Le 5ème Séminaire International sur les Energies Nouvelles et Renouvelables
The 5th International Seminar on New and Renewable Energies
Unité de Recherche Appliquée en Energies Renouvelables, Ghardaïa – Algeria 24 - 25 Octobre 2018

Heat transfer enhancement in parabolic trough collector tube using Al_2O_3/synthetic oil nanofluid

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***Abstract*— Given to the environmental and uncertainty about future energy supplies, solar energy is the best alternative in spite of its slightly higher operating costs. Currently, solar power plants play an important role in energy production by converting solar radiation into heat or electricity. The technology of parabolic trough collector is the most economical and most proven one. One of the major problems of this technology is energy storage and compact designs. The solution is to replace the working fluid with a nanofluid as a new strategy to improve the heat transfer proprieties of the fluid. A numerical simulation of the flow and heat transfer in a parabolic trough solar collector subjected to non-uniform solar flux (concentrated on the focal strip) was carried out using two heat transfer fluids (Syltherm and nanofluid). The simulation by the fluent software was performed using the single phase for nanofluids and then compared to the results from the based fluid . The results show that the use of nanofluids improves satisfactorily the heat flux exchanged compared to the based fluid.**

***Keywords*— nanofluid, parabolic trough solar collector, heat Flux, solar radiation.**

1.INTRODUCTION

Naturally, while zeroing down the alternative source economic constraints, environmental and safety concerns need to be taken into consideration. Solar energy is widely believed to be the most sustainable form of energy among various alternatives among non-conventional sources. [1].Recent developments in nanotechnology and related manufacturing techniques have made possible to manufacture the nano sized particles. Fluids with nanoparticles (diameter less than 100 nm) suspended in conventional fluids are called nanofluids, as coined by Choi S.U.S to increase the heat transfer characteristics. The main goal of nanofluids is to achieve highest possible value of thermal conductivity at the smallest possible concentration of nanoparticles. [2].

Nanoparticles of materials such as metallic oxides (Al2O3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO2, SiC),

single, double or multi walled carbon nanotubes (SWCNT,DWCNT, MWCNT), alloyed nanoparticles (Al70Cu30) etc. have been used for the preparation of nanofluids. These nanofluids have been found to possess ennhanced thermal conductivity (Shyam et al., 2008; Choi et al., 2001; Eastman et al., 2001) as well as improved heat transfer performance (Xuan et al., 2003;Yu et al., 2003; Vassalo et al., 2004; Artus, 1996) at low concentrations of nanoparticles. Even at very low volume fractions (< 0.1%) of the suspended particles, an attractive enhancement up to 40% in thermal conductivity has been reported on these nanotechnology based fluids (Wang et al., 1999 [3]. Recent development in this field indicates that application of nanofluid in this thermal system showed promising performance. Most of the researchers focused their researches on flat plate sand direct absorption solar collectors. Concentrating solar collector such as trough solar collector has been given less attention among the researchers. In another aspect, there are several issues that need further investigation, namely the stability of nanofluid, effect of variation non viscosity and cost, and lastly design optimization of the solar collector. All of these issues should be addressed before nanofluids can be fully utilized and commercialized in this area.[4].

2. MATHEMATIC MODEL

2.1 physical Model:

The physical phenomena of heat transfer and fluid flow are governed by physical laws of conservation of mass, the momentum and energy.

2.1.1 Continuity equation:

$$\frac{\partial \rho}{\rho t} + \nabla\left(\rho \vec{V}\right) = 0 \qquad (1)$$

For a steady flow and mass conservation equation becomes: $\frac{\partial \rho}{\rho t} = 0$

$$\nabla\left(\rho \vec{V}\right) = 0 \qquad (2)$$

2.1.2 Dynamics equations (Navier-Stokes)

The equation that describe the motion of a fluid particle derived from the conservation of momentum. The differential form of the conservation equation of momentum can be obtained from the integral relations on a volume control and the application of the divergence theorem. If the fluid is Newtonian, gravity is the only force acting on the volume of the field in question, the governing flow equations can be expressed as [5]:

$$\left[\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right] = -\frac{\partial p}{\partial x}\mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right] \qquad (3)$$

$$\rho\left[\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right] = -\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right] \qquad (4)$$

$$\rho\left[\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right] = -\frac{\partial p}{\partial z} - \rho g + \mu\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right] \qquad (5)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad (6)$$

In stationary incompressible flow, the equation is written:

$$V_j \frac{\partial V_i}{\partial x_i} = -\frac{1}{\rho}\frac{\partial \rho}{\partial x_i} + v\frac{\partial^2 V_i}{\partial x_j \partial x_i} + g_i \qquad (7)$$

Where g_i is the volume force

2.1.3 Energy Equationn

The equation of energy is derived from applying the first law of thermodynamics. In the steady state is given by the following expression:

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{k}{\rho\, C_p}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) \qquad (8)$$

3. RESULTS

On Fig.1 and Fig.2 are shown respectively the temperature contours on the surface of the absorber tube and in section of the collector z = 1.25 m. V = 1.5 m /s and the fluid inlet temperature equal to 513 K. there is a non-uniform temperature distribution, high temperature values are located on the focal band of the absorber tube where the concentrated solar flux is imposed. These temperature differences induce a non-uniform distribution of the thermal stresses on the periphery of the absorber, which can cause a hot mechanical strength of the tube. For the cladding glass tube temperatures remain low thereby protecting the glass thermal deformations. The temperature of the Heat-transfer fluid inside the absorber tube increases only slightly because the heat capacity of the Syltherm oil is quite high.

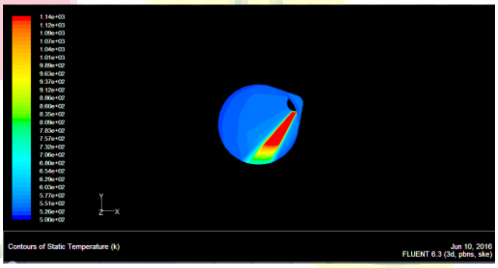

Figure 1. Temperature contours on the surface of the absorber tubecase V = 1.5 m / s and fluid temperature at the inlet equal to 513°K.

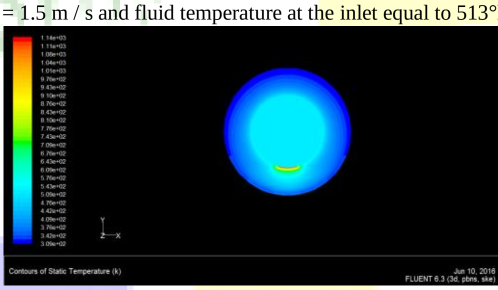

Figure 2. Temperature contours in a section of the solar collector at z = 1.25m cases: V = 1.5 m / s and fluid temperature at the inlet equal to 513°K.

3.1 Based fluid case :

The variation of the local Nusselt number along the axial direction of the tube is shown in the Fig.3. The Nusselt number (Nu) is a dimensionless number used in the heat transfer phenomena. It represents is the ratio of convective to conductive heat transfer across (normal to) the boundary. The number of Nusselt decreases as the flow advances in the tube, this is due to changes in the thickness of the thermal boundary layer with the abscissa z producing temperature gradients increasingly low in successive sections. The high values of Nusselt number indicate a predominance of convective heat transfer compared to conduction heat transfer, the thermal conductivity of the heat-transfer fluid is low

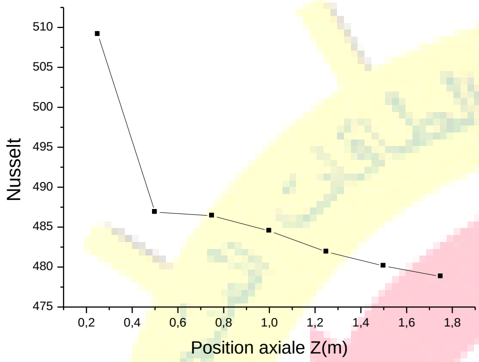

Figure 3. Change in local Nusselt number along the axial direction of the tube: T = 513°K and V = 1.5 m / s

3.2 Case of nanofluid :

Fig.4 is shown the variation of the local convection coefficient along the tube for both Syltherm based fluid and nanofluid. At the concentration of 1%. The two curves have the same shape reflecting a gradual decrease in h when the fluid in the tube advance, It is noted that the values of the coefficient of convection h for the case of nanofluid are greater than those of the fluid Syltherm due to improved thermal properties of nanofluids. This will result in increasing the convective heat exchange.

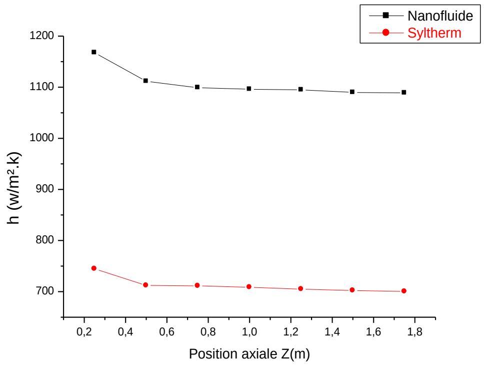

Figure 4. Variation of the local convection coefficient h for Syltherm fluids and nanofluids: V = 1.5m / s, T= 513°K and φ = 1%

4. Conclusions

In this paper we conducted a numerical simulation of flow and heat transfer in a parabolic trough solar collector subjected to non-uniform solar flux (concentrated on the focal band). The study was carried out using two heat transfer fluids (Syltherm oil and nanofluids) in order to compare their effectiveness. The results obtained in this study confirm on one hand that the development of the convective heat exchange along the axis of the flow gradually decreases along the absorber due to the development of the thermal boundary layer. And secondly, that the addition of aluminum oxide nanoparticles in the based fluid (Syltherm) increases the values of the convection coefficient and thus the convective heat exchange, this is due to the improvement of the thermal properties of nanofluids.

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