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OPTIMIZATION OF NUSSELT NUMBER FOR INCLINED RIBS USED AS ROUGHNESS ELEMENT IN SOLAR AIR HEATER DUCT

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ABSTRACT

These days, the interest of researcher growing in the field of optimization of solar systems in order to improve the heat transfer rate by reducing friction losses either using optimization techniques or improving system design by introducing roughness elements. In this work, Genetic algorithm has been implemented to optimize the value of heat transfer and the same is compared with the experimental result of flat plate solar air heater and predict the optimized set of design and operating parameter. The operating parameters which affect the heat transfer rate are relative roughness pitch (p/e) from 8 to 16, relative roughness height (e/D_h) from 0.021 to 0.043, angle of attack (α) from 30° to 75° and Reynold number (Re) from 5600 to 28000. The optimized set of these parameters are obtained and compared with experimental result which shows that Nusselt number is 1.23 times as compare to that of experimental one.

Nomenclature:

p/e: relative roughness Pitch

e/D_h: relative roughness height

α: Angle of Attack

Re: Reynolds number

Nu: Nusselt number

f: friction factor

Key Words: Optimization, Roughness element, heat transfer rate, Solar Energy

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1. INTRODUCTION

In the present situation, the country's improvement and advance in expectation for everyday comforts are assessed by per capita vitality utilization because of which quick exhaustion of traditional sources, henceforth for nonstop and solid supply of vitality substitute vitality assets that are inexhaustible has been sought and vitality change frameworks in view of these innovations are found and introduced that can give a manageable future. Sun powered vitality is a standout amongst the most promising among such assets and can possibly supplies and satisfies all the present and future vitality needs on a long lasting premise[1,2].

The easiest methodology for making the proper use of solar energy is its conversion to thermal energy using solar collector. These solar collector are the part of solar air heater and solar water heater which are used for heating air and water respectively. Fabrication of solar air heater is quiet easy due to its compactness. Moreover, solar air heater are cheaper as compared to solar water heater due to use of less material. Solar air heater has wide area of application such as curing of industrial products, space heating, crop drying, wood seasoning, etc. Efficiency of solar

air heater is low due to the low specific heat of air and low heat transfer rate between absorber plate and flowing air inside duct. So, to make solar air heater efficient it is necessary to enhance the heat transfer rate. For this reason, the surfaces are sometimes roughened or longitudinal fins are provided in the air flow passage[3,4].

This research paper give the emphasis on the optimization of roughness parameters with help of Genetic algorithm which was used in experimental investigation of equilateral triangular duct with inclined ribs on absorber plate of solar air heater [5].

2. OPTIMIZATION USING GA

This section explains the detailed methodology used for the optimization of the objective function raised in this paper. The problem depicted above may have an excessively vast set of parameters or even boundless. Thus, in order to find the optimal solution, we have used the technique that attempt with get to it through the dynamic improvement of suboptimal arrangements which they have found. For this we have used Genetic Algorithm specifically.
New technologies applied for the optimization allow us to extract plenty of data about the usual behavior of variables in our analysis. To achieve the possible optimization using the correlation developed by experimental data in previous our research, we make use of the tools provided by artificial intelligence. Today the use of these techniques in solving problems is fully extended. Among the best known we will focus on the application of genetic algorithm to optimize the Nusselt Number to enhance the heat transfer in Ribbed Triangular Duct Solar Air Heater in this paper.

Genetic algorithms depend on the thoughts of natural selection and hereditary qualities. This article proposes the classification of duct design parameters which may define the profile of the duct in Solar Air Heater to maximize Nussselt Number using Genetic Algorithm for the different Reynolds numbers used in experimental analysis. To optimize this objective functions random population of relative roughness pitch, relative roughness height, angle of attack and with constant Reynolds number for bounds as used for experimental analysis in previous research, is iterated using multi-objective GA from optimization toolbox in MATLAB 2016.
Objective functions what we have tried to optimize: 1. The maximization of Nusselt Number through for the optimized profile of duct. 2. The minimization of Friction factor for the same profile of duct. After establishing several basic suboptimal solutions, they are combined randomly, through the crossover, mutation and cloning, to try to find the optimal.
Phases of the analysis are described below.

2.1. Modeling

The function file in MATLAB is developed comprising of Objective functions to call using GA toolbox in MATLAB 2016. There are two objective functions which are obtained as the correlations from the experimental analysis.

Objective Function 1. Nusselt Number (*Nu*) is one whose maximum value leads to maximum heat transfer which depends upon the input parameters as relative roughness pitch (*P/e*), relative roughness height (e/D_h), angle of attack (α) and Reynolds number (*Re*). The Objective function is :

Maximize,

$$Nu = 3.1\times10^{-3}\times \mathrm{Re}^{1.0972}(\alpha/60)^{0.0792}\exp\left[-0.1908(\ln(\alpha/60))^2\right](p/e)^{1.0832}\exp\left[-0.246(\ln(p/e))^2\right] \times (e/D_h)^{0.3585} \quad 1\ [5]$$

Objective Function 2.

Friction factor (*f*) which depends upon the input parameters as relative roughness pitch (*P/e*), relative roughness height (e/D_h), angle of attack (α) and Reynolds number (*Re*). The Objective function is :

Minimize,

$$f = 11.845\times \mathrm{Re}^{-0.693}(\alpha/60)^{0.0418}\exp\left[-0.1686(\ln(\alpha/60))^2\right](p/e)^{1.1389}\exp\left[-0.2644(\ln(p/e))^2\right] \times (e/D_h)^{0.3365} \quad 2\ [5]$$

2.2. Constraints

The bounds of the problem are shown in Table 1.

Table 1 Bounds for GA Optimization

Sr. No.	Re	α		P/e		e/D_h	
		Lower	Upper	Lower	Upper	Lower	Upper
1	5600	30°	75°	4	16	0.021	0.043
2	8000	30°	75°	4	16	0.021	0.043
3	11200	30°	75°	4	16	0.021	0.043
4	17700	30°	75°	4	16	0.021	0.043
5	22500	30°	75°	4	16	0.021	0.043
6	28000	30°	75°	4	16	0.021	0.043

The constraints are taken from experimental analysis to optimize the experimental results. The roughness parameters are varied for a fixed value of Reynolds Number.

2.3. GA using MATLAB

The procedure of natural selection begins with the determination of fittest individuals from a populace. They deliver offspring which acquire the attributes of the parents and will be added to the generation to come. In the event that parents have better fitness, their offspring will be superior to parents and have a superior possibility at surviving. This procedure continues emphasizing and toward the end, a generation with the fittest will be found.

Varun and Siddharath [6], developed a GA optimization strategy for the thermal optimization of a flat plate solar air heater. A Genetic Algorithm can introduce distinctive variations, contingent upon how genetic operators (crossover, mutation) are connected, how the choice and substitution of individuals chose to frame the new generation.

The plan of the proposed GA is depicted as follows. The individuals (decision variables) are represented by double vector values. The selection process uses a roulette wheel selection method [7] to prevent premature convergence. As genetic operators, the arithmetic recombination and the Adaptive feasible mutation are considered, both with adjusting values. Finally, parameters are set as follows: a population size of 50 individuals, a crossover probability of 0.8. Optimization results are contrasted with an exhaustive search and a random search.

As GA is a stochastic algorithm, we reach under the most favorable solution after various iterations. The best solution is the optimal estimations of the measures of Nusselt number (*Nu*) for a corresponding set of relative roughness pitch (*P/e*), relative roughness height (e/D_h), angle of attack (α) and Reynolds number (*Re*) utilized for evaluation.

3. RESULT AND DISCUSSION

In this section value of Nusselt number is calculated using optimization using GA. It has been seen that Nusselt number increases with increase in Reynolds number (Table 2). Now the GA result is compared with the experimental result (Table 3) and ploted in Figure 1. It can be seen from the graph that the Nusselt number which we get from GA is 1.23 times of Experimental result.

Table 2 Comparison of Experimental & GA Obtained results

Sr. No.	Re	Experimental Results		GA Obtained results	
		f	Nu	*f*	Nu
1	5600	0.031086	35.60719	0.031619	38.79282
2	8000	0.024908	44.46032	0.024999	58.95277
3	11200	0.019927	64.91666	0.019524	83.87669
4	17700	0.014347	113.0537	0.014421	140.9039
5	22500	0.0122	159.4196	0.01221	183.3374
6	28000	0.010462	186.6721	0.010493	233.0541

Table 3 GA Obtained results

Sr. No.	Re	α	P/e	e/D_h	*f*	Nu
1	5600	51.55775	15.66484	0.042001	0.031619	38.79282
2	8000	75	16	0.043	0.024999	58.95277
3	11200	71.36613	15.96613	0.04101	0.019524	83.87669
4	17700	74.53571	16	0.043	0.014421	140.9039
5	22500	74.92179	16	0.043	0.01221	183.3374
6	28000	74.9705	16	0.043	0.010493	233.0541

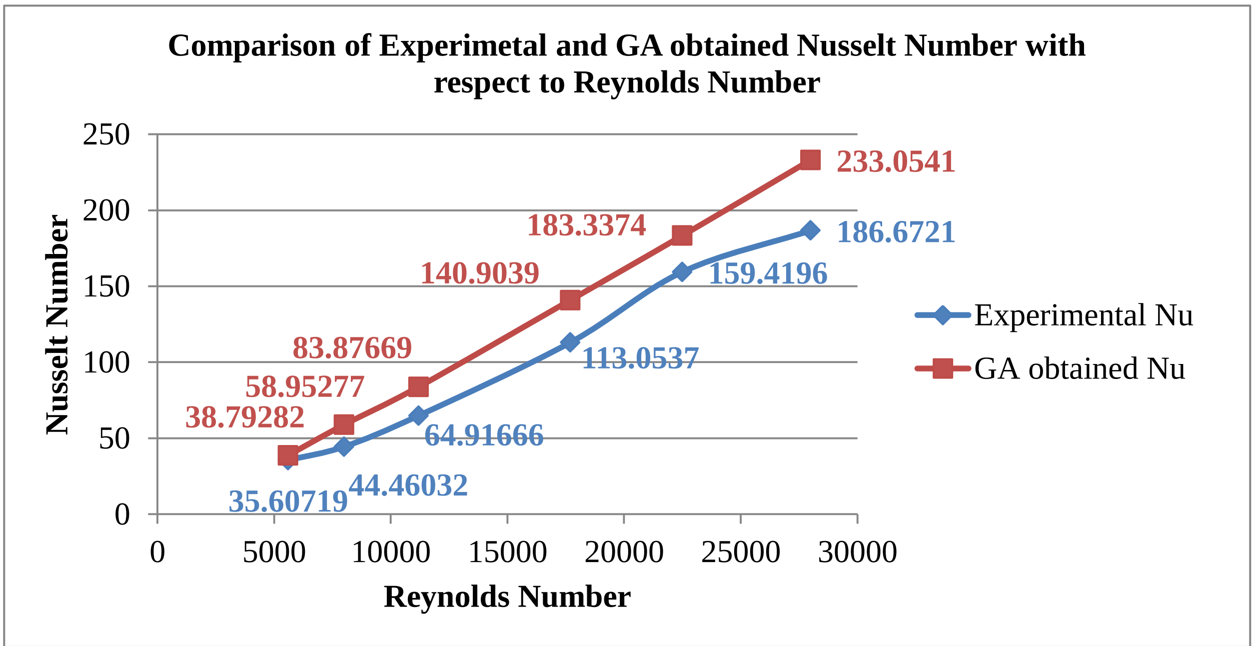

Figure 1 Comparision of Experimental and GA obtained Nusselt number w.r.t Reynolds number

4. CONCLUSIONS

It is concluded that Genetic algorithm has been implemented to optimize the value of heat transfer and the same is compared with the experimental result. It will give the better result for heat transfer rate i.e. 1.23 times of experimental value for same operating parameters.

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