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Experimental Study of Parabolic Trough Receiver with Perforated Twisted Tape Insert Using Fuzzy Model Analysis

S. M. Naif [a], S. A. Mutlag [a] , W. H. Khalil [b], H. K. Dawood[a*]

[a] *Department of Mechanical Engineering, College of Engineering, University of Anbar, Ramadi, Anbar, Iraq*
[b] *The Renewable Energy Research Centre, University of Anbar, Anbar, Iraq*

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ABSTRACT

A solar water heating system has been fabricated and tested to analyze the thermal performance of Parabolic Trough Solar Collector (PTSC) using twisted tape insert inside absorber tube with twisted ratio about TR=y/w=1.33. The performance of PTSC system was evaluated by using three main important indicators: water outlet temperature (T_{out}), useful energy and thermal efficiency (η_{th}) under the effect of mass flow rate ($\dot{m}$) ranges between 0.02 and 0.04 Kg/s with the corresponding of Reynolds number (Re) range (2000 to 4000). In a parallel, a fuzzy-logic model was proposed to predict the thermal efficiency (η_{th}) and Nusselt number (Nu) of PTSC depending on the experimental results. The fuzzy model consists of five input and two output parameters. The input parameters include: solar intensity (I), receiver temperature (T_r), water inlet temperature (T_{in}), water outlet temperature (T_{out}) and water mass flow (m^o) while, the output include the thermal efficiency (η_{th}) and Nu. The final results indicate that, owing to the mixture of the swirling flow of the perforated twisted-tape insert, the perforated twist tape insert enhances the heat transfer characteristics and the thermal efficiency of the PTSC system. More specifically, the use of perforate twist tape inserts enhanced the thermal efficiency by 4% to 4.5% higher than smooth absorber tube. Also, the predicted values were found to be in close agreement with the experimental counterparts with accuracy of ~92 %. So, the suggested Fuzzy model system would have high validity and precision in forecasting the success of a PTSC system compared to that of the traditional model. Pace, versatility, and the use of expert knowledge for estimation relative to those of the traditional model are the advantages of this approach.

1. Introduction

Several issues, such as rising oil demand and costs, depletion of oil reserves, reduced fossil fuel supply, ozone layer depletion, health risks, reasonably obvious aesthetic concerns related to environmental protection concerns, and global climate change and other air pollution problems, all of which are primarily caused by the use of these hydrocarbons as a source of heat energy, have resulted in a rise in global climate change and other air pollution problems, have resulted in a rise in global climate change and other air pollution problems [1].

In 1970 solar energy was used in several techniques [2]. Amongst solar energy–depended on techniques, the solar water heating (SWH) system is the only one that has been broadly marketed globally due to high reliability and economy compared to the traditional water heating systems [3]. SWH system is a renewable energy technology available worldwide and is perfect to use with high potential [4]. SWH systems are often used at a larger scale as they provide eco-friendly heat for different areas such as domestic water heating, heating of swimming pools, and other places where hot water is required [5]. The heat from the sun is collected and used to heat air or water in this method [6].

The solar collector used in this analysis is a parabolic trough. The PTSC system is the most

* Corresponding author. : S. M. Naif ; : s.Naif@uoanbar.edu.iq ; +964782147887

important type of solar concentrators because it produces a high output power [6,7]. The PTSC system is a parabolic-shaped reflector that focuses the solar radiation from the sun on a receiver tube at its focal point [8]. The collector tracks the sun to make sure the exact focus of the solar radiation is on the receiver tube [9]. The PTSC system can focus the sun 30 to 100 times its normal intensity on the receiver tube located along the focal line of the trough and the operating temperature of the system is around 400 ˚C [10]. The thermal efficiency of the PTSC system is mainly dependent on the characteristics of internal heat gain, fluid velocity, surface heat loss, and geometric concentration ratio [11].

Evaluation of the efficiency of a solar water collector and its characterization from traditional test methods relevant to international requirements requires expensive test procedures and limits to satisfy the criteria of the standard[12]. In this regard, precise prediction methods, particularly fuzzy models, valuable in predicting the efficiency of renewable energy systems, including solar water heater collectors [13].

Zadeh presented the concepts of fuzzy simulation structures in [1945]. Zadeh introduced a modern method that offers an acceptable and effective way of understanding the behavior of structures that are too complex or too ill-defined to accept the use of reliable mathematical analysis [14]. A fuzzy model system's basic structure consists of four main elements, 1-a knowledge base that contains both a set of fuzzy rules known as the rule base and a set of membership functions known as the database. 2- a fuzzifier that transforms crisp inputs into fuzzy values, 3- an inference engine that implements a fuzzy logic process to generate a fuzzy output, and 4- a defuzzifier that converts the above output into a crisp value [15]. The above processes necessary for fuzzy inference are handled by these components. The relationships between variables are defined in rule-based fuzzy model systems by means of fuzzy if-then laws, If antecedent proposition then consequent proposition [16].

2. Experimental Set-up and Procedure

2.1 Description of the PTSC

The PTSC was easily constructed with low-cost materials. An acrylic sheet of size (98 ×128) mm with 1mm thickness placed longitudinally on the PTSC frame was used as a reflector to reflect about 65% of sunrays. The acrylic sheet is placed on the system structure without any modification, where the parabolic profile is specified by the shape of the ribs and rest on side ribs.

A parabolic arc was drawn using AutoCAD according to the equation (y=x2/4F. Assuming that the length of focus (F = 0.34 m). Length of that parabolic arc was extracted from the drawing as illustrated in Figure (1). The arc width (W) is calculated using equation of parabolic arc.

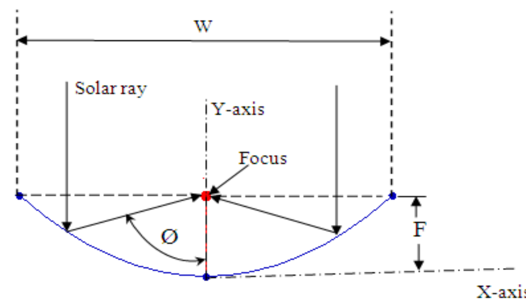

Figure 1. drawing the arc of the reflected.

The designed parameters for the PTSC were found as listed as in Table 1. In order to efficiently benefit by most of the solar reflected radiation, the sun rays must be highly concentrated on the receiver. In this system, a perforate twisted tape insert inside the receiver tube is used as technique. The thermal performances of the PTSC system were evaluated using two kinds of receiver tubes: the first receiver was cupper smooth absorber tube with 800 mm length, inner diameter 12.7 mm, and outer diameter is 15.2 m. The second receiver was a perforate twisted tape insert inside the absorber tube with twisted ratio TR=y/W=1.33. The absorber tubes enclosed by glass cover to decreases convective heat losses from the absorber tube.

Table 1. parameters the fabricated PTSC system.

Parameters	Value	Parameters	Value
Aperture area	1.25 m	Thermal conductivity of Cu	400 W/m.k
Rim angle	90˚	Glass length	0.80 m
Focus length	45 cm	Glass inner Di.	24 mm
Concentration ratio	48.08	Glass outer Di.	28 mm
Reflector material	Acrylic	Twisted ratio	1.33
Receiver length	0.80 m	Tank material	Galvanize
Smooth tube inner diameter	12.7 mm	Storage tank capacity	31.5 L
Smooth tube outer diameter	15.2 mm	Water pump	120 W

2.2 Experimental Setup

The improvement of the PTSC system's thermal performance was presented in the experimental work. This experiment will be completed in two cases, the first case is a smooth receiver tube. In the second case, a perforate twisted tape insert inside the absorber tube was implemented in the experimental work. Then, the comparison of thermal performance between the two cases is done experimentally. The experimental was carry out at on five different $\dot{m}$ of 0.02 Kg/s, 0.025 Kg/s, 0.03 Kg/s, 0.035 Kg/s, and 0.04 Kg/s. The Reynolds number was ranged from 2000 to 4000. Water was used as heat transfer fluid. At the Department of Mechanical Engineering / University of Anbar, Ramadi city, the experimental work was carried out. The study was performed between December 2019 and February 2020. The work was done every day from 11.00 AM to 14.00 PM for the whole duration of the work period.

Figure.2 shown the PTSC system that consists of the reflected, receiver tube, heat transfer fluid, storage tank, water pump, heat exchanger, mechanical tracking system, pipes, and valves, etc. The reflected surface of the collector is insulated with glass wool material. The copper receiver tube was placed along the focus line of the reflected surface of the collector. The absorber tube was enclosed by glass cover to reduce the convective heat losses. In this experimental work, a parabolic trough solar collector system was designed and manufactured with a 1.25 m^2. Figure.3 shown the cupper smooth absorber tube of the PTSC system with 800 mm length, inner diameter 12.7 mm, and outer diameter is 15.2 m. Figure.4 shown the perforated twisted tape insert with twisted ratio is equal to 1.33.

First case, the smooth absorber tube is fixed at the focus of the reflected. The PTSC experimental setup is combined with a storage water tank of 31.5 litter capacity, mounted on the structure by screws to keep natural flow of working fluid (water) inside the PTSC.

The water temperature of the Tin, Tout, and Tr, are continuously measured by a thermocouples that are mounted on the receiver tube. The ΔP measured for each flow rate using the pressure sensors at the inlet and outlet of the absorber tube. The I is measured by Pyrometer. The device is switched on before recording readings for a period of twenty minutes to maintain its stability. After that the values of Tin, Tout, Tr, I, and ΔP will be recorded when the fluid flow reached a steady-state.

A perforated twisted tape insert is the second case of the experimental task. The experimental setup is replicated in the second case of the experimental work, in the same fashion as the experimental planning for the first case and for the same flow speeds.

Figure 2. The PTSC system.

Figure 3. Smooth absorber tube .

Figure 4. Perforate Twist tape insert in tube

2.3 Mathematical Formulation

The general mathematical equations that were used to evaluate the results are presented in this section. Since the PTSC only uses solar intensity (I), the available solar irradiation on the collector aperture (Q_s) is measured as follows:

$$Qs = A_a I \quad (1)$$

$$A_a = (W - d_{ro})L \quad (2)$$

The Qu captured by the fluid is calculated according to [9]:

$$Q_u = m^o \; C_p(T_{out} - T_{in}) \quad (3)$$

$$m^o = \rho \, V \quad (4)$$

The ηth of the PTSC system is defined as [11]:

$$\eta_{th} = \frac{Q_u}{Qs} \quad (5)$$

The h between absorber and fluid can be calculated by:

$$h = \frac{Q_u}{A_{ri}\,(T_r - T_m)} \quad (6)$$

$$A_{ri} = \pi\, d_{ri}\, L \quad (7)$$

$$Tm = \frac{T_{in} + T_{out}}{2} \quad (8)$$

The Nu is calculated using equ. [18]:

$$N_u = \frac{h\, d_{ri}}{K} \quad (9)$$

The f can be calculated using the pressure drop (ΔP) [18] :

$$f = \frac{\Delta P}{\frac{1}{2}\rho\, U^2}\, \frac{d_h}{L} \quad (10)$$

The Re is determined as following

$$\text{Re} = \frac{\rho\, U d_h}{\mu} = \frac{4 m^o}{\pi\, d_{ri}\, \mu} \quad (11)$$

$$d_h = \frac{4\, Ac}{P} \quad (12)$$

$$Ac = \frac{\pi\, d_{ri}^2}{4} \quad (13)$$

3. Proposed Fuzzy Model System

FL is a multi-valued logic that uses estimated values to reason rather than crisp 0 and 1 values (Zadeh, 1965). It is, thus, known as approximate reasoning. Fuzzy logic uses the principle of the fuzzy set, which is the theory of groups of un sharp class constraints. If an element x is a member offset A in classical set theory, the membership function A(x) = 1, otherwise A(x) =0.0. Fuzzy sets, however, have graded membership between 0 and 1 in fuzzy set theory, as follows[19,7]:

$$A = \int (\mu(X1)) \;/\; (X1\,), \text{ if A is continuous} \quad (14)$$

$$A = \mu(X1)/X1 + \cdots + X\,\mu n\,(Xn)/Xn \text{ or}$$

$$A = \mu 1\, X1 + \cdots + \mu n\, Xn\,, \text{ if A is finite} \quad (15)$$

Where $\mu A\,(X){:}\, X \rightarrow [0,1]$ is Membership Function (MF). A is fuzzy set and usually fuzzy sets are identified with linguistic values including such as high, low, etc. X is the discourse universe. In the fuzzy set A, the higher the membership degree of x, the more real x is in A.

In order to map inputs to outputs, A FIS uses the principle of fuzzy sets and inference rules. Inputs and outputs can be represented by fuzzy sets in the Mamdani FIS. Since output is expressed in the information by fuzzy sets, we use Mamdani FIS. The suggested FIS consists of five procedures: input and output determination of fuzzy sets, fuzzification of input values, fuzzy if-then rules determination, fuzzy inference and defuzzification. According to these measures, the explains the proposed FIS as below.

3.1. Selection of Inputs of Fuzzy Sets

The various data that has been obtained on the PTSC system during the experimental study of the PTSC system; Tin, Tout, Tr, ΔP, Qu, and I for five different m^o , as described in the above section. After analysis of the data collected, found that the most significant knowledge that affects the prediction accuracy using the proposed fuzzy model analysis is T_{in}, T_{out}, T_r, I and m^o experimental data. Therefore agreed to use only T_{in}, T_{out}, T_r, I and m^o as the inputs of the analysis of the fuzzy model, and the estimated amount of η_{th} and Nu from the actual experimental data is acknowledged as the output of the analysis of the fuzzy model.

First, founded the discourse universe (U) for T_{in}, T_{out}, T_r, I, $\dot{m}$, η_{th} and Nu as follows:

U_{Tin}=[25.7,39.4] is divided into three intervals and represented by Tg MFs of L, M & H, and so on {U_{Tout}=[31.9,48.5], U_{Tr} =[39.1,52.6], U_I=[972,985], $U_{\eta th}$ = [65.6,78.5], U_{Nu} = [49.45, 70.18]}, while U_{m^o} =[0.02,0.04] is partitioned into five intervals and represented by Tg MFs of VL, L, M, H & VH.

MFs are experimentally calculated by the number of fuzzy sets that give the minimum RMSE and the optimal R^2. According to the MFs as given in Figure 4, each information obtained from the experimental data is fuzzified. For each fuzzy linguistic value varying between [0,1], determine a membership degree according to the input value.

3.2 Determination of Fuzzy Inference Rules

As the most important factor within the fuzzy model structure, the rule base governs output variables. In simpler language, as a simple IF-THEN law that involves a condition and inference, a fuzzy rule is represented. According to the values of T_{in}, T_{out}, T_r, I, m^o obtained from the experimental data as shown in Figure 5, we have defined fuzzy inference laws. By using RMSE, we have optimized the number of laws. We have 12 laws in all, as shown in the figure 6.

1. If (Tin is L) or (Tout is H) or (Tr is not H) or (I is L) or (m is VL) then (Eff is L)(Nu is L) (1)
2. If (Tin is L) and (Tout is L) and (Tr is L) and (I is L) and (m is VL) then (Nu is L) (1)
3. If (Tin is H) or (Tout is H) or (I is L) or (m is VL) then (Eff is not L) (1)
4. If (Tin is L) or (Tr is M) or (I is L) or (m is VH) then (Nu is L) (1)
5. If (Tin is H) or (Tout is H) or (I is H) or (m is not M) then (Eff is H) (1)
6. If (Tin is L) and (Tr is M) and (I is M) and (m is H) then (Nu is not H) (1)
7. If (Tin is H) or (Tout is H) or (I is L) or (m is VL) then (Eff is H) (1)
8. If (Tin is L) and (Tr is L) and (I is H) and (m is M) then (Nu is not M) (1)
9. If (Tin is L) and (Tout is M) and (I is L) and (m is VH) then (Eff is H) (1)
10. If (Tin is L) and (Tr is H) and (I is L) and (m is M) then (Nu is M) (1)
11. If (Tin is L) or (Tout is not H) or (I is not M) or (m is M) then (Eff is M) (1)
12. If (Tin is M) or (Tout is not H) or (I is not H) or (m is not VH) then (Eff is not H) (1)

Figure 6: Fuzzy inference rules for the PTSC system.

3.3 Forecast and Defuzzify Forecasted Output

This is achieved by the process of centroid defuzzification, where the empirical measurement of the 'gravity' center of the generated region for the combined membership function in the inference rule stage above determines a crisp value for the output element. In the fuzzy model, each rule of inference has a left side (antecedent) and a right side (consequent). A fuzzy implication operator is introduced to achieve a new fuzzy collection for the conclusion of the law, according to the membership degree of each precedent.

A fuzzy aggregation operator is implemented to merge the outputs obtained by each rule into a single fuzzy set after obtaining each rule's conclusion. In the fuzzy model analysis, which is experimentally calculated to produce the minimum RMSE, used the minimum implication operator.

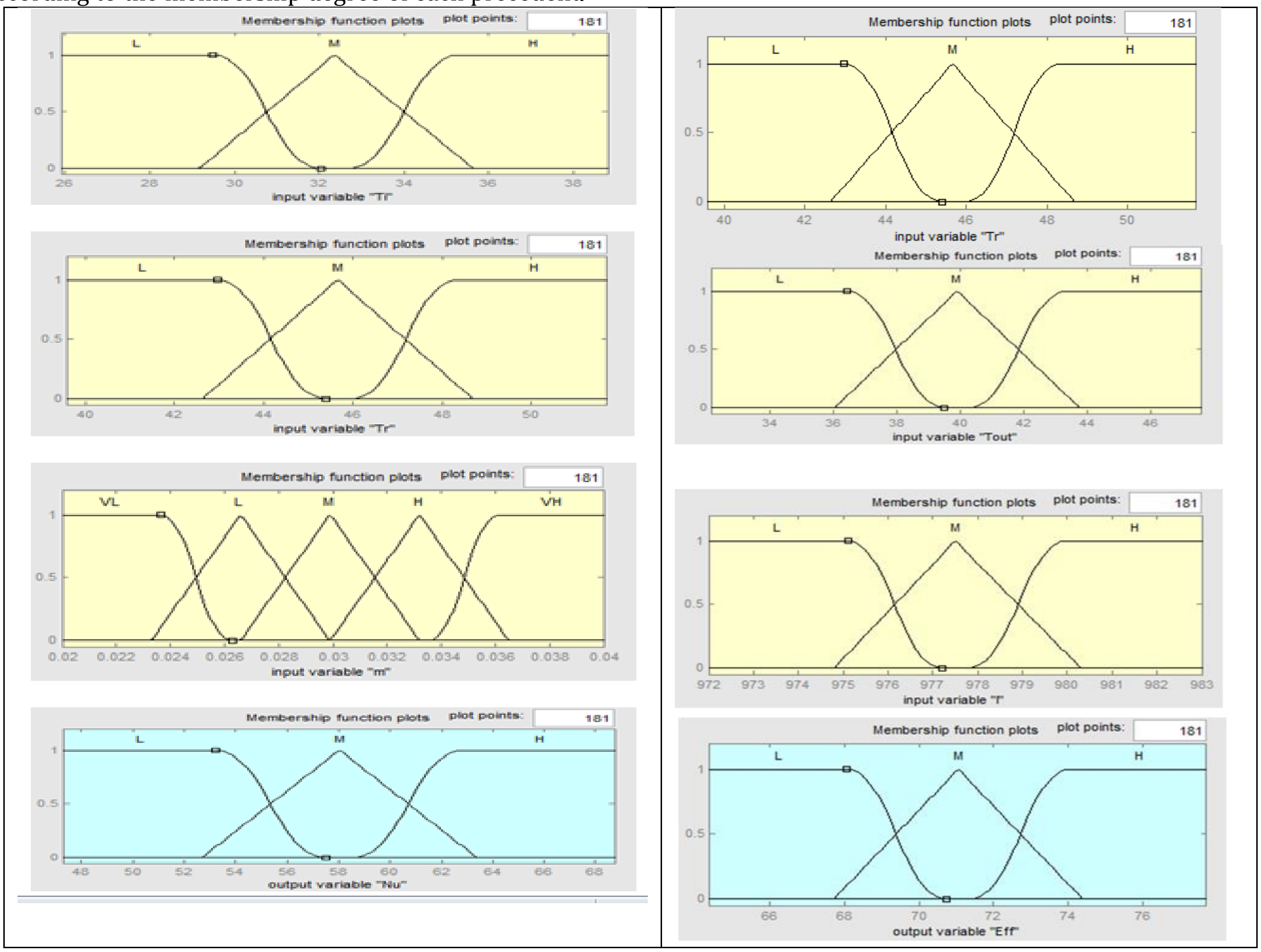

Figure 5. Fuzzy MFs for the inputs and output of the FIS.

Table 2: Input data, η_{exp}, η_{pr}, Nu_{exp} and Nu_{pr} of the PTSC system for twist tape insert.

Data No	T_{in}	T_{out}	T_r	I	m°	η_{exp}	η_{pr}	Nu_{exp}	Nu_{pr}
1	26.4	35.8	41.8	973	0.02	64.4	71.1	47.32	52
2	28.1	37.6	43.3	974	0.02	65.5	71.1	49.52	52
3	32.8	42.5	47.7	976	0.02	66.7	71.1	52.71	52
4	34.1	43.9	48.9	977	0.02	67.5	71.1	54.33	52
5	36.8	46.8	51.2	979	0.02	68.5	71.1	57.74	52
6	37.4	47.6	51.7	981	0.02	69.7	71.1	60.13	52
7	37.8	48.1	52.1	982	0.02	69.9	71.1	59.92	52
8	35.1	44.9	49.2	979	0.02	67.6	71.1	58.63	52
9	34.3	44.1	48.3	978	0.02	66.9	71.1	57.93	52
10	32.9	42.5	46.8	976	0.02	65.5	71.1	56.51	52
11	26.3	34.1	40.8	974	0.025	66.5	71.1	49.42	52
12	28.1	35.9	42.4	976	0.025	67.4	71	51.58	52

13	33.1	41.1	47.1	977	0.025	68.5	71	54.62	52.5
14	34.6	42.7	48.4	979	0.025	69.5	71	56.76	52.1
15	36.7	44.9	50.2	980	0.025	70.6	71.1	59.83	52
16	38.4	46.8	51.7	982	0.025	71.8	71.1	62.69	52
17	37.2	45.5	50.4	981	0.025	70.8	71.1	61.97	52
18	35.8	43.9	48.9	980	0.025	69.7	71.1	61.58	52
19	34.6	42.61	47.7	979	0.025	68.7	71	59.84	52.1
20	32.5	39.3	44.9	975	0.03	69.7	71.1	60.43	52

Finally, the outputs produced by each rule are aggregated in the defuzzification stage and a numeric value is generated as the rule with the highest conclusion is chosen as the rule output using the maximum operator. A numerical value is needed to be generated in order to complete the defuzzification. To produce a numeric score, the centroid function was implemented on the performance Efficiency MFs. The fired rules, expected Performance linguistic values and Nusselt number and the defuzzified numerical values for the whole experimental results are outlined in Table 2.

4. Results and discussion

Most techniques of enhancement heat transfer will provide enhanced performance of heat transfer but with pressure drop penalty. The experimental values for Q_u, η_{th}, h, Nu, and ƒ were evaluated by conducting experiments in a smooth absorber tube and corrugated absorber tube at different Re.

4.1 Impact of Twist Tape on Performance PTSC

The effect of the perforate twisted tape inserts on the thermal performance of the PTSC system was presented in Figures 7, 8(a), 8(b) and 9. From Figure 7, it is observed that the thermal efficiency of the perforate twisted tape inserts outperforms those of the plane tube geometry. Figure 7 shows that thermal efficiency is improved by 4 % to 4.5 % at m^o0.04= Kg/s. This increase is due to the fact that the twisted tape inside a tube reduces the hydraulic diameter of the tube. Thus, this leads to an increase in the flow velocity and the fluid bending inside the tube. The generated vortex flows through the absorber tube was leading to mixing the fluids in a good way. The vortex flow leads to more destruction effect in the thermal boundary layer and continues better heat transfer between the core and the absorption tube wall. The thermal performance of the PTSC system's was supposed to be higher but there are many influencing factors such as lampshade misalignment, tube misalignment, tracking errors, low absorption tube absorption and low permeability of the glass cover.

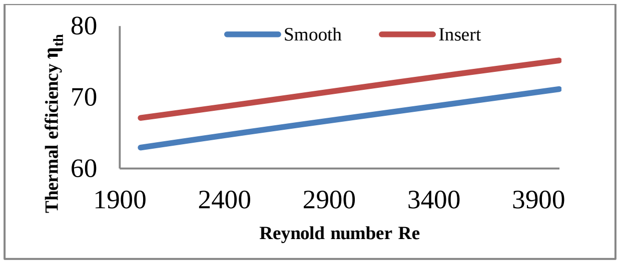

Figure 7: Variation of η_{th} with Re of case 1 and case 2.

Figures 8(a) and 8(b) respectively revealed the experimental data of the h, Nu, and their variance to a Re of perforated twisted tape inserts. The findings revealed that the h and Nu obtained from case 2 were higher than case 1 in the presence of the perforated twisted tape due to strong swirl flow. The swirl was enhanced the flow turbulence that lead to a good transfer of heat from the convection. So, the combination of increased effective heat transfer area, swirl generation, and an increase in flow turbulence with interruption to the growth of the boundary layer were lead to heat transfer enhancement of the PTSC system. The results showed that the heat transfer enhancement of the tube with perforate twist tape insert could be significantly increased as the twisted of the twisted tape was increased. With increasing both the twisted of the twist tape and Reynolds number, higher values of the heat transfer efficiency enhancement might be obtained.

In comparison to the smooth absorber tube, the heat transfer coefficient and Nusselt number that had been obtained from the case 2 were higher than the case1by 2.7% and 5.4% respectively.

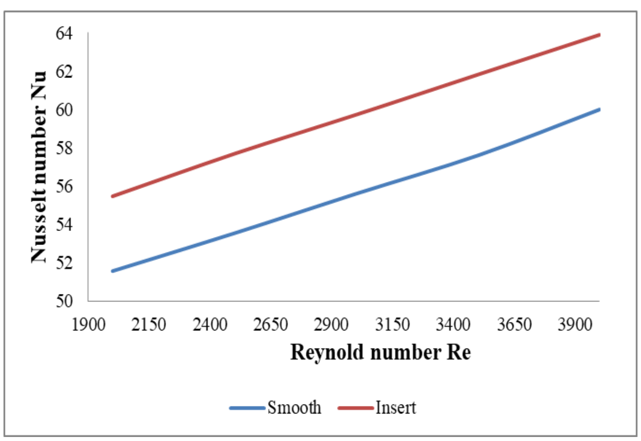

Figure 8(b): Variation of the Nu with Re of case 1 & 2.

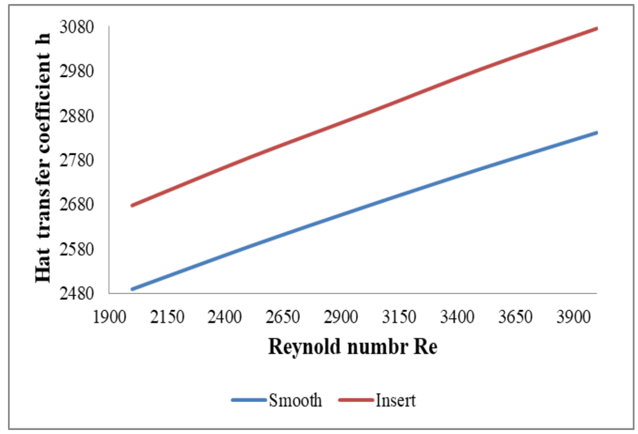

Figure 8(a): Variation of the h with Re of case 1 & 2.

The relationship between ƒ and Re for perforate twisted tape inserts were show in Figure 9. It could be seen that the ƒ was in a similar trend for both copper smooth absorber tube and copper smooth absorber tube with perforate twist tape insert. As expected from Figure 9, the ƒ obtained from the perforate twist tape inserts was significantly higher than a copper smooth absorber tube by 1.06%. This increase was due to wider touch surface areas and the dissipation near the absorber wall of the fluid's dynamic pressure at high viscosity loss. In addition, the loss of pressure was extremely likely to occur by the presence of pressure forces in the boundary layer. Also, because the motion was not in an axial direction, the flow velocity was greater.

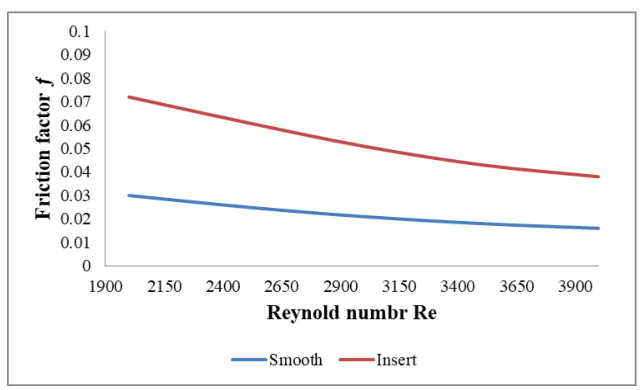

Figure 9: Variation of the ƒ with Re of case 1 & 2.

Finally, the results showed that the h of the case 1 comparing with the case 1 was considerably increased under the same flow conditions. The increase of h was more than the growth of hydraulic resistance at the same time. So, the perforate twist tape insert could considerably enhance the heat transfer with a significantly increasing friction factor.

4.2 Comparison Fuzzy Model and Experimental Results

With the sum of the squares (R^2), the error (E) and root mean square errors (RMSE), the accuracy of the fuzzy model was evaluated. The coefficient of determination (R^2) values, which quantify the degree of agreement between the experimental data and the values obtained of the fuzzy model, were defined as:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(\boldsymbol{actual\ efficiency} - \boldsymbol{predicted\ efficiency})^2}{\sum_{i=1}^{n}\boldsymbol{predicted\ efficiency}^2} \quad (16)$$

The value of the RMSE was defined as

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(actual\ efficiency - predicted\ efficiency)^2}{n}} \quad (17)$$

In order to test and ensure the robustness of the fuzzy model analysis as well as its accuracy and error rate for the expected values, the validation of the results from the fuzzy model analysis is done against actual experimental evidence. The accuracy and error rates are calculated using the following expression for each of the expected values from the fuzzy model analysis [13]:

$$Error = \frac{1}{n}\sum_{i=1}^{n}\frac{|actual\ efficiency - predicted\ efficiency|}{actual\ efficiency} \quad (18)$$

Where n is the number of data samples used in experimental data.

The graphical representation in Figure 10 shows that data points for fuzzy model analysis (outlined by the red line) and obtained experimental data (outlined by the blue line) were near to each other and imply good agreement. In addition, less than 8 % of percentage (%) error is obtained between the unit expected by the fuzzy model analysis and experimental results.

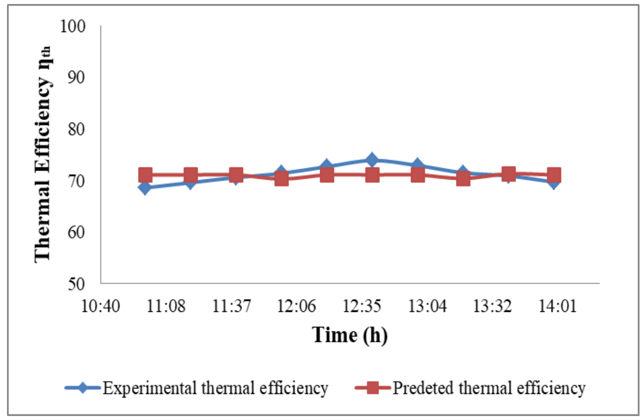

Figure 10: Comparison of η_{th} of fuzzy model with experimental with Re results of case 2

It can be shown that the expected results of thermal efficiency are in line with the experimental data with an accuracy of ~92%. Consequently, for any solar energy collector, the adaptive fuzzy model analysis could be used systematically to predict optimum performance parameters.

5. Conclusion

This paper is an experimental study executed using a perforated twisted tape insert inside the absorber tube to evaluate the thermal performance of a PTSC system. A madman fuzzy method has been used to predict the thermal efficiency of the PTSC system and the Nusselt number. The following can be conclusions from the study results:

1- Results show that the increase in Re leads to increase the η_{th} and Nu of the PTSC system. While the friction factor decreased as the Re increases for both cases. The maximum thermal efficiency value of 77.8 percent at m = 0.04 Kg/s was also obtained in the current analysis.

2- The suggested adapted solar collector that uses a twisted perforated tape insert has a higher thermal performance than the traditional collector. In general, the collector's thermal efficiency that use the perforated tape insert was about 4 % to 4.5 % higher than the smooth absorber tube.

3-There is a convergence between the experimental and the fuzzy model results. So, the proposed fuzzy model can provide a high reliability and accuracy in expecting the thermal efficiency values of a PTSC system. Fuzzy model analysis might be able to model the parabolic trough solar collector system and provide comparable and acceptable results.

4- The thermal efficiency of the experimental and the fuzzy model results were compared. The results realized that there was a clear agreement between the crisp outputs that had been obtained for both methods. The results revealed that the agreement in the thermal efficiency between the fuzzy model analysis and the experimental results about of 92%.

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