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NUMERICAL ANALYSIS OF A FLAT PLATE SOLAR COLLECTOR WITH BAFFLES IN THE AIR DUCT

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***Abstract*—This paper aims to investigate a simple structure of an air flat plate solar collector with baffles in the air duct. A numerical analysis is developed to predict the heat transfer and the internal flow. Inclusion of baffles is introduced as a solution to optimize the performance of a flat plate solar collector as this type of collector presents the problem of low performance. In a first part our numerical model realized with the software gambit and exported towards Fluent was well validated by referring to an experimental study. The effects of the most active geometrical parameters of baffles on the efficiency of the solar air collectors as well as on the processes of heat transfer and fluid flow within the collector were discussed in detail. Numerical analyses on different models of flat plate solar collectors with various heat transfer enhancement strategies were shown.**

***Keywords*— Solar energy; Solar air collector; Rectangular fins; Thermal efficiency; Pressure drop; Effective efficiency; Serpentine flow; Numerical analysis.**

I. INTRODUCTION

Global renewable energy reserve can be considered inexhaustible. Solar energy is considered to be the energy of the future. The thermal conversion of solar energy heater is undoubtedly the most mature. Flat plate solar collectors (FPSCs) remain commonly used devices for converting solar radiation into useful heat to cover the human need for a variety of thermal applications. Solar heat has long been used in many activities, such as drying clothes, fish, and other agricultural products (cocoa, coffee, rubber, pepper, tobacco, pepper, tea, bananas, anchovies and seaweed). [1] Ahmad Fudholi. View their numberless environmental and economic benefits; flat plate solar collectors (FPSCs) represent an interesting topic to study. Two types of flat plate collector exist; solar water heaters and solar air heaters which have lower thermal efficiency than solar water collectors, which is due to the low thermodynamic air properties and the presence of a viscous sub-layer in the vicinity of the hot wall, S.B.Bopche et al [2].

Many studies on solar collector have been reported on flat plate solar collector particularly focusing on improving thermal efficiency; it was found that the heat transfer coefficient can be enhanced by generating the turbulence in the flowing fluid which is possible with the help of artificial roughness.

C.Foued et al.[3] have experimentally developed a solar collector with five semi-cylindrical shapes attached to the absorber. They found that the most important thermal efficiency found was in the order of 51.5% corresponding to a finned collector with a solar heat flux of 480 W / m² a flow rate of 0.016 Kg/s angle of inclination of the collector of 45°.

A.Aben et al. [4] tested delta-winglets in solar collector: useful heat quantities were increased by a factor of about 1.65 compared to the case of the classic solar collector.

A. Kumar [5] studied experimentally effect of multi v-shaped rib with gap roughness on one broad wall. For (Nu), the maximum enhancement of the order of 6.74 times of the corresponding value of the smooth duct has been obtained, however the friction factor (f) has also been seen to increase by 6.37 times of that of t:he smooth.

S.Youcef et al. [6] have experimentally the influence of increasing the number of baffle rows on thermal efficiency. An increase in efficienc

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the order of 2% on average at each addition of a row.

N.Moummi et al.[7] have developed an experimental study of the collector with rectangular fins which occupied 80% of the height of the air channel. In the presence of the fins in the air channel the improvement of the coefficient of forced convection transfer is 50%.

Several experimental studies have been conducted to investigate rectangular fins, thermal performance of an air duct, in general, improves as a result of providing the fins, but this improvement is also accompanied by an improvement of pressure drop. Hence a thermo hydraulic analysis should be done for various cases studied

The main idea of the present study is the creation of an air collector with higher thermo hydraulic efficiency.

II. ANALYSIS AND MODELLING

A. SOLUTION DOMAIN:

The three-dimensional computation model of the solar air collector has 1,6 m length an 0.8 m width. The transparent cover is in alveolar polycarbonate sheets 10 mm thick and the gap between the cover and the absorber-plate was 25 mm. The collector is formed by a black-painted aluminium sheet 0.4 mm thick used as an absorber plate and by a wooden plate as the back side of the collector duct. N.Moummi.[7]. Second model was the same collector with rectangle fins having 50mm of width and 20mm of height and attached to the lower wall of the duct, the total number of fins added was 1056 fins.

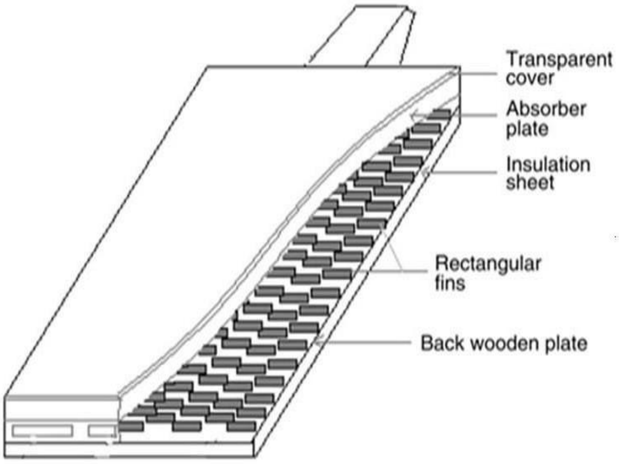


Fig.1:Solution domain

The developed numerical model is solved using the commercial software of Fluent6.3.26. The results were obtained for a heat flux of 900 W/m2.

B. VALIDATION OF NUMERICAL MODEL:

The first part of our numerical simulation aims to validate our numerical model, so first configuration is chosen. Present numerical results of the collector efficiency in a smooth duct were compared with those experimental of N. Moummi [7], in figures blown.

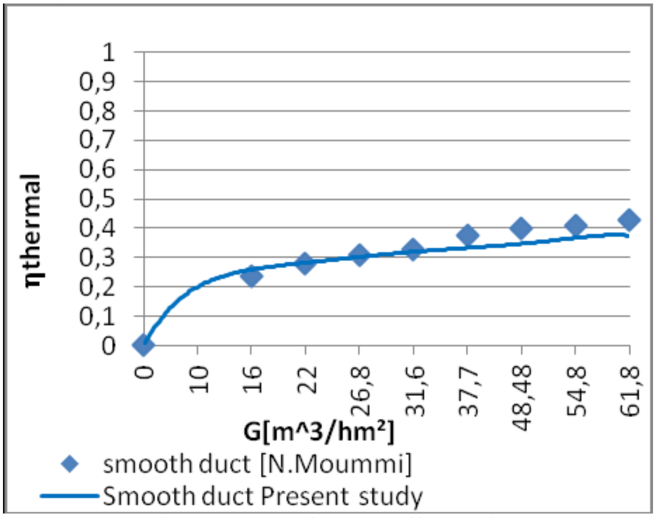


Fig.2 Validation for smooth duct of collector efficiency factor vs. the air volume flow rate at constant flux of 900 w/m².

Numerical results of solar collector’s thermal efficiency are found to be in excellent agreement with experimental values of N.Moummi [7]. The model is then modelled correctly.

III. RESULTS AND DISCUSSION

Once we have proved the good agreement between our numerical results and experimental results, we opt to ameliorate the performance of solar collector.

The previous curve shows the influence of the inlet volume flow rate on the thermal performance of the collector; more than volume flow rate increases more than thermal efficiency increases. Hence, the solar collector efficiency's relies heavily on volume flow rate.

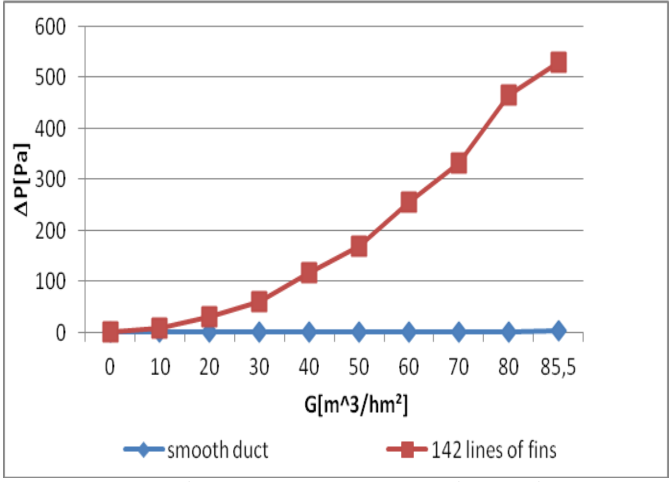


Fig.3 Variation of pressure drop with air volume flow rate for smooth and finned duct.

Variations of pressure drop according to the air volume flow rate of smooth and roughened duct are illustrated in Figure 2. The curves show that increasing the volume flow rate of air causes a significant increase in friction losses. Also, addition of fins on the lower wall increases the pressure drop.

Hence it is clear that the well thermal efficiency enhancement was accompanied with an important increase of pressure drop. The presence of 142 lines of fins of 5cm of width and 20 mm height, is associated with a very important pressure drop and increased weight and cost of the collector.

The objective of our numerical study is to predict a lightweight solar air collector with low pressure drop, which has driven us to minimize the number of fins.

Hence, a thermo hydraulic analysis will take place in our present study by evaluating the effective efficiency reported by Cortes [8] as follow;

$$\eta_{eff}=(Q_u-(\Delta P*G)/C)/(A_c*I)$$

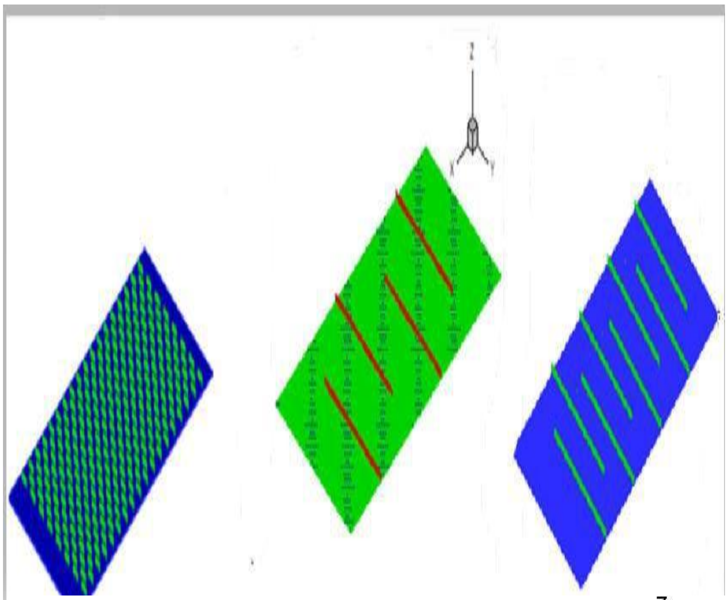
The following part mainly discusses the influence of the baffles number in the air duct;

Four baffles:

The collector is equipped with four baffles, attached on the lower wall of the air channel, of 0.6m (l'/l=0.75) of width and 0.02m (e'/e=0.8) of height, which divide the cavity into five several chambers and form a serpentine flow channel.

Eight baffles:

Eight fins are attached to the lower wall of the air duct and divide the channel into nine chambers.



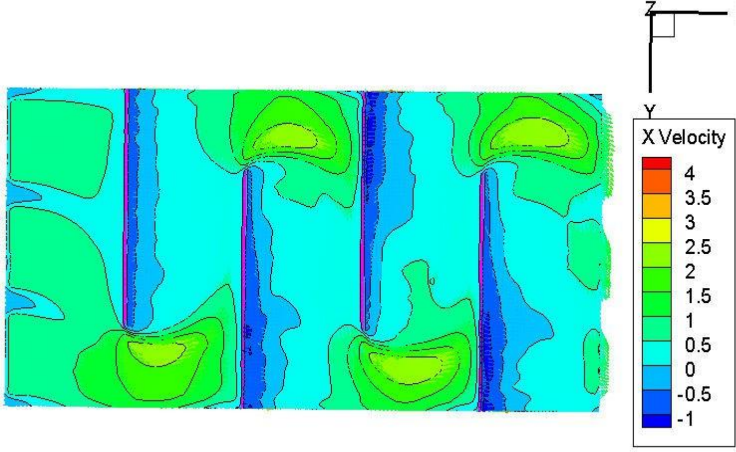


Fig.5 Vectors of velocity in the air channel with four fins

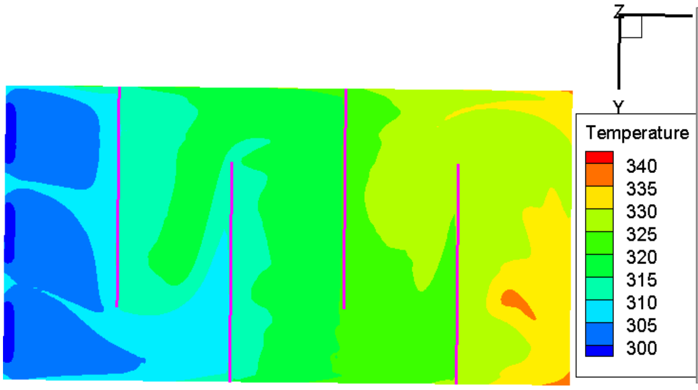


Fig.6:Contour of temperature on absorber plate
With four fins

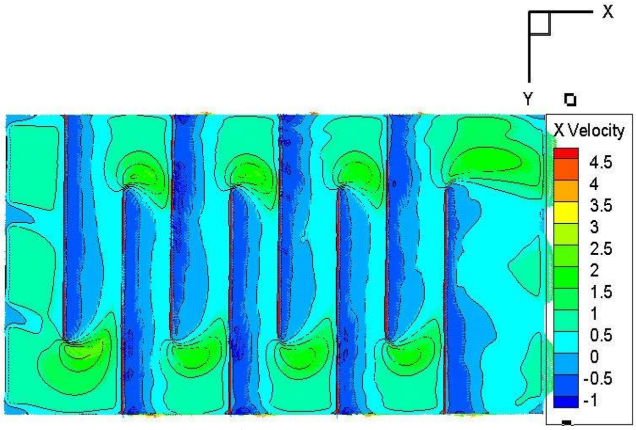


Fig.7: Vectors of velocity in the air channel with eight fins

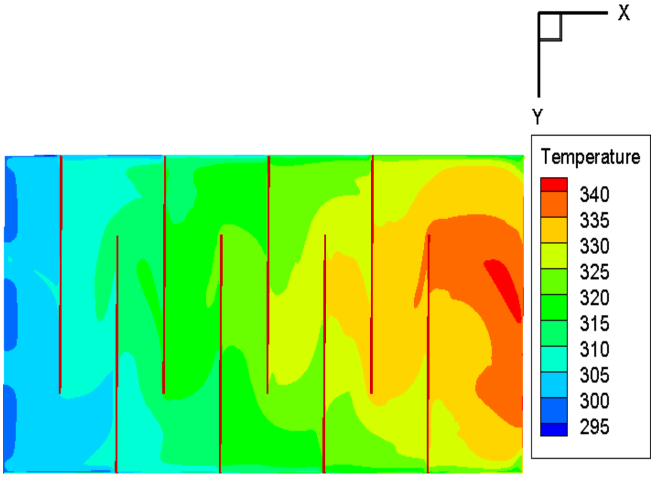


Fig.8: Contour of temperature on absorber plate with eight fins

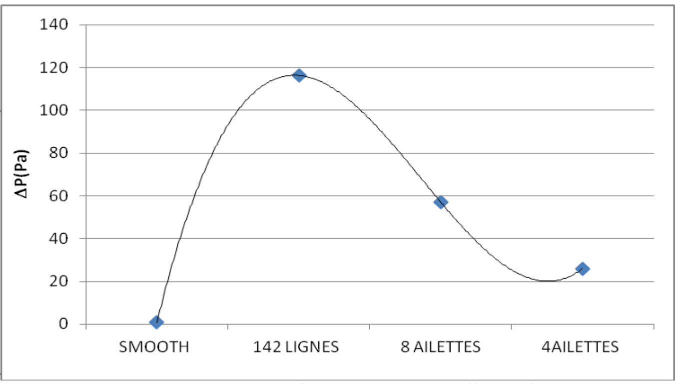


Fig.9: Variations of pressure drop at different fins
Numbers for G=40[m^3/hm²].

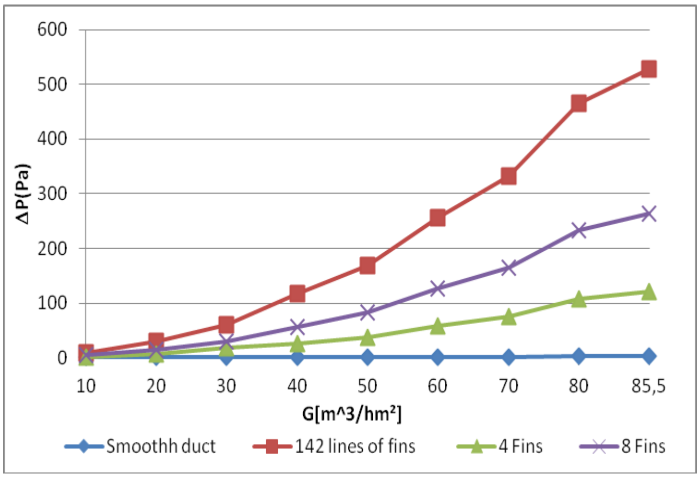


Fig.10:Variation of pressure drop with air volume flow rate for smooth duct and various number of fins.

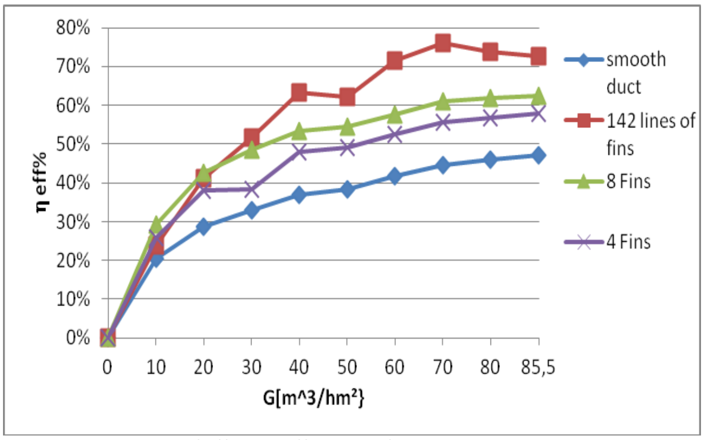


Fig.11: Variation of effective efficiency of smooth duct and various numbers of fins according to air volume flow rate

The performance evaluation index of the SAC mainly includes the treatment capacity, the temperature rise between the inlet and outlet, the pressure drop and the heat collecting efficiency.

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Figures 3 and 5, show the vectors of velocity in the air duct for four fins and eight fins. It is observed that the air gets into the cavity from the entrance and goes along the serpentine passage before coming out from the exit. The air's residence time in the channel was prolonged thanks to the arrangement of fins in the duct, the residence time of the serpentine flow increase more than the fins number increase. A significant flow separation and reattachment which results in flow loss to some extent is shown in the air channel. The dead zones reduce as the number of fins increases.

The flow pattern in the collector influences the temperature distribution significantly. The temperature distribution on the absorber plate is shown in Fig.4 and Fig.6 for both cases at solar intensity of 900w/m^2. It indicates that the high temperature zone exactly corresponds to the vortex zone while the low temperature zone corresponds to the direct flow zone.

Fig. 7 reflects the influence of the number of fins on the pressure drop with fixed volume flow rate of 40[m^3/hm^2]. Pressure drop is the higher for the 142 lines of fins for all volume flow rates studied, then for the eight fins and the lower pressure drop was found corresponding to the four fins.

Evolution of pressure drop versus flow rate for smooth and various fins arrangement is illustrated in figure 8.

Figure 9 shows the variation of effective efficiency with the volume flow rate without fins and with various numbers of fins.

For volume flow rate of 85.5m^3/hm^2 the effective efficiency of solar collector without fins is 47% while for collector having 4 fins is 57.7% and for eight fins is 62.5%.

IV. CONCLUSIONS

In this paper, an air flat plate solar collector is numerically analysed. To summarize we can conclude that;

-Solar collector efficiency's relies heavily on volume flow rate.

-Pressure drop in the air duct relies also heavily on volume flow rate.

-The addition of fins causes a significant flow separation and reattachment which results in flow loss to some extent.

-Number of fins has a remarkable effect on pressure drop.

-The addition of four fins in the air channel has the advantages of simple structure, convenient installation and easy maintenance, and low pressure drop.

References

[1] Ahmad Fudholi, Kamaruzzaman Sopian A review of solar air flat plate collector for drying application, Renewable and Sustainable Energy Reviews 102 (2019) 333–345, https://doi.org/10.1016/j.rser.2018.12.032

[2] Santosh B. Bopche a,*, Madhukar S. Tandale, Experimental investigations on heat transfer and frictional characteristics of a turbulator roughened solar air heater duct, International Journal of Heat and Mass Transfer 52 (2009) 2834–2848, doi:10.1016/j.ijheatmasstransfer.2008.09.039.

[3] Foued Chabane, Noureddine Moummi,Said Benramache, Experimental study of heat transfer and thermal performance with longitudinal fins of solar air heater, Journal of Advanced Research (2014)

[4] A. Abene, V. Dubois, M. Le Ray, A.OuaguedA. Abene, V. Dubois, M. Le Ray, A. Ouagued, Study of a solar air flat plate collector: use of obstacles and application for the drying of grape, Journal of Food Engineering 65 (2004) 15–22, doi:10.1016/j.jfoodeng.2003.11.002.

[5] Anil Kumar, R.P. Saini, J.S. Saini, Development of correlations for Nusselt number and friction factor for solar air heater with roughened duct having

[6] S. Youcef-Ali, J.Y. Desmons, Numerical and experimental study of a solar equipped with offset rectangular plate fin absorber plate, Renewable Energy 31 (2006) 2063–2075, doi:10.1016/j.renene.2005.10.008

[7] N. Moummi, S. Youcef-Ali, A. Moummi, J.Y. Desmons, Energy analysis of a solar air collector

withrows of fins, Renewable Energy 29 (2004) 2053–2064, doi:10.1016/j.renene.2003.11.006.) 5, 183 192,http://dx.doi.org/10.1016/j.jare.2013.03.001

[8] S.K. Saini a, R.P. Saini, Development of correlations for Nusselt number and friction factor for solar air heater with roughened duct having arc-shaped wire as artificial roughness, Solar Energy 82 (2008) 1118–1130, doi:10.1016/j.solener.2008.05.010997.