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Control of heat exchangers using artificial neural networks

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ABSTRACT

In this paper, the author has studied the artificial neural network (ANN) technique to the simulation of the time-dependent behavior of a heat exchanger and its uses to control the temperature of air passing over it. In such type of technique, a methodology is proposed for the training and prediction of the dynamic behavior of thermal systems with heat exchangers. Then an internal model scheme is developed for the control of the over-tube air temperature with two artificial neural networks, one to simulate the heat exchanger and another as controller. An integral control is implemented in parallel with the filter of the neural network controller to eliminate a steady-state offset. The results are then compared with those of standard PI and PID controller. There is less oscillatory behavior with the neural network controller, which allows the system to reach steady-state operating conditions in regions where the PI and PID controllers are not able to perform as well.

Keywords: Control, heat exchangers, artificial neural networks, tube.

INTRODUCTION

Heat exchanger process is complex due to its nonlinear dynamics and particularly the variable steady state gain and time constant with the process fluid [1]. Heat exchangers are utilized to transfer the heat between two liquids over a strong surface that are at various temperatures. The generally utilized shell and cylinder heat exchangers are utilized in refrigeration, control age, warming, cooling substance procedures, assembling and restorative applications [2]. These heat exchangers comprise of a heap of cylinders and encased inside a round and hollow shell. One type of liquid transfer is through the cylinder and second kind of liquid streams among shell and cylinders. The presentation of heat exchanger crumbles with time because of arrangement of fouling. It is an extremely confused wonder and can be extensively ordered into particulate, consumption, natural, crystallization, compound response and stop. It is only because of single component by and large. It will in general increment after some time, the direction being very site explicit. Elements that effects fouling are feed quality, divider temperature, speed, natural action and the treatment strategy [3,4].

Performance of heat exchanger is monitored by the following methods:

i) Outlet temperature of the hot stream (Tho) profile,

ii) Approach temperature (Tho - Tci) profile,

iii) Log Mean Temperature Difference (LMTD) with time,

iv) Heat load profile, and

v) Time series of overall heat transfer coefficient.

The first four methods are widely used and are ineffective in terms of isolating the net impact of fouling from process upsets. In any case, the general heat transfer coefficient strategy requires point by point figurings and learning of the geometry of the exchangers [5,6]. Administrators figure these parameters on more than one occasion in per week dependent on either prompt temperature and stream estimations or every day arrived at the midpoint of tests of the estimations. Any deviation from the heat transfer coefficient of configuration/clean heat exchanger will

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demonstrate the event of fouling [7,8]. Cylindrical Exchanger Manufacturing Association suggests a reasonable fouling factor (FF) or fouling protection from endure some horizontal of fouling before cleaning must be embraced. This remittance is given to avoid incessant procedure interferences for cleaning of heat exchanger [9,10]. Consequently, checking framework is expected to evaluate the exhibition of heat exchanger. The procedure pursued to screen the framework depends basically on the embraced practice in the plant, application, sort of heat exchanger, and experience of the administrator. A portion of the checking methodologies are adhoc where as some include fastidious figuring.

To conquer this, heat exchanger execution ought to be observed online with savvy devices and evaluate the exhibition occasionally [11,12]. It needs able prescient model of a framework to evaluate the heat exchanger execution. Demonstrating is a portrayal of physical or concoction process by a lot of scientific connections that successfully clarify the critical procedure conduct. These models are as often as possible utilized for procedure structure, security framework examination and procedure control [14]. In exploratory investigations and designing uses of warm science, scientists and architects are relied upon to lessen trial information into at least one basic and conservative dimensionless heat exchange connections [16]. The downsides of this technique are heat transfer coefficients emphatically rely upon their definitions and temperature contrasts, and surely need iterative strategy to discover relationships when liquid properties are reliant on liquid temperatures [17,18].

The impediments of connection strategies are tended to by computational intelligence (CI) procedures, for example, ANNs and fluffy rationale (FL). ANNs is one of the most dominant PC displaying procedures, in light of factual methodology, at present being utilized in numerous fields of building for demonstrating complex connections which are hard to portray with physical models. It just needs input/yield tests for preparing the system and learn complex nonlinear relationship [19]. As of late, ANNs have been utilized in warm frameworks for heat transfer investigation, execution expectation and dynamic control [20].

Applications of ANN in Thermal Engineering

The applications of ANN and genetic algorithms in thermal engineering are very wide. ANN is applied in heat transfer data analysis, evaluating heat transfer coefficients from experimental data [21], distinguishing and controlling heat exchangers, reproduction of heat exchanger execution utilizing constrained trial information, demonstrating of heat exchanger dynamic qualities, dynamic displaying and controlling of heat exchangers with GA, dynamic forecast and neuro controller structure for heat exchangers, neuro prescient controller plan of heat exchangers, deciding balance and-cylinder heat exchangers execution with restricted exploratory information utilizing delicate processing and worldwide relapse, foreseeing heat transfer pace of a wire-on-tube heat exchanger [22], heat transfer examination of air streaming increased channels and demonstrating the warm exhibition of conservative heat exchanger.

From the previously mentioned fruitful applications, ANNs are well appropriate for warm examination in designing frameworks, particularly in heat exchangers. In this paper, an internet checking framework is produced for a shell-and-cylinder heat exchanger utilizing auxiliary estimations to be specific the temperatures and stream paces of the hot and cold liquid (water). Test framework is created to explore the presentation of heat exchanger. ANN is applied to demonstrate the heat exchanger with trial information. The information parameters to build up a model for configuration/clean heat exchanger are gulf temperature and stream pace of shell and cylinder side liquids and yield is generally speaking heat transfer coefficient (UDesign). The general heat transfer coefficient of genuine/fouled framework (UReal) is determined utilizing on the web estimated qualities, for example, bay temperature, outlet temperature and stream pace of shell and cylinder side liquids. The heat exchanger execution is evaluated by looking at the consequences of clean/plan and fouled/genuine framework [23].

MATERIALS AND METHOD

The schematic diagram of the experiment's set up is shown in Fig. 1. It consists of a rectangular fluidized column that is 0.1 m 0.15 m in cross section and 0.4 m height, with provision to install central horizontal heated brass tube and tube bundles in in-line and staggered arrangement. The heat transfer tube was 110 mm in length and its outer diameter was 13 mm. The ends of tubes were fitted with nylon plug at the both ends of duct to reduce axial heat loss.

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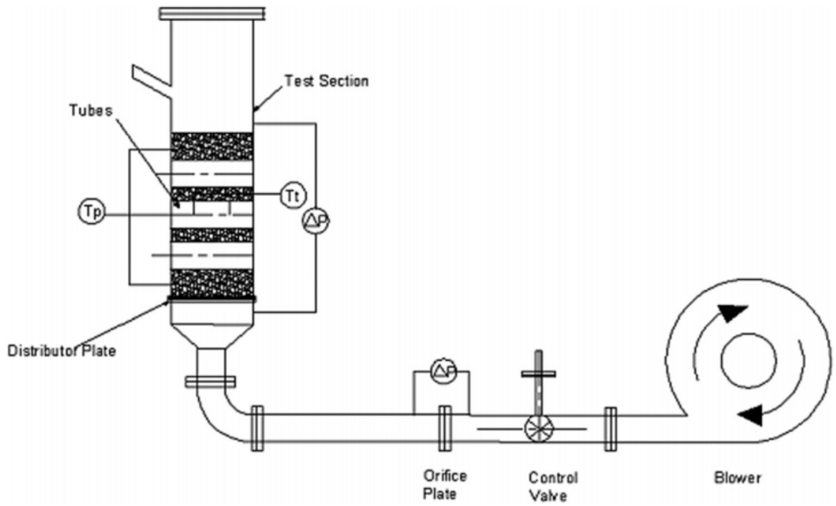

Fig. 1: Schematic diagram of experimental setup [13]

Three rows of tubes were used in all experimental runs as shown in Fig. 2 for in-line and staggered arrangement. The horizontal and vertical pitch for cylinder groups was kept steady for in-line and stunned course of action in every exploratory run. Cylinder groups with same measurement as of focal warmed cylinder were chosen of nylon material. Just the center container of the group was warmed and the others were going about as sham cylinders. The cartridge warmer was embedded inside the focal cylinder, and the heat contribution to the cylinder was constrained by a variable direct current power supply. The heat info was dictated by estimating voltage (V) and current (I) of the power provider (voltmeter and ammeter with a precision of 1% are utilized) [24].

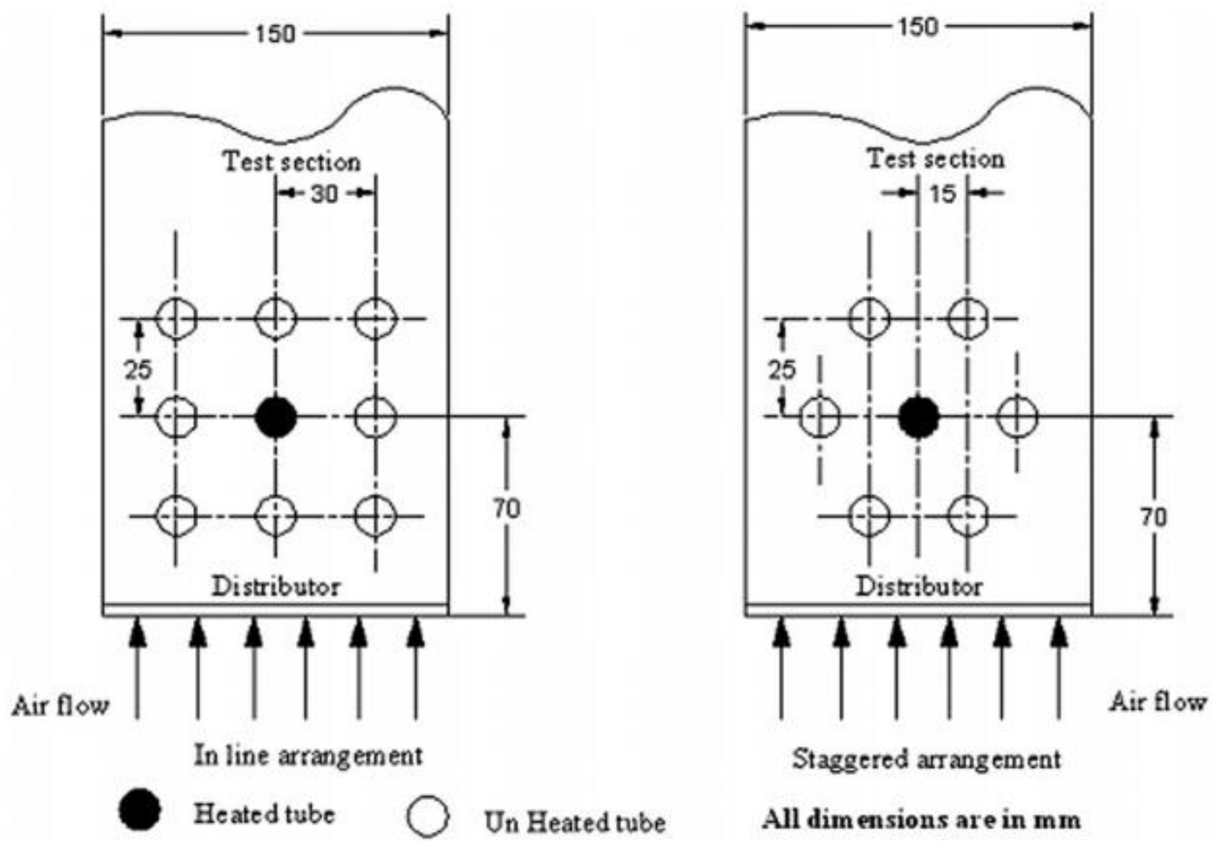

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Fig. 2: In-line and staggered arrangement of tubes [12]

The warmed cylinder was introduced at a stature of 70 mm from the merchant plate. The air was utilized as a fluidizing gas at air weight. The shallow air speed was changed in the scope of 0.7–1.3 m/s. The nature of fluidization was improved by giving decreased diffuser and plenum segment, in this way limiting the quickening impacts in view of the high stream rate. The arrangement was instrumented for estimating the bed temperature, surface temperature of heat transfer tube, wind current rate, and electrical vitality provided to the cylinder. The strong particles utilized in this investigation were mustard, raagi and bajara. Fluidized beds are broadly utilized not just in enterprises for drying of manures, synthetic substances, pharmaceuticals, and minerals yet additionally to discover expanding application in the drying of rural material (nourishment grains) like mustard, raagi, wheat, bajara, corn, and natural products. Rural materials which are coarse particles are somewhat hard to fluidize [25].

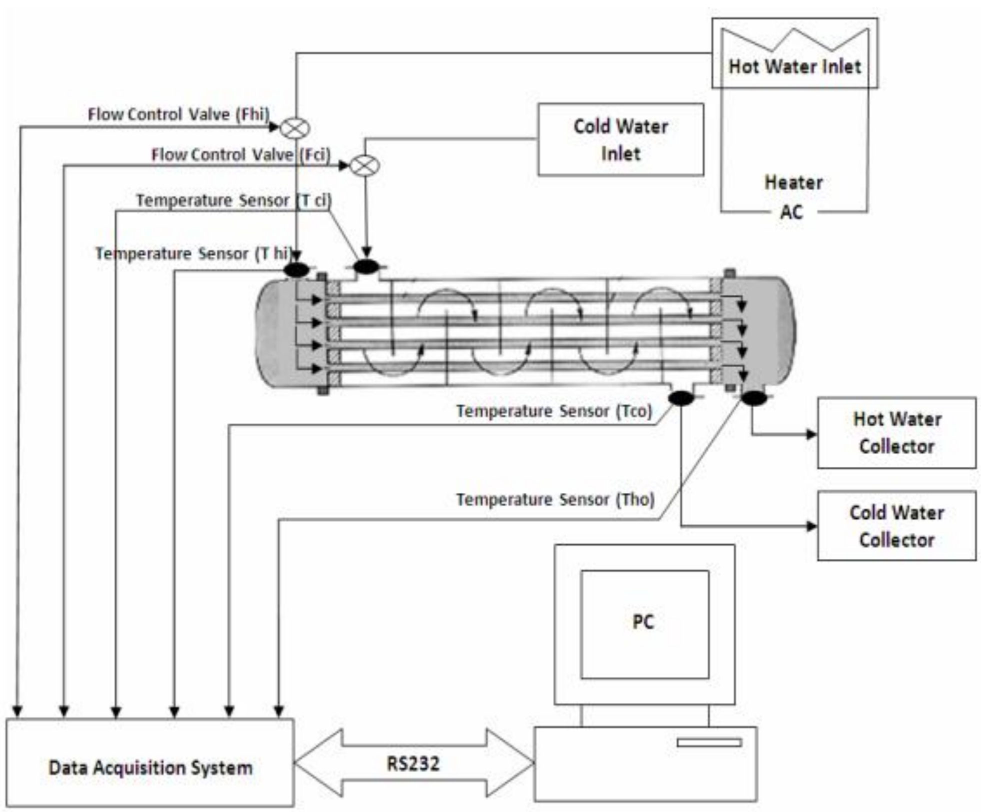

Figure 3: Schematic diagram of experimental set-up in shell and tube heat exchanger [19]

The fluidized bed drying find many advantages such as quick heat transfer, high heat limit of the bed, uniform drying method, low lingering dampness content, high horizontal of effectiveness, less time of drying, ease in dealing with, and transport of fluidized solids and henceforth conservative when contrasted with other drying systems. This system is advantageous for heat touchy nourishment materials as it keeps them from overheating. The dampness substance of these nourishment grains must be diminished to under 10% dampness content for safe stockpiling for longer period. Legitimate drying methods can take out the capability of waste during resulting stockpiling and improve the nature of grain. Subsequently, the particles were picked like mustard, raagi and bajara so this examination can be broadened further in the investigation of impact of temperature, time, dampness substance and gas speed on the drying execution. It is chosen to set up the research facility trial set up for the investigation of heat transfer in fluidized bed [26].

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The extent of the weight drop is straightforwardly relative to the ability to fluidize the bed. As weight drop through the bed is proportionate the weight per unit region of the bed bolstered, it was chosen that the power devoured in suspending the bed ought to be kept low, henceforth the low thickness particles chose like mustard, raagi, and bajara. The thickness of these particles is in the scope of 1000–1200 kg/m3. The state of the particles is circular which aides in the examination. Likewise the drying of these nourishment grains utilizing fluidized bed [27] is one of the developing regions where much examination should be possible by utilizing ANN displaying. The molecule distance across was dictated by standard test sifters of 30 cm measurement (GI outline). The test strainers were of standard sizes 1 mm, 1.18 mm, 1.8 mm, 2.8 mm, and 2.36 mm, and so on. We haphazardly chose some example from the bed material and the known weight (300 g) of particles was weighed precisely in a physical equalization.

The gauged molecule was moved to the upper sifter as the strainers were orchestrated one over the other running from most extreme to least esteem. Proposals strainers with gauged molecule were kept in the middle of two jaws of the sifter shaker. This strainer shaker is worked for about 30 minutes. The rate weight of the bed molecule held in the progressive sifters was estimated precisely. At that point the normal molecule distance across (dp) is determined utilizing the condition where wi is the weight portion between continuous sieving screens and dpi is the number juggling normal measurement of progressive screens. A similar technique is applied for other bed materials for computation of molecule breadth. The mean molecule breadth of the mustard, raagi, and bajara were 1.8 mm, 1.4 mm, and 2 mm, separately. The static bed tallness was 110 mm and the conduit is upheld by a punctured wholesaler plate 4 mm thick at the base, which comprised of various little openings. The fundamental weight drop over the wholesaler is determined dependent on weight drop over the bed. At that point Reynolds number is determined for the all out stream moving toward the plate. The speed of gas through the hole was resolved, estimated at methodology thickness and temperature [28].

CONCLUSION

This study is to demonstrate the capability of the ANN techniques for the prediction of heat transfer coefficient between fluidized bed and tube bundles immersed in it. ANN model are being created to foresee the normal heat transfer coefficient and Nusselt number for horizontal cylinders drenched (inline and lurched) in gas–strong fluidized bed of enormous particles. The system is prepared independently for in-line and amazed game plan utilizing test information. The anticipated qualities utilizing ANN models have been contrasted and the relating trial ones and those acquired with the assistance of relationships. In light of the trial information, direct relationships are proposed for forecast of heat transfer coefficient. Study demonstrates that there is a decent understanding among trial and anticipated outcomes by ANN. The ANN model, with feed-forward engineering and prepared by the back spread strategy, speaks to framework conduct more precisely than ordinary models dependent on first standards.

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