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Experimental Study on the Thermal Performance of a Solar Air Heater (SAH) with Different Absorber Plate Configurations

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ABSTRACT

Experimental study on the thermal performance of a Solar Air Heater (SAH) with different absorber plate configurations, specifically focusing on S-shaped ribs with gaps. The study explores the impact of varying mass flow rates on the SAH with and without ribs and assesses the thermal efficiency based on experimental outputs such as outlet air temperature. Here are some key points from your description: S rib with gaps S rib without gaps Plain absorber plate. Varying mass flow rates were considered. Thermal performance was assessed using parameters such as outlet air temperature and thermal efficiency. The S rib with gap absorber plate SAH demonstrated the highest thermal efficiency, reaching 77.9% at a mass flow rate of 0.045 kg/s. This efficiency was reported to be 27.81% and 37.7% higher than SAH with continuous ribs and without ribs, respectively. Artificial roughness in the form of S ribs with symmetrical gaps was experimentally examined. Reynolds number (Re) ranged from 3000 to 6500.

Relative gap width (g/e) ranged . Relative roughness pitch (P/e) is 10. Angle of attack is 60 degrees. The study suggests that S-shaped ribs with gaps in the absorber plate configuration offer superior thermal performance compared to continuous ribs and smooth plate SAH. The information provided in your summary indicates that the experimental study focused on optimizing the design of the solar air heater for enhanced thermal efficiency. The use of S-shaped ribs with gaps seems to have proven effective in achieving higher efficiency levels compared to other configurations. This research contributes valuable insights to the field of solar air heating and could have implications for the design and improvement of solar thermal systems.

Key Words:- Solar Air Heater (SAH), mass flow rates, S-shaped ribs, solar thermal systems

INTRODUCTION

The importance and various applications of heat exchangers in different processes. Heat exchangers play a crucial role in optimizing energy usage and improving overall system efficiency. Here's a summary and expansion on some of the key points you've mentioned:

Recovery and Rejection of Heat: Heat exchangers are used to recover or reject heat in various industrial processes.

Sterilization and Pasteurization: They are employed in applications where sterilization or pasteurization is required.

Fractionation, Distillation, Concentration, Crystallization: Heat exchangers are integral in processes involving fractionation, distillation, concentration, and crystallization.

Process Fluid Control: They play a role in controlling the temperature of process fluids.

Performance Metrics:

Heat Transfer Efficiency: The efficiency of heat exchangers is measured by the amount of heat transferred. Area of Heat Transfer: Achieving efficient heat transfer with the least possible area is a key design consideration.

Pressure Drop: It's essential to manage pressure drop to maintain optimal performance. Balancing Act in Design: Tradeoff Between Efficiency and Size: Designing heat exchangers involves a tradeoff between system efficiency and size. Application-Specific Variations: The optimal balance varies based on the specific energy conversion system application. Role in Energy Efficiency: Heat Transfer Optimization: Heat exchangers facilitate the transfer of heat from areas where it is not needed to locations where it can be effectively utilized. Combined Cycle Gas Turbine Technology: An illustrative example is the use of waste heat from a gas turbine to generate additional electricity through a steam turbine. Examples of Heat Exchangers: Shell-and-Tube Exchangers: Commonly used in various industries for their efficiency and versatility. Automobile Radiators: Essential for cooling engines by transferring heat from the coolant to the air. Condensers and Evaporators: Found in refrigeration and air conditioning systems. Air Preheaters: Used to heat air before it enters a combustion chamber for improved fuel efficiency. Cooling Towers: Employed in industrial processes to dissipate heat from cooling water.

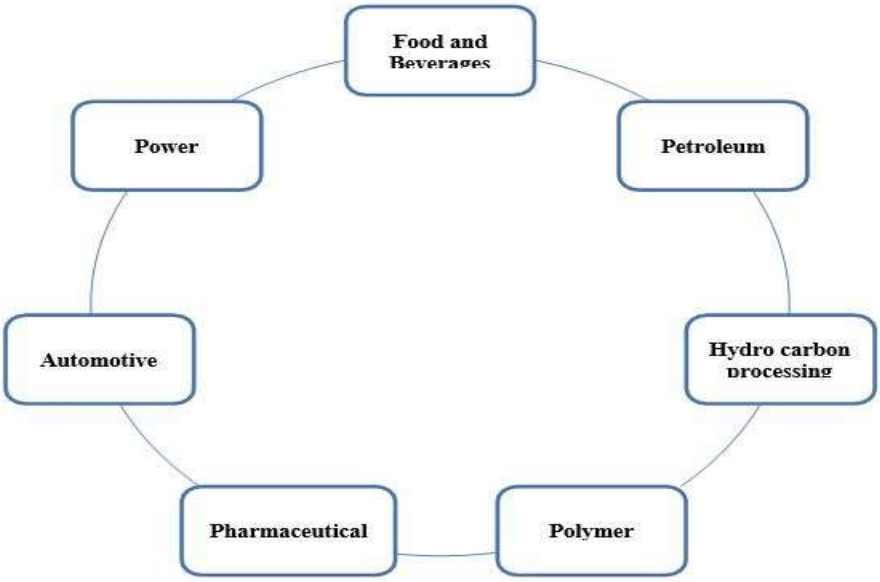


Figure 1 Heat Exchanger Applications in Different Industries

Objective

- To evaluate the performance of heat transfer efficiency of the proposed heat exchanger by changing the distance of pitches in the proposed heat exchanger.
- The proposed distance between the fins are 5 mm, 10 mm and 15 mm in three proposed setups for the ACHE.

LITERATURE REVIEW

Zhisong Li et al. In this study, author has proposed another heat pipe structure, replacing the traditional axial-grooved or sintered wicks with simple piping container & spiral coil. So, this proposed heat pipe structure is presented for its design and operational system. With assistance of two test articles manufactured preliminary experiments were done to explore the heat transfer performance with various wire diameters and also compared with a charged container without coil wick. They also found that the spiral coil effectively functioned as a capillary wick. The suggested arterial heat pipe with coil wick of 0.5 mm wire acknowledged high powerful thermal conductivity of the similar order of magnitude with an AGHP.

Pengxiao Li, Peng Liu et al. In this paper, author has investigated the flow performance & heat transfer and in turbulent flow of the tube close-fitting with the drainage insertions. The outcomes show that the new-type addition can lead the fluid at the center to the tube wall; also it reinforces the mixing of cold and hot fluid. Furthermore, the addition likewise produces the vortex to make agitation in the fluid domain. This experiment explores the impact of pitch ratio on the Nusselt number and friction factor.

METHODOLOGY

From the above section of literature review we can analyses the present era research in air cooled heat exchanger; hence we are mainly focus on the experimental and comparative analysis along with the study on different parameters of heat exchangers, with a counter to cross-flow technique using with and without an internally spiral grooved aluminum annular tube attached with rectangular copper fins forced convection ACHE. The main objectives of this dissertation are as follows:

- ✓ To enhance the rate of heat transfer ACHE by internal spiral grooving with rectangular fins.
- ✓ To enhance the Thermal efficiency of ACHE by using the aluminum annular tube with internal spiral grooving along with rectangular Copper fins.
- ✓ To evaluate the performance of heat transfer efficiency of the proposed heat exchanger by changing the distance of pitches in the proposed heat exchanger.
- ✓ The proposed distance between the fins are 5 mm, 10 mm and 15 mm in three proposed setups for the ACHE.
- ✓ The number of fins used for the above 3 proposed setups is 105 with variable pitch of ACHE.

CALCULATION & RESULTS

The various results are calculated in this section using four setups for proposed Heat Exchangers designs viz.

Simple heat exchanger without grooving with 105 rectangular copper fins

Heat exchanger with internal spiral grooving of pitch 05 mm along with 105 rectangular copper fins.

Heat exchanger with internal spiral grooving of pitch 10 mm along with 105 rectangular copper fins.

Heat exchanger with internal spiral grooving of pitch 15 mm along with 105 rectangular copper fins.

The second, third and fourth design are basically an internally grooved heat exchanger with rectangular aluminum fin for variable pitches. We are taking three variations in pitches to evaluate the performance of heat transfer efficiency of the proposed heat exchanger by changing the pitch distance but the numbers of fins used in the proposed heat exchanger are constant to 105. The proposed distance between two successive pitches are 05 mm, 10 mm and 15 mm in 3 test setup for the ACHE with 105 copper fins.

FIRST TEST SETUP OF HEAT EXCHANGER DESIGN

Calculation for 1st Design of Simple heat exchanger without grooving with 105 copper fins is the base of our research, outcome of the proposed setup is listed in this section in tabular form. We start the calculation with keeping some basic parameters of fluid used for our experimental setups.

Different Air-Cooled Heat Exchanger (ACHE) configurations under natural convection and forced convection. Here's a summary of the information you provided:

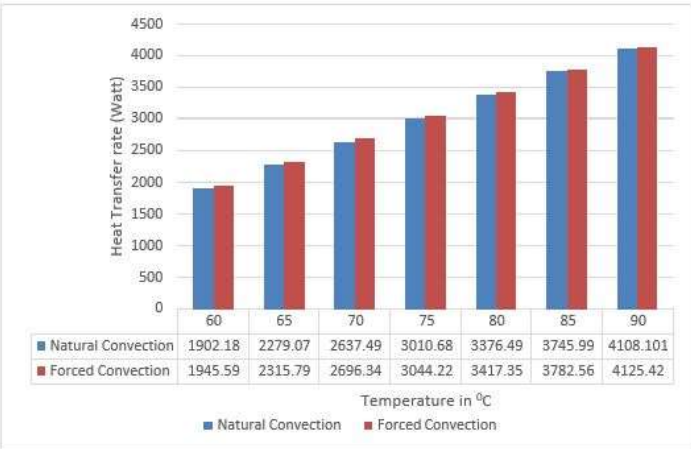
Natural Convection:

- Simple tube without grooving: 3010 watt
- Tube with 15 mm pitch distance: 3058 watt
- Tube with 10 mm pitch distance: 3078 watt
- Tube with 5 mm pitch distance: 3112 watt

Forced Convection:

- Simple tube without grooving: 3044 watt
- Tube with 15 mm pitch distance: 3063 watt
- Tube with 10 mm pitch distance: 3099 watt
- Tube with 5 mm pitch distance: 3146 watt

The analysis of heat transfer rate in air cooled heat exchanger for simple tube without grooving with 105copper fins is shown in Fig. 1. The analysis gives a quick glimpse of natural as well as forced convection



	60	65	70	75	80	85	90
Natural Convection	1902.18	2279.07	2637.49	3010.68	3376.49	3745.99	4108.101
Forced Convection	1945.59	2315.79	2696.34	3044.22	3417.35	3782.56	4125.42

Figure 2 Effect of hot fluid temperature on heat transfer rate for free and forced convection in simple tube without grooving.

CONCLUATION

The performance of an air-cooled heat exchanger with various configurations, specifically focusing on internal spiral grooving at a 0.5 mm pitch with rectangular copper fins. Here's a summary of the key findings from your analysis:

Optimal Configuration:

- ✓ The maximum performance is observed with internal spiral grooving at a 0.5 mm pitch with rectangular copper fins.
- ✓ The setup includes a total of 105 rectangular fins.

Forced Convection:

- ✓ 1.5% improvement for 0.5 mm grooving compared to 10 mm grooving.
- ✓ 2.71% improvement for 0.5 mm grooving compared to 15 mm grooving.
- ✓ 3.379% improvement for 0.5 mm grooving compared to a simple tube (without grooving).

Free Convection:

- ✓ 1.75% improvement for 0.5 mm grooving compared to 10 mm grooving.
- ✓ 2.41% improvement for 0.5 mm grooving compared to 15 mm grooving.
- ✓ 4.053% improvement for 0.5 mm grooving compared to a simple tube (without grooving).

Reynolds Number:

- ✓ Significant improvements in Reynolds number for 0.5 mm grooving compared to larger grooving and a simple tube.

Nusselt Number:

- ✓ Notable improvements in Nusselt number for 0.5 mm grooving compared to larger grooving and a simple tube.

Pressure Drop:

- ✓ Substantial improvements in pressure drop for 0.5 mm grooving compared to larger grooving and a simple tube.

Effectiveness:

- ✓ Improvement in effectiveness for 0.5 mm grooving compared to larger grooving and a simple tube.

Rectangular Fin Efficiency:

- ✓ The efficiency of the rectangular fin is reported to be 96.87%.

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