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RESEARCH ARTICLE

FUZZY LOGIC MODELING OF FLOATING CUM TILTED-WICK SOLAR STILL

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ABSTRACT

A fuzzy logic modeling and simulation of a floating cum tilted-wick solar still has been developed which makes transparent to qualitative interpretation and analysis. Different fuzzy rules have been developed based on general analogy applied between the changes in solar radiation intensity, yield of distillate output and subsequent changes in the wick and glass temperatures of the still. The experimental results along with the results generated from the modeling and simulation for different values of solar radiation and wicks temperature are incorporated. There is a good agreement between the results of the fuzzy system and the experimental ones.

INTRODUCTION

Dynamic nature of solar radiation due to its continuous variation over time corresponds to dynamic changes in the solar thermal systems, which work under its influence. There exists a lot of uncertainty in such systems in terms of absorption, temperature, yield and instantaneous efficiency etc.

Engelbert [1] has made an approach to derive fuzzy logic, which allows reasoning with the uncertain facts to infer new facts with a degree of certainty associated with each fact. Henceforth the fuzzy systems have been characterized by a set of linguistic fuzzy rules based on the knowledge and experience of a human expert within that domain. Jigeesh [2] has made preliminary work to model and simulate solar water desalination using fuzzy rule-based reasoning system. Solar stills in India for distillation of water have been investigated by several researchers [3-7]. Furthermore low cost solar water still has been designed by Jigeesh and Rangacharyulu [8] for drought-hit areas and the paper presented the design and performance of the still in detail. The present work details the result of the fuzzy logic modeling of the proposed still by incorporating both numerical and graphical results which are validated with the experimental results.

About the still

The schematic photograph of the floating cum tilted-wick solar still is depicted in Fig. 1a and sectional view of the still is depicted in the Fig. 1b. In the proposed still the blackened jute wick is spread along with 15º tilted portion and the remaining part of the wick has been prepared in a corrugated shape and floated in the inside water reservoir of the still with a thermocole sheet of 2 ½ cm thickness. The water level in the reservoir has been maintained not to overflow into the tilted portion and always to be 0.5 cm below the tilted portion through an inlet controlled by a valve. The corrugated floating-wick surface facing upwards towards the glass cover is also served as an effective evaporation area in addition to the tilted-wick water surface. The excess hot water from the still during late and early working hours is fed back to the water reservoir. This arrangement solves the problem faced in common tilted-wick solar still such as dryness of the wick surface, heat loss through excess of hot water during late and early working hours and salt scale formation in the basin**.**

Fig. 1a Schematic photograph of the still

Experimental observations have been carried out in a typical day in Dhanalakshmi College of Engineering, Chennai, and Tamilnadu, India between 9.00 am and 5.00 pm. Mamdhani model has been used to predict the distillate output for the same day. The experimental results are given in Table. 1 along with the results obtained using Mamdhani model.

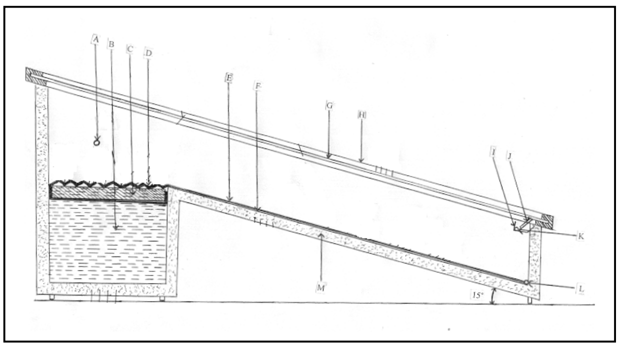

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Table 1 Experimental and Simulation results 21.01.2013

Tilted-wick Temperature (ºC)	Floating-wick Temperature (ºC)	Glass Temperature (ºC)	Solar Radiation (W/m^2)	Distillate yield (ml/hr)		Instantaneous Efficiency (%)	
				Exp.	Simul.	Exp.	Simul.
37	36	33	555.5553	68	71.21	16.13	16.89
48	46	42	797.101	140	147.25	23.14	24.34
53	53	46	905.7965	220	226.39	32	32.937
58	57	50	966.0183	270	275.87	36.83	37.63
62	62	53	1026.57	355	365.18	45.57	46.87
65	64	56	1014.492	340	347.54	44.16	45.14
60	59	53	845.4102	205	212.84	31.95	33.17
54	54	49	712.56	110	120.45	20.34	22.27
43	**43**	**40**	**483.0916**	**40**	**46.742**	**10.91**	**12.75**

Fuzzy Rule based floating cum tilted-wick solar still

Fuzzy rule based reasoning system consists of three components which will perform a specific task in the reasoning process i.e. fuzzification process, inferencing and defuzzification. The fuzzification process predicts a fuzzy representation of non-fuzzy input values by applying membership functions associated with each fuzzy set in the rule input space. The process of mapping the fuzzified inputs into the rule base and to provide a fuzzified output to each rule in inferencing. Defuzzification process converts the output of the fuzzy rules into a scalar or non-fuzzy value.

Membership functions

Here four dynamic variables have been considered; Solar radiation intensity (I(t)), wicks temperature (T_{w1} and T_{wf}), instantaneous distillate output (D) and instantaneous efficiency (I_e) per hour. Since solar radiation intensity varies continuously and these variation influence the wicks temperature and thereby the distillate yield and instantaneous efficiency. The evaporation of water also affects the wicks temperature. Hence, the four variables have been treated as the dynamic ones and the new designed still as a fuzzy system and fuzzy logic has been proposed to that system. From the experimental results of the proposed still, the observed range of solar radiation intensity was from 483.0916 to 1026.57 W/m^2 and the range of wicks temperature were from 37 to 65ºC for tilted-wick and from 36 to 64ºC for floating-wick water surface. The minimum and maximum distillate collected was 71.21 and 365.18 ml/hr respectively. Since the floating-wick and tilted-wick temperatures are more or less equal, tilted-wick temperature has been taken as one of the dynamic variables instead of taking both the tilted- wick and floating-wick water surface temperatures. Based on these ranges of experimental results, the patterns of membership functions for the four variables have been generated and are depicted in the Fig. 2.

Fuzzy Rules

Fuzzy rules have been framed in which more cases could be possible with variable results.

Rule 1: IF (Solar Radiation is High) AND (Wicks Temperature are Low), THEN (Distillate yield is Low).

Rule 2: IF (Solar Radiation is High) AND (Wicks temperature are Normal), THEN (Distillate yield is Normal).

Rule 3: IF (Solar radiation is Normal) AND (Wicks temperature are Low), THEN (Distillate yield is Normal).

Rule 4: IF (Solar radiation is Normal) AND (Wicks temperature are Normal), THEN (Distillate yield is Normal).

Rule 5: IF (Solar radiation is High) AND (Wicks temperature are High), THEN (Distillate yield is High).

Rule 6: IF (Solar radiation is Normal) AND (Wicks temperature are High), THEN (Distillate yield is Low).

Rule 7: IF (Solar radiation is Low) AND (Wicks temperature are Low), THEN (Distillate yield is Low).

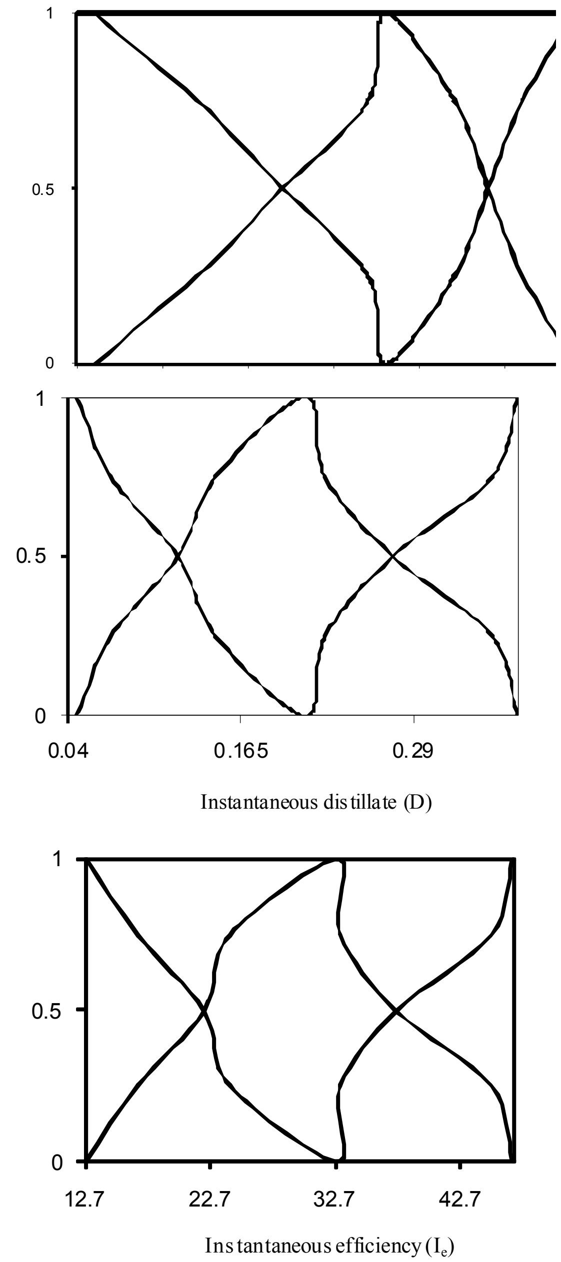

Fig. 2 Membership functions

Rule 8: IF (Solar radiation is Low) AND (Wicks temperature are Normal), THEN (Distillate yield is Low).
Rule 9: IF (Solar radiation is Low) AND (Wicks temperature are High), THEN (Distillate yield is Low).
And similarly
Rule 1a: IF (Solar Radiation is High) AND (Wicks Temperature are Low), THEN (Instantaneous efficiency is Low).
Rule 2a: IF (Solar Radiation is High) AND (Wicks temperature are Normal), THEN (Instantaneous efficiency is Normal).
Rule 3a: IF (Solar radiation is Normal) AND (Wicks temperature are Low), THEN (Instantaneous efficiency is Normal).
Rule 4a: IF (Solar radiation is Normal) AND (Wicks temperature are Normal), THEN (Instantaneous efficiency is Normal).
Rule 5a: IF (Solar radiation is High) AND (Wicks temperature are High), THEN (Instantaneous efficiency is High).
Rule 6a: IF (Solar radiation is Normal) AND (Wicks temperature are High), THEN (Instantaneous efficiency is Low).
Rule 7a: IF (Solar radiation is Low) AND (Wicks temperature are Low), THEN (Instantaneous efficiency is Low).
Rule 8a: IF (Solar radiation is Low) AND (Wicks temperature are Normal), THEN (Instantaneous efficiency is Low).
Rule 9a: IF (Solar radiation is Low) AND (Wicks temperature are High), THEN D (Instantaneous efficiency is Low).

The above rules were inferenced and executed for different values of solar radiation intensity, wicks temperature and henceforth the values of the quantity of distillate yield and instantaneous efficiency were found.

RESULTS AND DISCUSSION

The amount of the distillate yield and instantaneous efficiency derived using different values of solar radiation intensity and wicks temperatures are given in Table.1, along with the experimental results for comparison purposes. From the results, three-dimensional graphs were generated between the four variables and depicted in Figs. 3 and 4. The relative standard deviation has been found between the experimental and simulation results in order to signify the closeness of the trend. It is observed that there is a reasonable agreement between the simulation and experimental results. In all the cases the minimum and maximum relative standard deviation between them is 1.13 and 14.4% respectively.

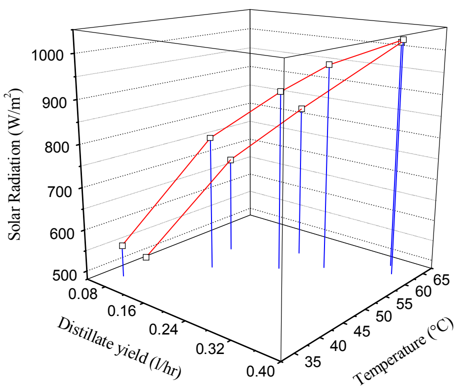

Fig. 3 Three-dimensional graphs between Instantaneous distillate yield Temperature of the wicks and solar radiation.

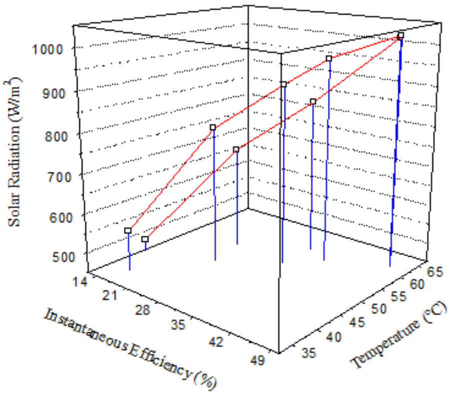

Fig. 4 Three-dimensional graph between the Instantaneous efficiency,Temperature of the wicks and solar radiation

CONCLUSION

The concept of fuzzy logic modeling of floating cum tilted-wick solar still and the results pertaining to the theory is quite impressive. It provide not only the with a meaningful and powerful representation of measuring uncertainties, but also with a meaningful representation of vague concepts expressed in natural languages. Thus a fuzzy model of the system can be defined mathematically by assigning to each possible individual a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which its individual is similar or compatible with the concept. These results provide enormous scope for the applications of the developed fuzzy system to optimize the still.

Nomenclature

D	-	Instantaneous distillate output (ml/hr)
I(t)	-	Instantaneous solar radiation intensity (W/m^2)
I_e	-	Instantaneous efficiency (%)
T_{wl}	-	Instantaneous tilted-wick water surface temperature (°C)
T_{wf}	-	Instantaneous floating-wick water surface temperature (°C)
T_g	-	Instantaneous glass temperature (°C)

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