emissivity of Surface, ε**= 0.85 – 0.95 [20].
T_{surr} is usually a theoretical value that stands for the estimated temperature of the objects surrounding the HCSC and the temperature of earth's lower atmosphere (water vapour, clouds, and air). The "sky temperature" is an approximation temperature that is normally used to express T_{surr}. The value of the approximation temperature (T_{sky}) is normally a function of the prevalent conditions of the lower atmosphere, ranging between 230K for low temperatures in cloudless conditions to 285K in higher temperatures in cloudy conditions [21].

Heat Flux at the HCSC Surface

The transfer of heat at the surface of the HCSC is mainly through convection and is calculated as:
$Q= hc\ (T_{air} – T_{O})$ (1.3)
Researchers have used numerous experimental models to compute coefficient of heat transfer (hc) associated with the convection taking place on the surface of HCSCs. For this particular investigation, however, the used experimental equations to compute on forecast the thermal efficacy of the HCSC [22]. The model equation chosen can be represented as
$H_c= 5.6 + 4^* V_w$ (1.4)
In this case, V_w is the surrounding air speed.
Since the heat transfer in HCSCs is often made possible by the operating fluid, the probable overall heat gains of the entire system can be computed by considering several features characteristic of the operating fluid. The features include T_{fin}, T_{fout}, representing the entry temperature, exit temperature correspondingly. As well as the most important influencing factor is the thermal conductivity of the solar concrete collector.

Numerical Solution

Numerical solutions are essentially approximates of actual solutions obtained from analytical techniques which (like a majority of complicated three dimensional geometry problems) are usually too challenging to compute. Accuracy in numerical solutions is often achieved through the use of an increased number of small-sized finite elements. However, the accuracy comes at a cost of increased computational loads that require more effort and time to handle. The net effect of increasing mesh resolution is that computation load and effort required are greatly decreased without significant impact on the accuracy of the obtained solutions. For the purpose of mesh development, the geometry of the HCSC is often segmented into three major domains:

1. The tubes/pipes and the operating fluid flowing in them.
2. The concrete in which the tubes/pipes are embedded.
3. The insulations on the sides that do not absorb incoming solar radiation.

The mesh is made finer around the tubes/pipes and a stable condition simulation is calculated.

Development of Models

The following table (1) summarizes the features of various models for development.

Table 1: Model Development

Model Number	**Model Specifications**
Model 1	3 circular cross-sectional area tubes, arranged parallel to each other (d=9mm, L=3m)
Model 2	3 rectangular cross-sectional area tubes, arranged parallel to each other
Model 3	3 square cross-sectional area tubes, arranged parallel to each other
Model 4	3 triangular cross-sectional area tubes, arranged parallel to each other

The diagrams below show schematic representations of the above mentioned models. The diagrams were drawn using the ANSYS R18 software.

After obtaining the desired three dimensional representations of the 4 models using ANSYS R18 software version, the next step is to simulate the radiation and transfer of heat through convection hence establish the design performance characteristics of each model of HCSC.

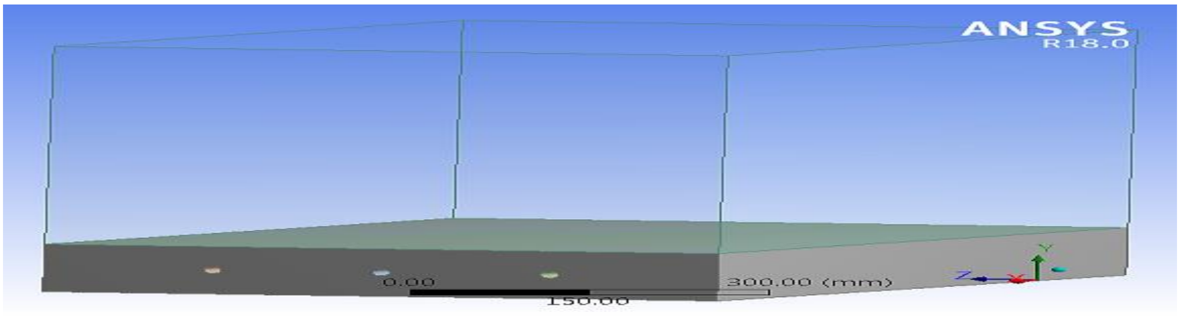

Fig. 1 The Model 1 of with Three Circular Tube Embedded in Concrete

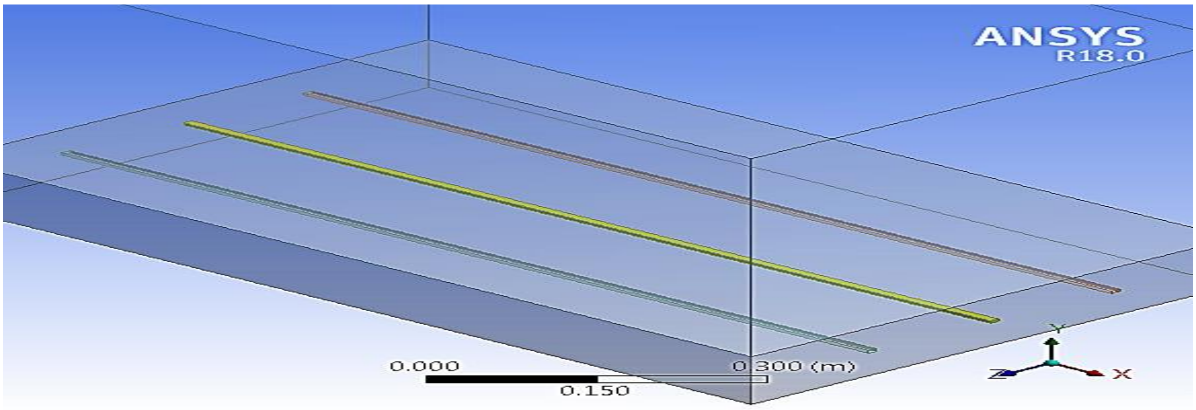

Fig. 2 The Model 2 of with Three Rectangular Tube Embedded in Concrete

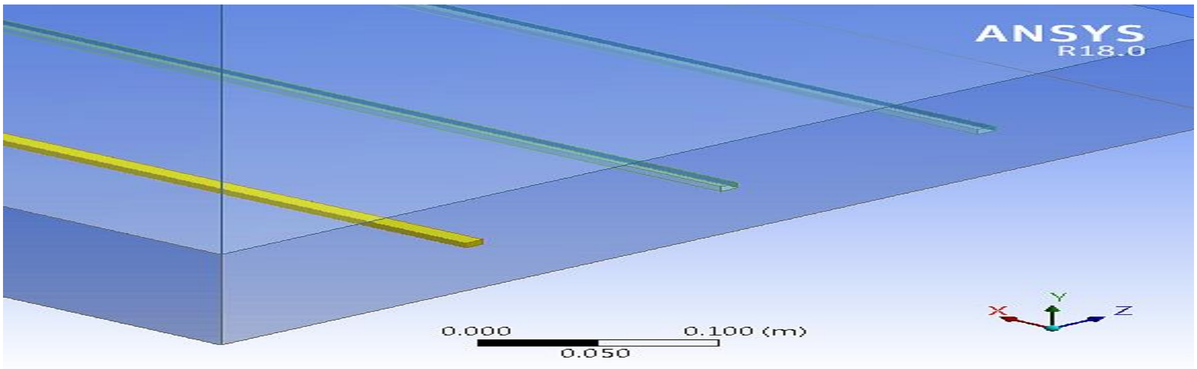

Fig. 3 The Model 2 of the Rectangular Cross-Section of the Embedded Tubes

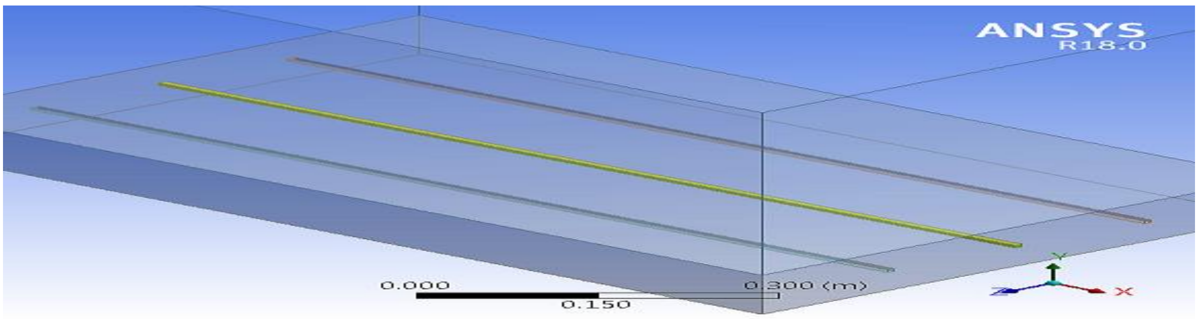

Fig. 4 The Model 3 of with Three Square Tubes Embedded in Concrete

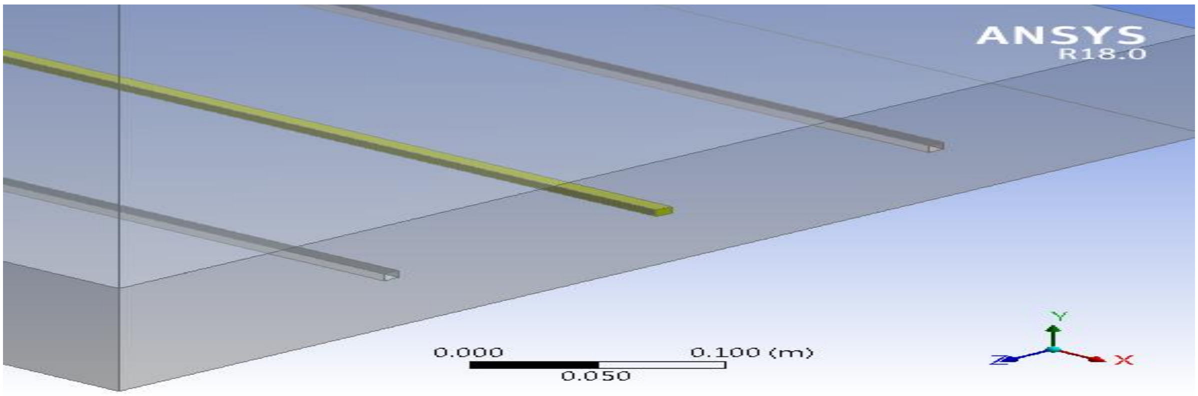

Fig. 5 The Model 3 of the Square Cross-Section of the Embedded Tubes

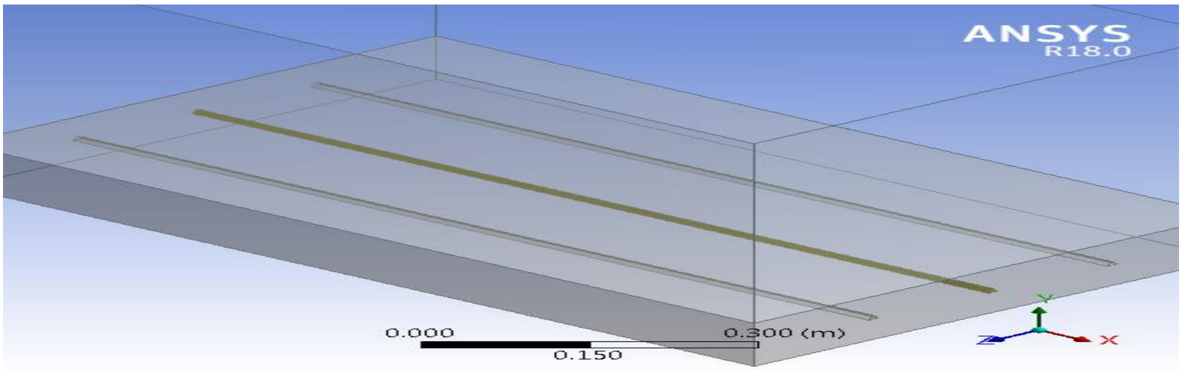

Fig. 6 The Model 4 of with Three Triangular Tubes Embedded in Concrete

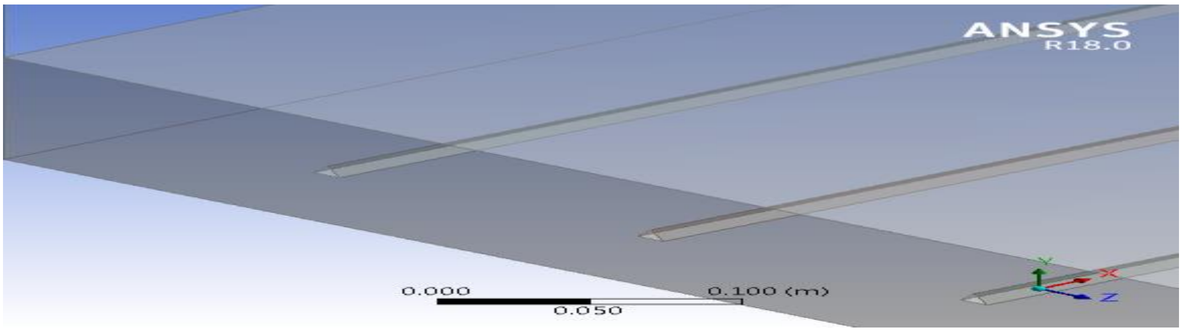

Fig. 7 The Model 4 of the Triangular Cross-section of the Embedded Tubes

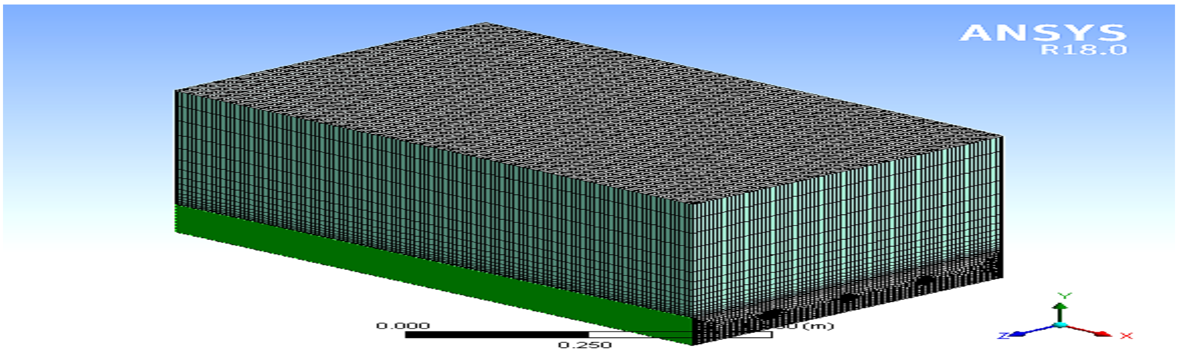

Fig. 8 The Model 1 with Generated Mesh Network

Governing Expressions

The numerical analysis in this case will be enabled by a combination of the Navier-Stokes equations, the first law of thermodynamics, and the principles of the conservation of mass in the 3D representations of the model HCSC platforms. The simulations will be done under steady state conditions. Fluent-18 utilizes a method with limited size, giving an expression for computing momentum, mass, and energy of systems.

2. EXPERIMENTAL WORKS

The main schematic that presents the set up for the experiment is in Figure (9). It is within the indicated system that the HCSC experiment will take place. Further, the horizontal concrete solar collector has its specifications shared in Table (1). It is important to note that the halogen lamp to be used with this solar collector will be set up vertically. For the system to operate, one electrical pump will be utilized to push the water along with the working fluid out of the tank. In order for the process to take place effectively the HCSC will be hooked up to a tank with up to 10 liters in capacity. The intent is to have the system cycle lose heat through the water. On the other hand, heat within the working fluid will be transferred using a concrete heat exchanger to the water tank from the solar thermal cycle. In the course of the process, volume rates were using flow rate 900 Reynolds.

A flow meter networked with pipes was linked in order to control the working fluid's flow rate. It took up to 9 hours of tests in order to achieve the steady. It is required that Steady rate conditions are kept the same for close to 7 hours that is the correct length of the data period, The surface of the pipe along with the various locations of the concrete were measured through thermocouples. The thermocouples were also present at the outlet and inlet looking at the fluid temperatures as they worked through the solar collector along with temperature of the surrounding environment. The thermocouple readings on the solar radiation were captured by the TES 1333R meter in use during the test. All the measuring devices were calibrated in advance even before the experiment to ensure that they were at the correct level.

Fig. 9 Two Frame which Horizontal Collector

Fig. 10 Horizontal Solar Collector Containing Three Rectangle Tubes

Fig 11 This Model has a Single Tube is 3meters

3. RESULTS AND DISCUSSION

The experimental and numerical results of many different modules in this chapter were presented and analyzed, under different conditions of the HCSC. Fluent the numerical results obtained from the Ansysflunt version 18 have achieved good agreements with experimental results, so this package has been adopted to simulate this problem of changing thermal conductivity in the horizontal concrete solar collector. Every model was chosen to be optimal and was determined by the dimensions of the tubes from each other and their height from the level of the concrete surface.
The tubes in the middle of the concrete were selected, because the stress value in the middle equals zero and its maximum negative value at the top while its maximum positive value at the bottom of the concrete. Another factor was mass flow rate, which is very important as increasing the mass flowrate lead to increase of the efficiency, but at certain value. The best flowrate was 0.019kg/s, which is referring to Reynolds 900.

Validation of the Model

The (Ansys fluent version 18) was validated by using the model [23] and as shown in Figure(12) Where the model used for validation, while fig(13) shows the model used according to the reference [23]. Finally fig(13) shows the model drawing by solid work.The error was calculated and it was less than 6% according to the result. The factors that affect a wide range of thermal efficiency were taken, including the effect of the thermal conductivity coefficient of the horizontal concrete solar collector with four values.As well as the comparison with the experimental result was done of for $k = 0.8$ W/ m.C. only due to time and cost. Also water, was adopted in experimental tests at the same value$k = 0.8\ W/\ m.c.$

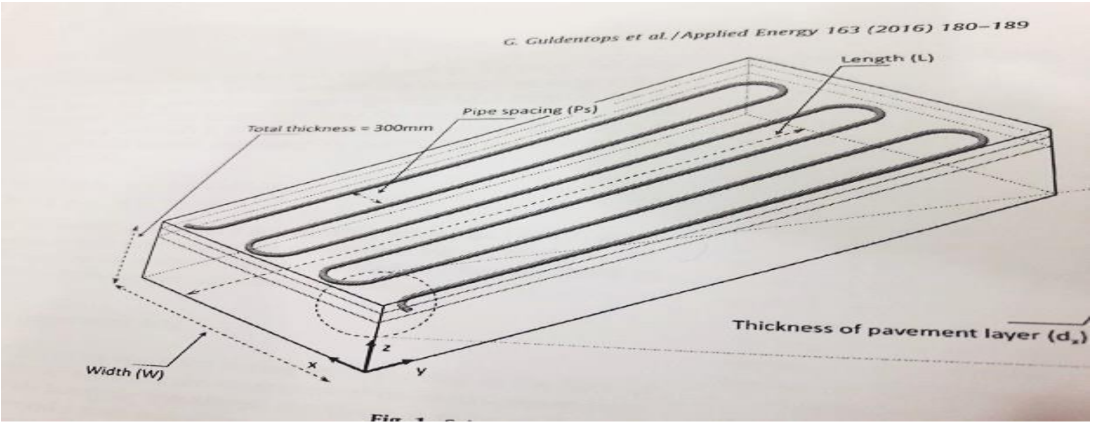

Fig. 12 The Model used for Validation

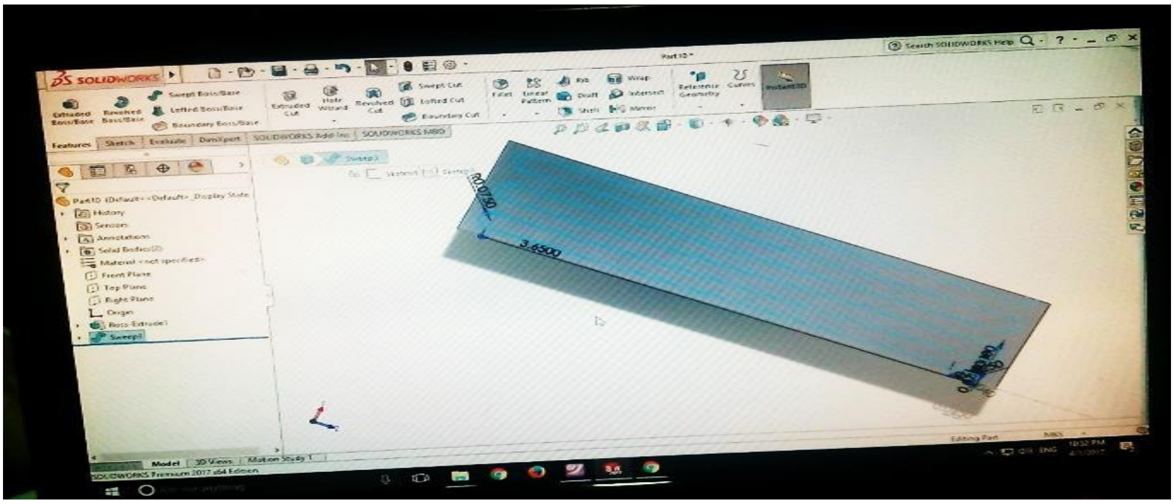

Fig. 13 CAD Geometry for the Model

The Effect of the Tube Crosses Area on the Efficiency of the HCSC

Four models of HCSC containing tubes with a different tube section cross area were used: circular, triangle, square and rectangular. Boundary conditions were included change the radiation intensity, change the thermal conductivity of the HCSC and change the inlet flow temperature as follows.

Figures (14) to (16) shows the relationship between the thermal efficiency with thermal conductivity coefficient of a HCSC containing a triangular section area tube with radiation heat flux changed from 400W/m^2 to 700, then to 1000 W/m^2.The results showed that increasing the change in radiation heat flux leads that increasing temperature the fluid coming out the solar collector and thus increase the thermal efficiency of the horizontal concrete solar collector. The highest thermal efficiency of the solar collector was 56.33% at 1000W/m^2 radiation and the lowest value was 23.4% at 400W/m^2 watts with the thermal conductivity coefficient of the solar collector equal 4 W/mc. Where the water temperature conditions of 15°C, It is illustrated that the efficacy of the HCSC increases with increasing radiation heat flux and decreases with increasing the inlet water temperature the solar collector.

Also Figures (17) to (19) shows the relationship between the thermal efficiency with thermal conductivity coefficients of a HCSC containing circular cross section area tube with radiation heat flux for three different values hanged from 400W/m^2 to 700W/m^2, and to 1000W/m^2. The results showed that increasing the radiation heat flux leads to increase the temperature of the fluid coming out of the solar collector.

Thus increase the thermal efficiency of the horizontal concrete solar collector from 12.35%, 27.89% and 43.81%.respectively. At inlet water temperature conditions of 15 ° C and thermal conductivity equal 4 W/m.C. it is illustrated that the efficiency of the HCSC increases with increasing radiation

heat flux and decreases with increase the entering water temperature of the solar collector.The result show the highest efficiency accrue with the HCSC which contains tubes with a triangular section area
While in Figures (20) to (22) the results showed that the thermal efficacy values of the HCSC containing square cross section area tubes was 20.2%, 42.12% and 53.4% when radiation heat flux changed from 400W/m^2 to 700 W/m^2, and to 1000W/m^2 respectively. At inlet water temperature conditions of 15°C and thermal conductivity equal 4 W/m.C. it is illustrated that the efficacy of the HCSC increases with increasing radiation heat flux and decreases with increasing the inlet water temperature the solar collector.
Finally, the figures show (23) to (25) showed that the solar collector containing rectangular cross section area tubes gave the highest thermal efficiency of all other solar collectors where the thermal efficiency value was 27.1%, 50.24% and 61.97% when radiation heat flux changed from 400W/m^2 to 700W/m^2, and to 1000W/m^2 respectively. At inlet water temperature equal 15°C and thermal conductivity equal 4 W/m.c. it is illustrated that the efficacy of the HCSC increases with increasing radiation heat flux and decreases with increasing the inlet water temperature the solar collector.
The result show the highest efficacy of the HCSC containing rectangle cross section area tubes and for all models so that the fluids exit temperature is higher than all other tubes.
The reason for the increased thermal efficiency of the HCSC, which contains tubes with an area of rectangular section, is that it is exposed to a larger area of thermal surface contact, which leads to higher temperature and thus increases the efficiency of the HCSC.
Also Figures (14) to (25) shows the effect of the inlet water temperature on the thermal efficiency of the horizontal concrete solar collector containing tubes with a different section area that are triangle, circular, square, and rectangular at a radiation heat flux equal of 400W/m^2, 700W/m^2, and 1000W/m^2. The results show that increasing inlet the water of temperature of the solar collector reduces the thermal efficiency of the horizontal concrete collector. The inlet water temperatures were 15°C, 20°C and 25 °C receptively.
Figure(26) show that the highest thermal efficacy of the HCSC containing rectangular cross section area tubes at the inlet water temperature equal 15°C and the radiation heat flux equal of 400 W/m^2 was 27.1%, while the lowest thermal efficiency of the solar collector containing circular cross section area tubes were 12.35%. For four all horizontal concrete solar collectors contain tubes with a different section area.
While Figure (27 show the highest thermal efficacy of the HCSC containing rectangular cross section area tubes at the inlet water temperature 20°C and the radiation heat flux of 400W/m.C was 21.374%, while lowest thermal efficiency of the HCSC containing circular cross section area tubes was 10.644%. For four cases HCSC contain tubes with a different section area.
While Figure (28) show the highest thermal efficacy of the HCSC containing rectangular cross section area tubes at the inlet water temperature of equal 25°C and the radiation heat flux 400 W/m.C was 17.546%. The lowest thermal efficiency of the HCSC containing circular section tubes was 7.97%. For four horizontal concrete solar collectors contain tubes with a different section area.
When compared the figures from (26 to 28). It is clear that the highest thermal efficiency of the HCSC which contains rectangular cross section area tubes when the radiation heat flux was established 400 W/m^2 so that the efficiency is increased by decreasing the inlet temperature.
Also the figures from (29) to (31) are shown the influence of the thermal conductivity of the HCSC thermal efficacy of tubes with different section area and at inlet water temperature equal 15°C., 20°C, and 25°C which at value radiation heat flux 700W/m^2.When the thermal conductivity of the HCSC increases, the thermal efficiency increases while the temperature of the inlet water temp increases, the thermal efficiency of the concrete solar collector decreases.
finally figures from (32) to (34) are shown the influence of the thermal conductivity of the HCSC on thermal efficacy of the tubes with different section area and at inlet water temp equal 15°C., 20°C, 25°C. At radiation heat flux equal 1000 W/m$^{2.}$ The best efficacy of the HCSC was that it contains tube with rectangle section area. Where the thermal conductivity was 4W/m.C, As well as the highest radiation which were 1000W/m^2 and the lowest inlet water temperature equal to 15°C.

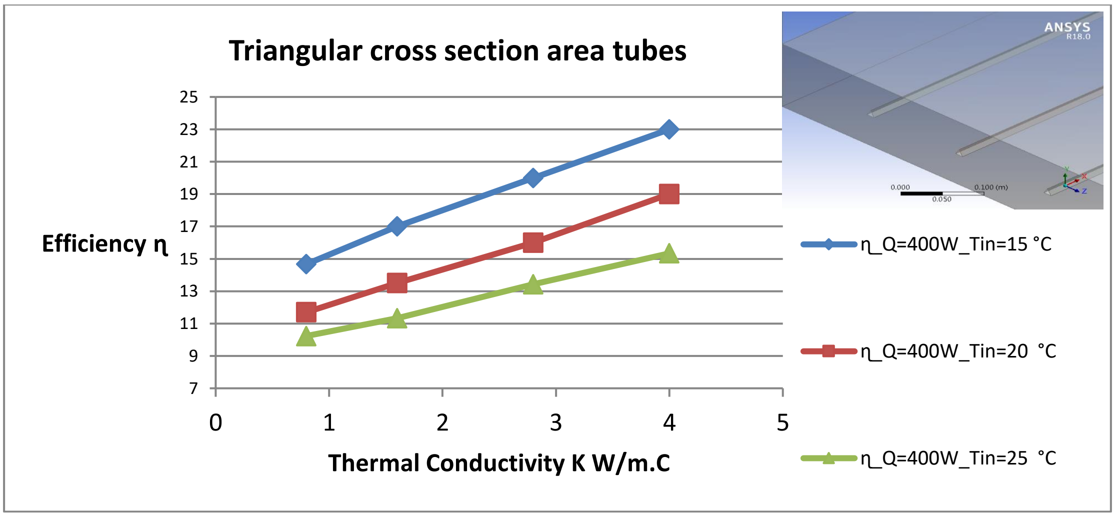

Figure 14 The Influence the Conductivity on Efficacy of HCSC with a Triangle Tube at Radiation Heat Flux equal 400W/m^2 and for Different Inlet Temperatures

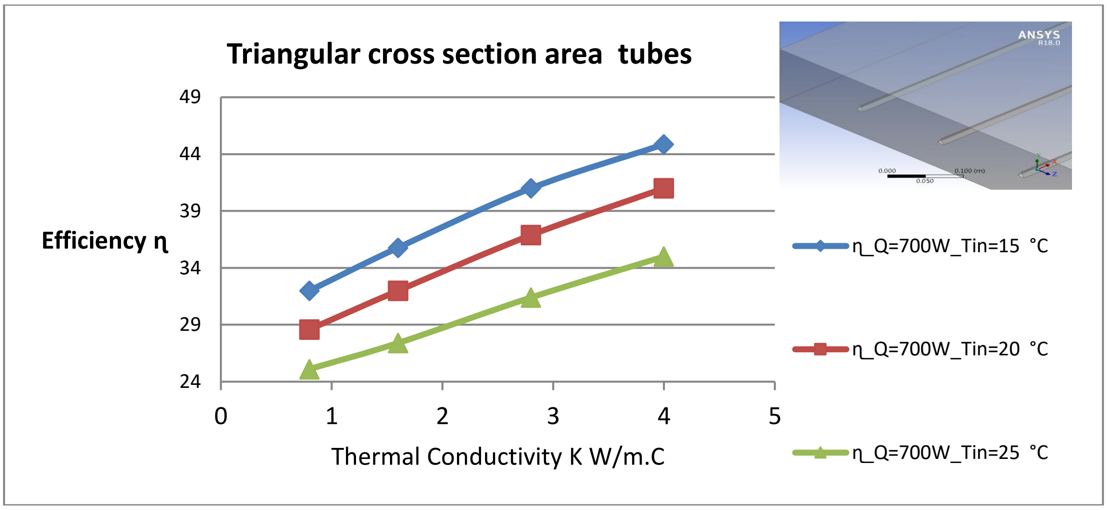

Figure 15 The Influence of Conductivity on Efficacy the HCSC with a Triangle Tube at Radiation Heat Flux Equal 700W/m^2 and for Different Inlet Temperatures

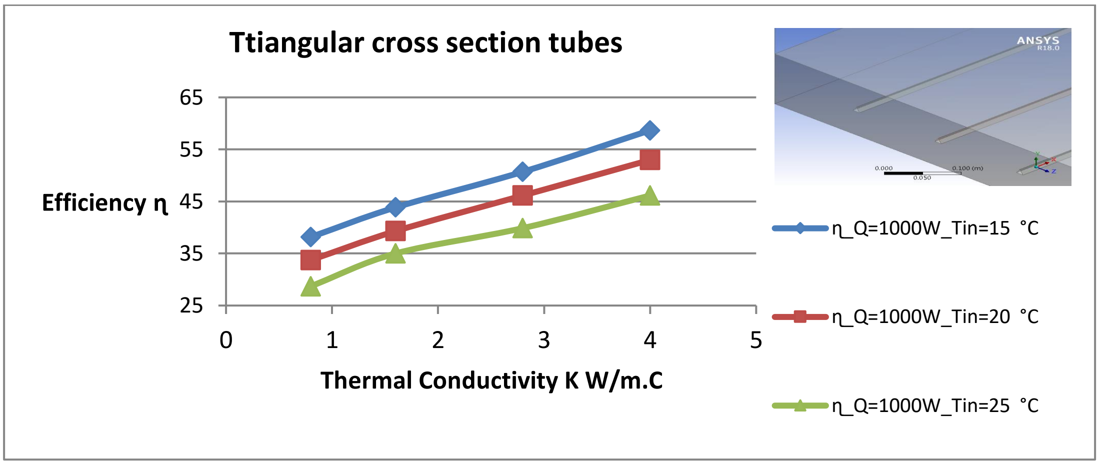

Figure 16 The Effect of Thermal Conductivity on the Thermal Efficiency of the HCSC with Triangle Tube at Radiation Heat Flux Equal 1000W/m^2 and for different Inlet Temperatures

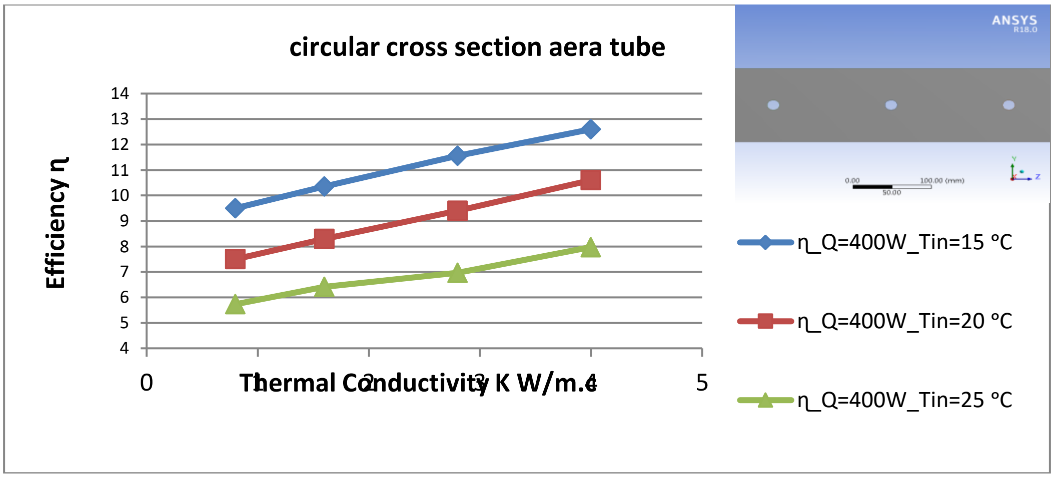

Figure 17 The Effect of Conductivity on Efficacy of the HCSC with a Circular Tube at Radiation Heat Flux Equal 400 W/m^2 and for different Inlet Temperatures

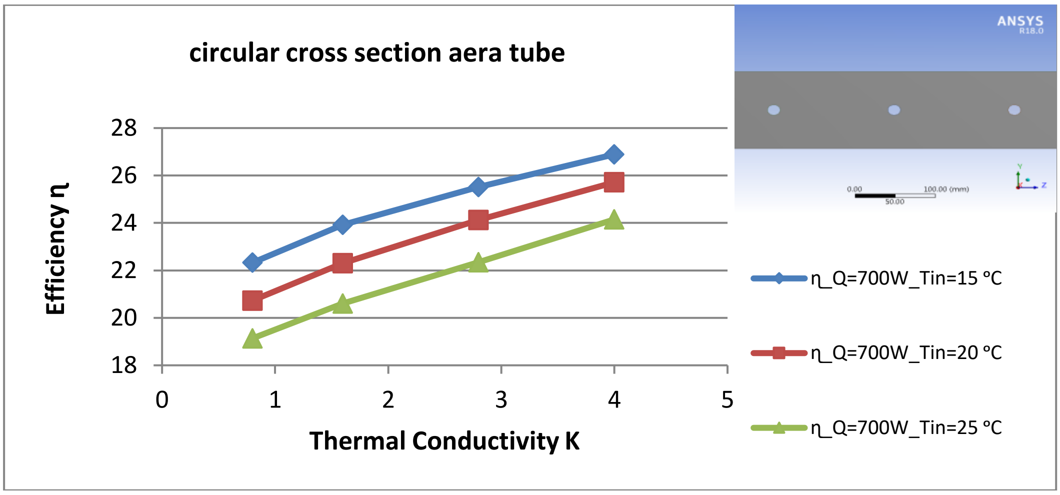

Figure 18 The Effect of Thermal Conductivity on the Thermal Efficiency of the HCSC with a Circular Tube at the Radiation Heat Flux Equal 700 W/m^2 and for different Inlet Temperatures

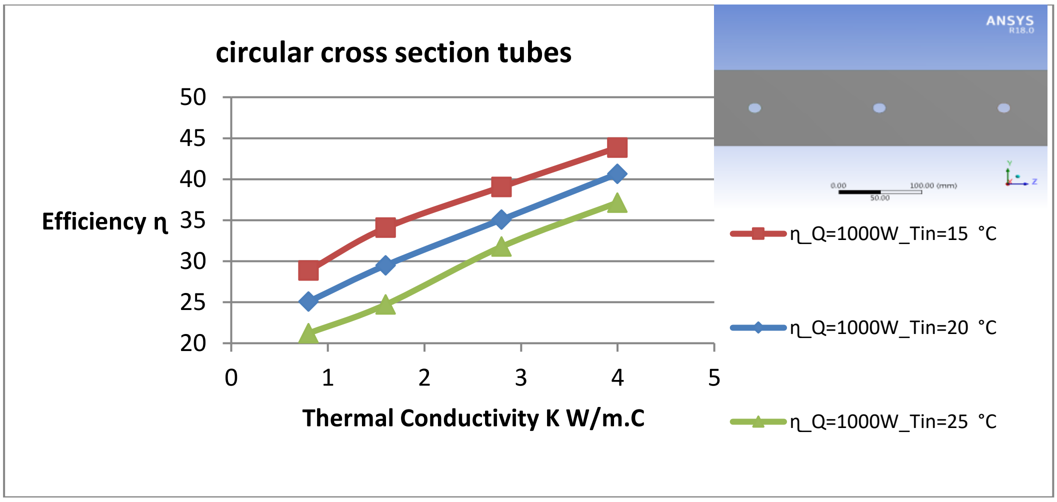

Figure 19 The Influence of Conductivity on Efficacy of the HCSC with a Circular Tube at the Radiation Value of 1000 W/m^2 and for different Inlet Temperatures

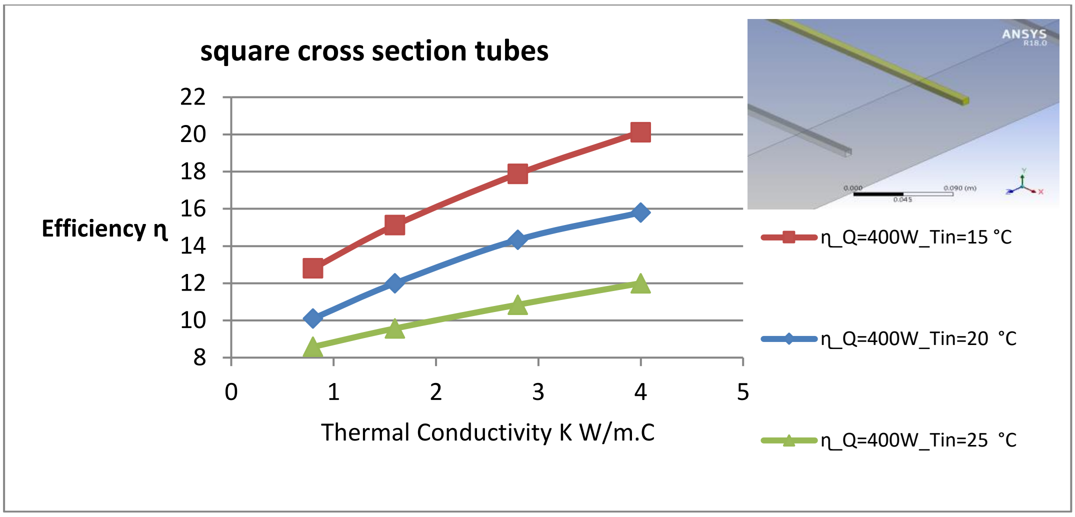

Figure 20 The Influence of Conductivity on the Efficacy of the HCSC with a Square Tube at the Radiation Value of 400W/m^2 and for different Inlet Temperatures

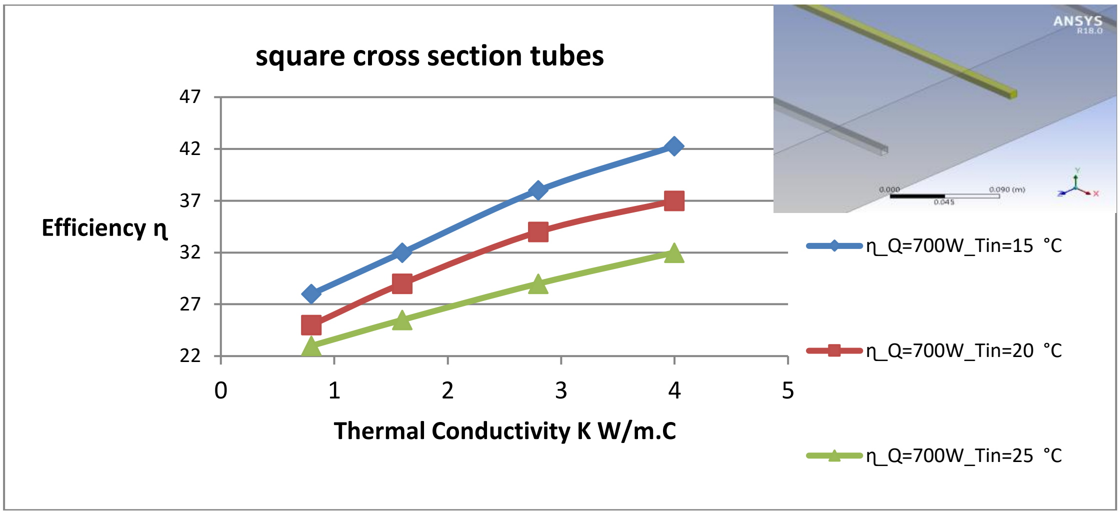

Figure 21 The Influence of Conductivity on the Efficacy of the HCSC with a Square Tube at the Radiation Value of 700 W/m^2 and for different Inlet Temperatures

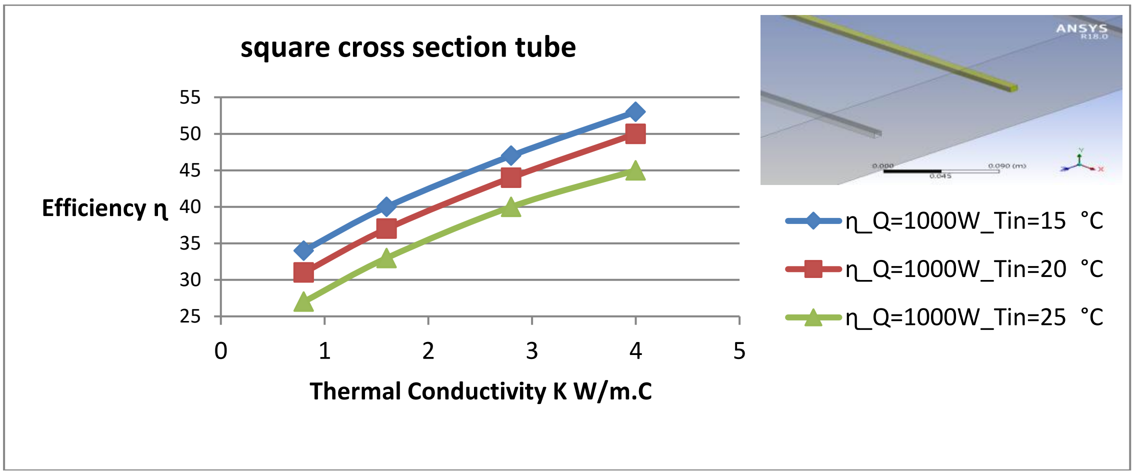

Figure 22 The Influence of Conductivity on the Efficacy on the HCSC with a Square Tube at the Radiation Heat Flux 1000 W/m^2 and for different Inlet Temperatures

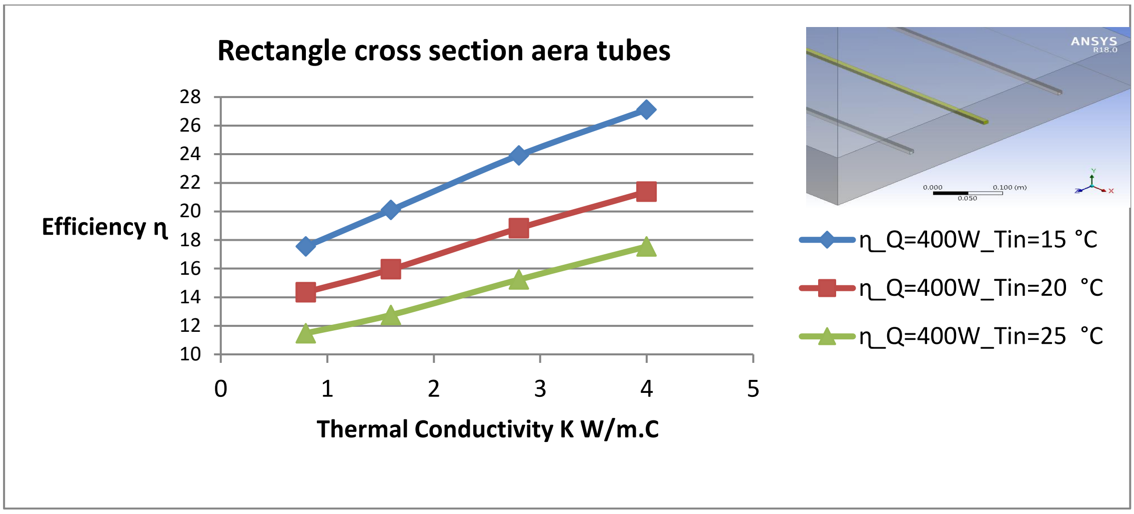

Figure 23 The Influence of Conductivity on the Efficacy the HCSC with a Rectangle tube at the Radiation Heat Flux 400W/m^2 and for different Inlet Temperatures.

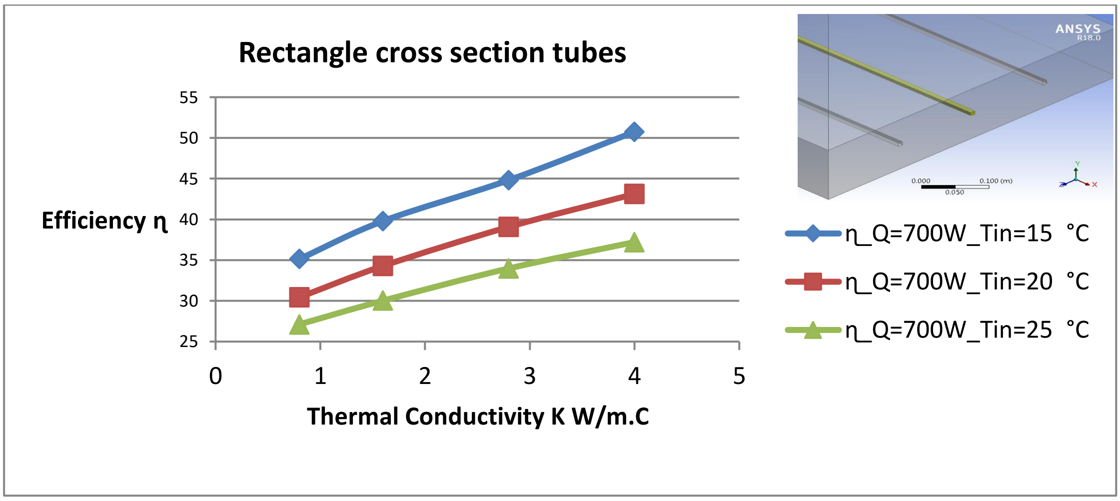

Figure 24 The Influence of Conductivity on the Efficacy of the HCSC with a Rectangle Tube at the Radiation Heat Flux 700W/m^2 and for different Inlet Temperatures

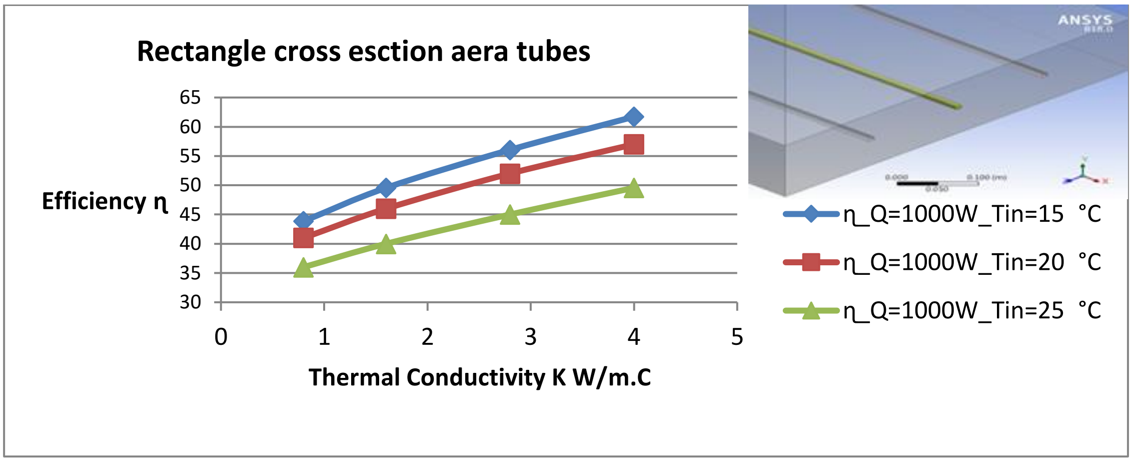

Figure 25 The Influence of Conductivity on the Efficacy on the HCSC with a Rectangle Tube at the Radiation Heat Flux 1000W/m^2 and for different Inlet Temperatures

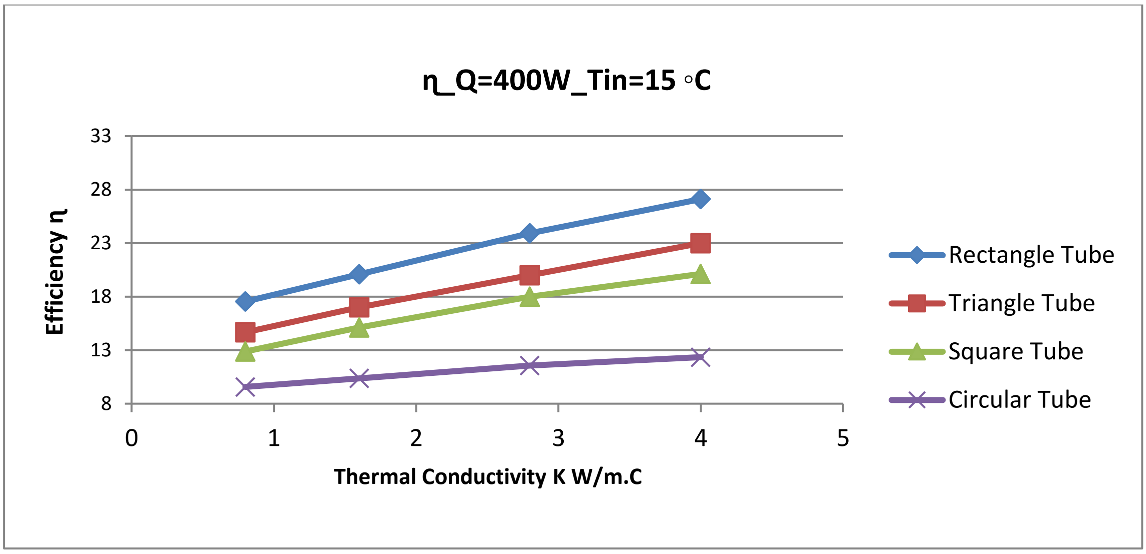

Figure 26 The Influence of the Conductivity on the Efficiency of the HCSC at tubes with different Section Area and at a Temperature of 15°C

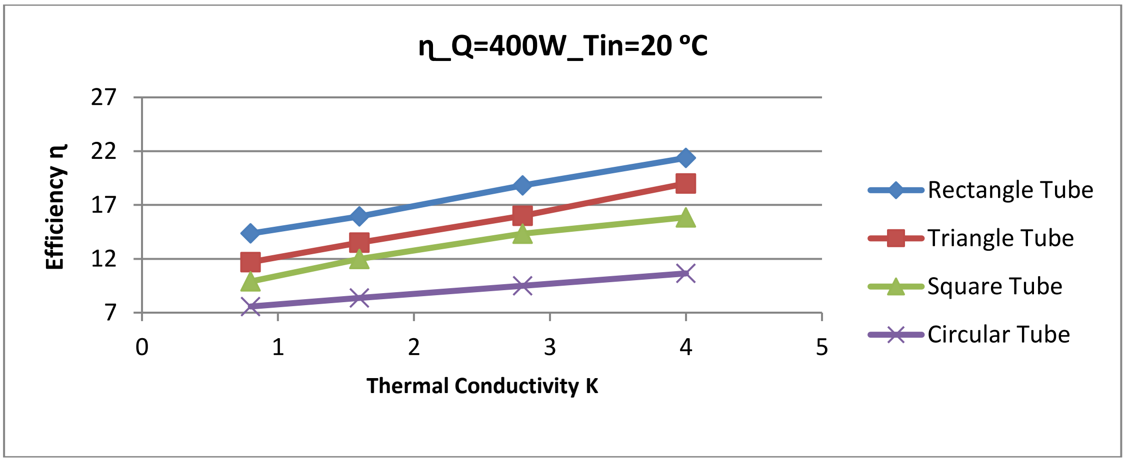

Figure 27 The Influence of the Conductivity of the HCSC on the Efficacy of Tubes with different Section Area and at a Temperature of 20°C

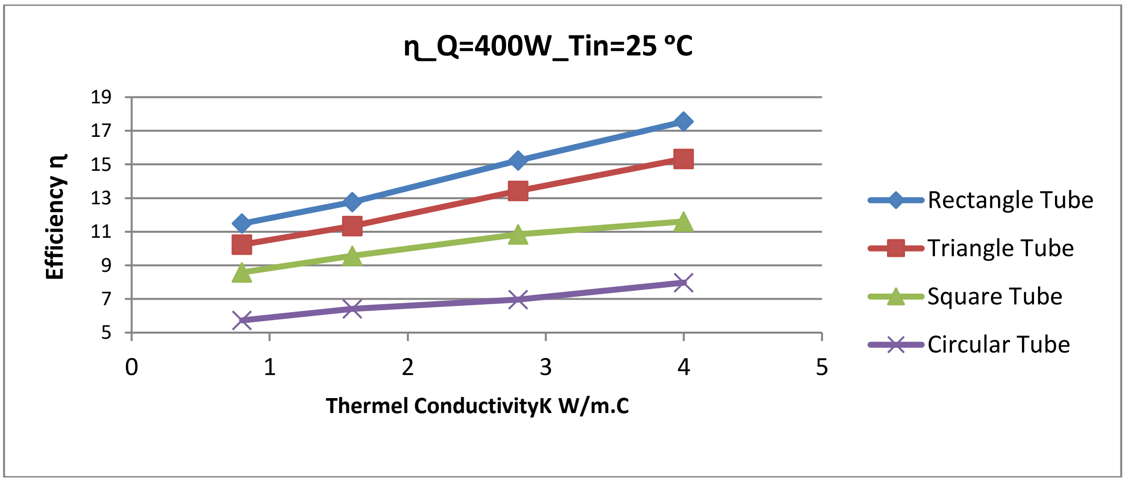

Figure 28 The Influence the Conductivity of HCSC on the Efficacy of Tubes with different Section Area and at a Temperature of 25°C

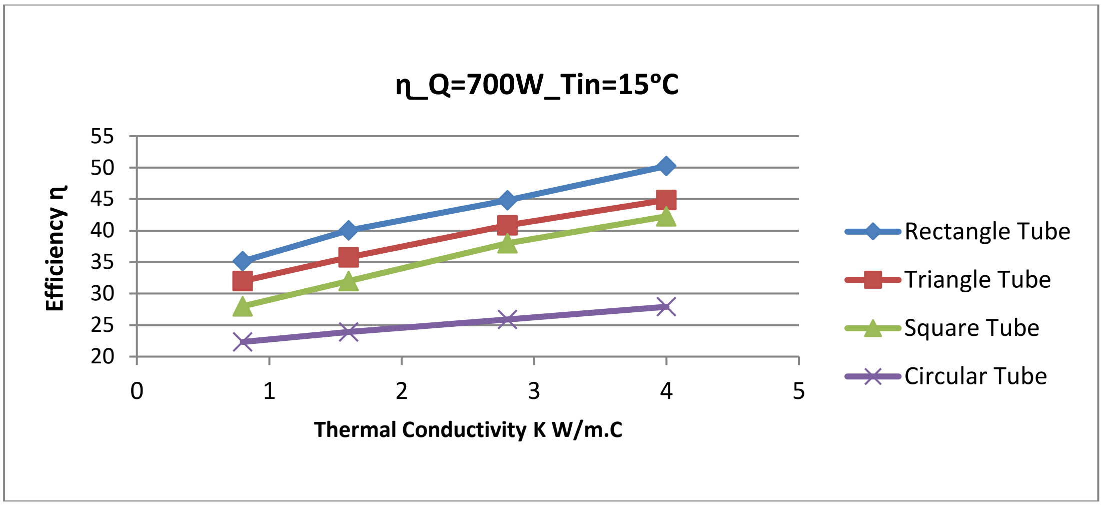

Figure 29 Influence of Conductivity of the HCSC on the Efficacy at Tubes with different Sections at Radiation 700W/m^2 for Tin 15^{o}C

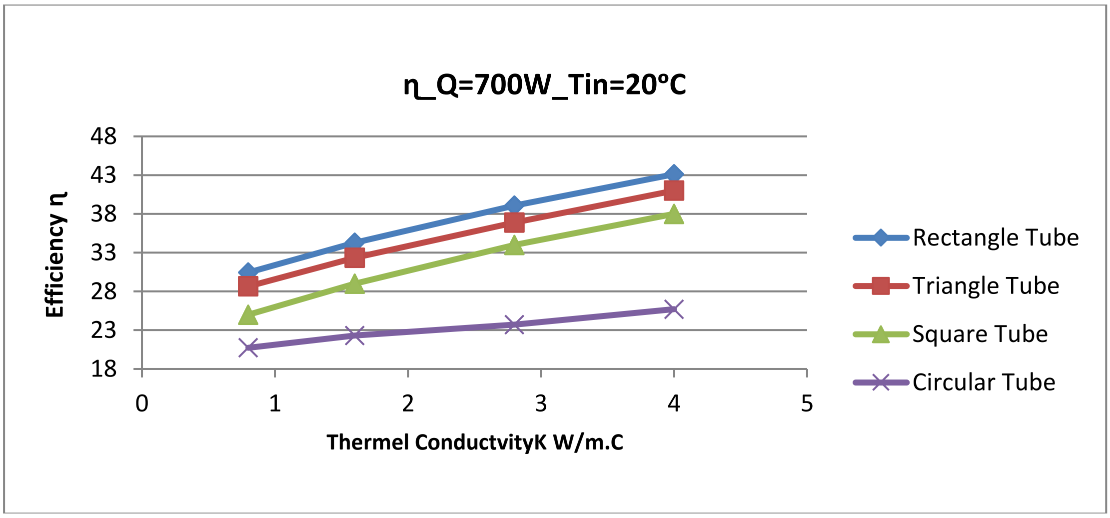

Figure 30 Influence of Conductivity of the HCSC on the Efficacy at Tubes with different Sections at Radiation 700 W/m^2 for Tin 20^{o}C

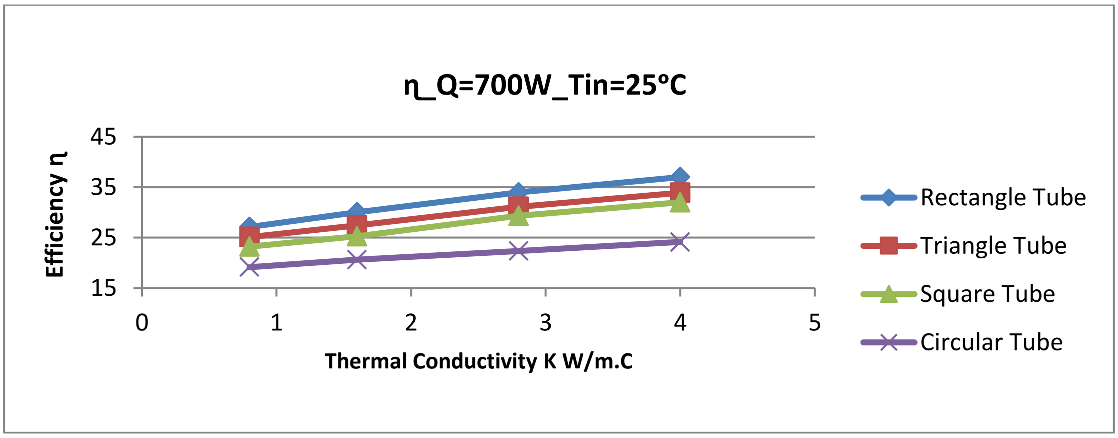

Figure 31 Influence of Conductivity of the HCSC on Efficiency at Tubes with different Sections at Radiation 700 W/m^2 for Tin 25^{o}C

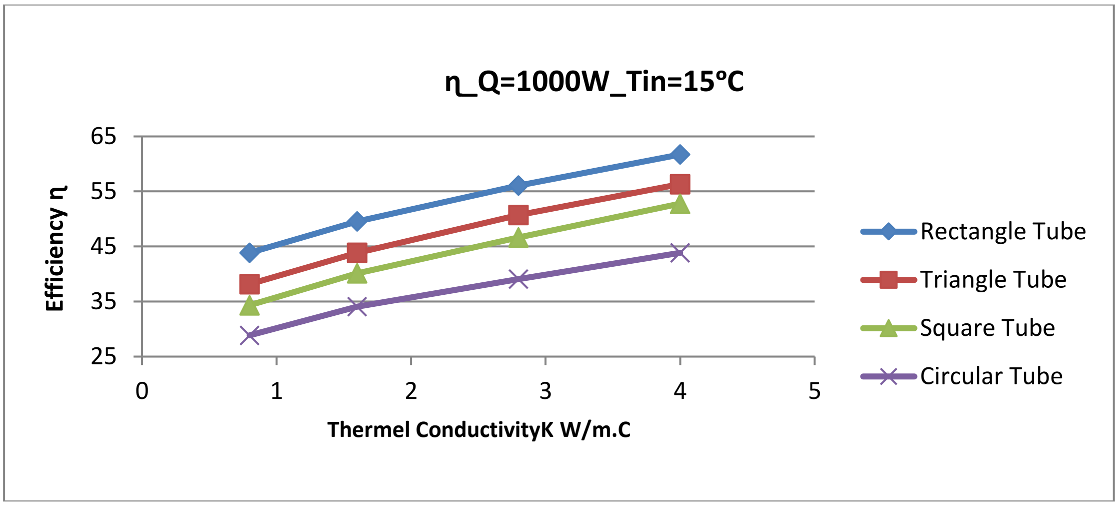

Figure 32 Influence of Conductivity of the HCSC on Efficacy at Tubes with different Sections at Radiation Heat Flux 1000 W/m^2 for Tin 15^{o}C

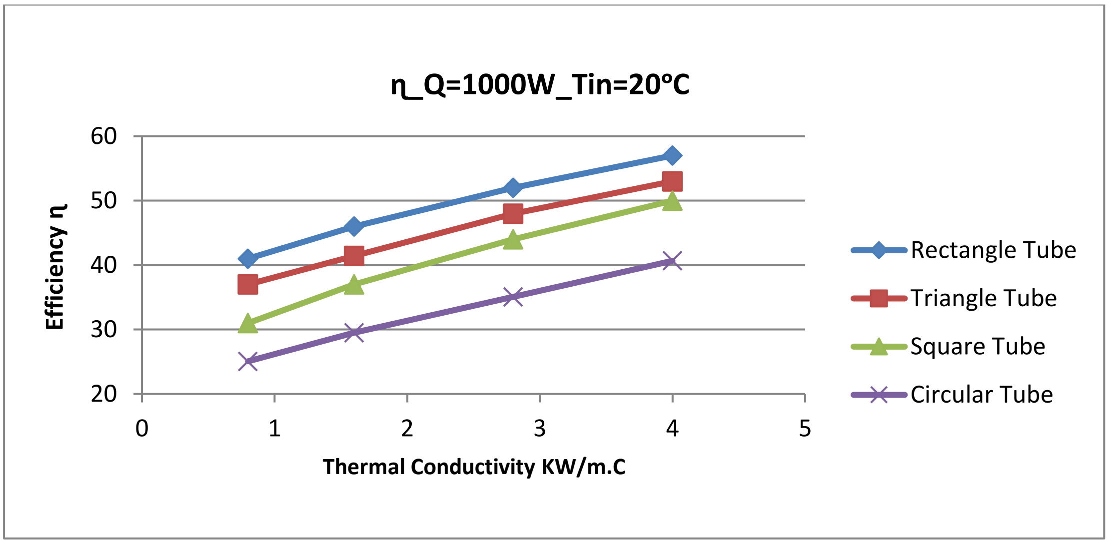

Figure 33 Influence of Conductivity of HCSC on Efficiency at tubes with different Sections at Radiation 1000 W/m2 for Tin 20°C.

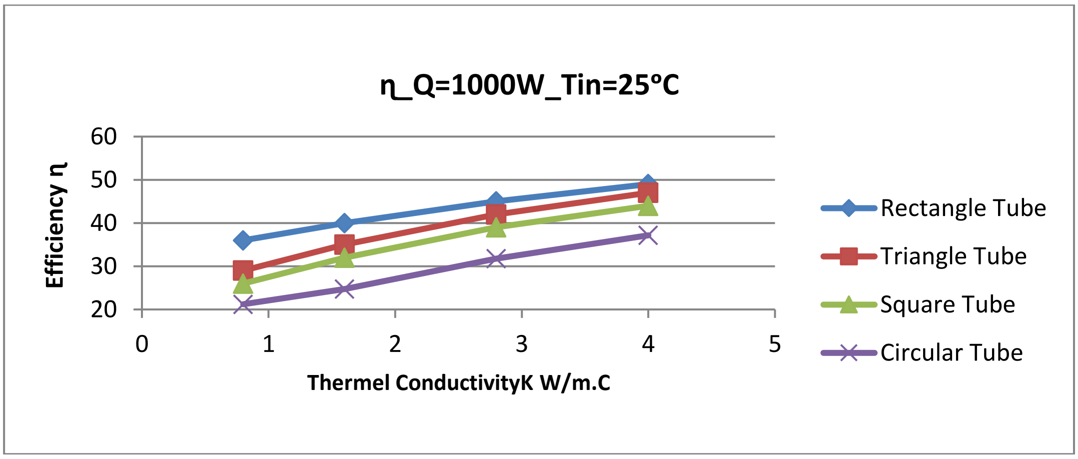

Figure 34 Influence of Conductivity of HCSC on Efficacy at Tubes with different Sections at Radiation 1000 W/m^2 for Tin 25°C

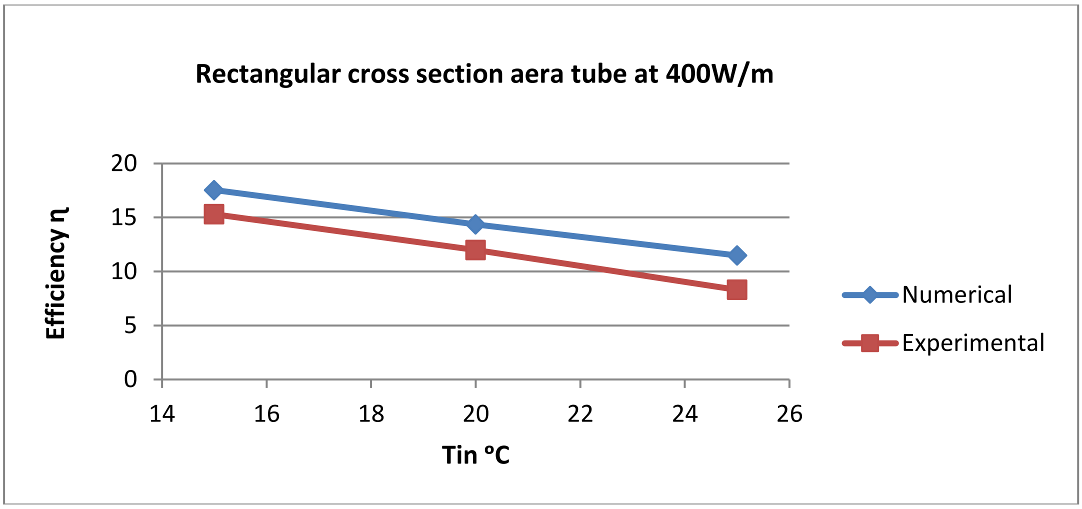

Figure 35 Comparison between Test and Numerical of Thermal Efficiency HCSC with different Temp at Radiation 400 W/m^2

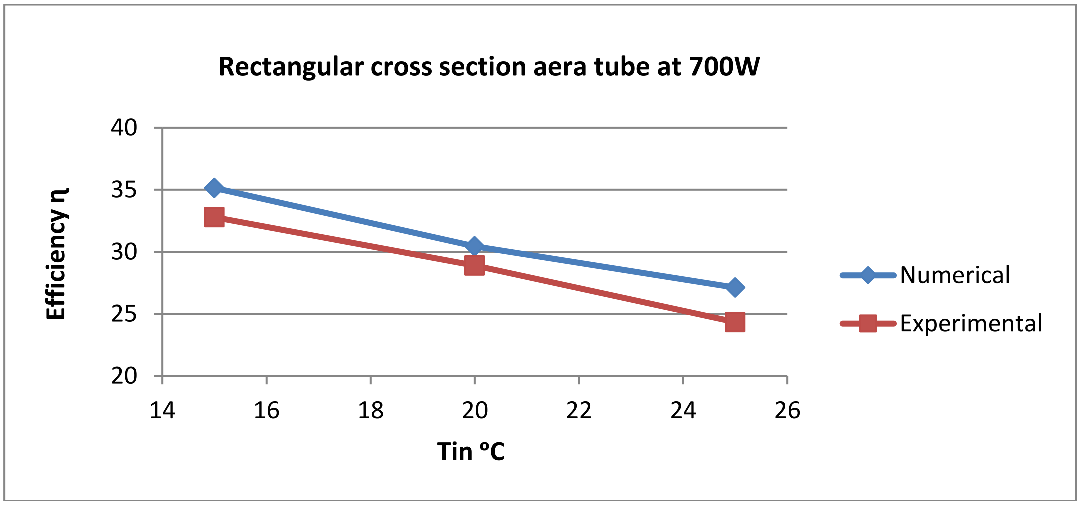

Figure 36 Comparison between test and Numerical of the Thermal efficiency HCSC with different Temp at Radiation 700 W/m^2

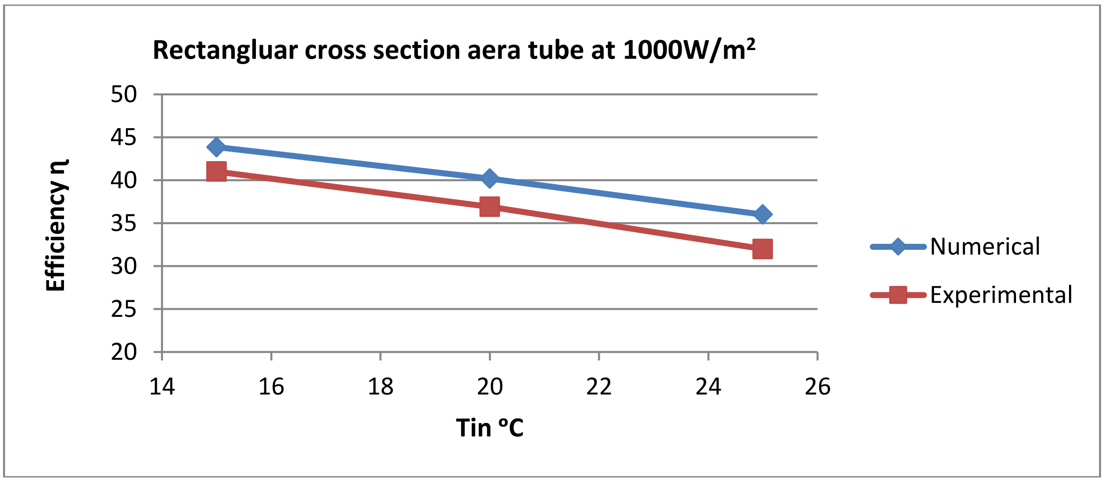

Figure 37 Comparison between Test and Numerical of Thermal Efficiency HCSC with different Temp at Radiation 1000 W/m^2

4. CONCLUSIONS

In the HCSC, concrete structures are equipped with tubes to flow working fluid in side it, in order to serve as a solar energy collector. The fluid in the tubes can absorb heat from concrete and deliver useful energy to buildings. Within the limitation adopted in this work, the following conclusions can be summarized,

1. To validate the results obtained in this research, a validation test was done. The test involved comparison of thermal efficiency results of the practical models and numerical models. The results show that the obtained converge rate ranged is from 7% to 12%.
2. The thermal efficiency has been calculated for tubes with rectangular, circular, and square cross-sections area within the HCSC. The results obtained established that the highest values of thermal efficiency are for tubes of rectangular cross-sectional area. Where of increase in thermal efficiency was 36% over the one-tube solar collector.
3. It was found that increasing the radiation heat flux leads to a nonlinear increase in thermal efficiency, and it was concluded that enhancing the thermal efficiency of a single-tube solar collector was 269.72% higher when the radiation heat flux increased from $400W/m^2$ to $1000W/m^2$.
4. By varying the inlet fluid temperature, the investigation established that high inlet fluid temperatures result in lower HCSC thermal efficiencies It is found that the thermal efficiency of the solar collector which contains one tube is increased by 15.6% when the water entering temperature decreases from 20°C to 15°C.While it was concluded that the enhanced of thermal efficiency was 13.1 % when the temperature of entering water decreases from 20°C to 15°C.

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