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Forced Convection Heat Transfer Enhancement Using Clockwise and Anticlockwise Bipartition Inserts

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Abstract

Several decades have been spent on methods to improve the transfer of heat through compound, passive, and active heat augmentation. The present research uses air as the working fluid and non-metallic i.e. Bakelite flow divider type inserts as part of a passive heat transfer augmentation technique. This paper presents an original experimental study on heat transfer enhancement by using arrangement of 4-4 45 degree's & 90 degree's clockwise insert. This study investigates the performance of a plain tube with a 90 degree's insert & 45 degree's clockwise bipartition insert focusing on the changes in Nusselt number, Reynold number and heat transfer coefficient through experimental methods. Through this experiment comparing the result of turbulent flow without insert, with 4-4 45 degree's & 90 degree's clockwise bipartition insert. The experimental setup involved systematically varying Reynolds numbers from range of 5000 to 23000 and heat input varied from 50 V, 75 V, 100V. Through in this study it is found that Nusselt number and heat transfer coefficient changes according to voltage. For 50 V, Nusselt number and heat transfer coefficient with 4-4 45 degree's & 90 degree's clockwise bipartition insert is 106% more than without insert. For 75 V, Nusselt number and heat transfer coefficient with 4-4 45 degree's & 90 degree's clockwise bipartition insert is 87% more than without insert. For 100 V, Nusselt number and heat transfer coefficient with 4-4 45 degree's & 90 degree's clockwise bipartition insert, is 102% more than without insert. So overall experiment shows that forced convection heat transfer using 4-4 45 degree's & 90 degree's clockwise bipartition insert clockwise and anticlockwise bipartition insert gives higher Reynold Number, heat transfer coefficient and Nusselt number effectively.

Keywords: Heat Transfer Coefficient, Turbulent Flow, Thermal Insulated Material, Nusselt Number, Reynold Number, Bakelite Insert.

1. INTRODUCTION

In engineering and natural processes, the transfer of heat is a fundamental phenomenon with significant implications for efficiency, safety, and performance. Forced convection, a subset of convective heat transfer, occurs when a fluid is forced to move over a surface by external means, such as fans or pumps. While passive techniques like twisted tapes are effective in laminar flow, they often perform poorly in turbulent flow because they block the flow and cause significant pressure drops. There is a need for inserts that offer a high overall enhancement ratio specifically in turbulent flow regions. This research focuses on studying forced convection heat transfer augmentation using passive bipartition type inserts with 90° and 45° clockwise and anticlockwise arrangements to improve system efficiency and performance. This research focuses on passive heat transfer augmentation techniques, which

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do not require external power and instead use geometry or inserts to improve thermal contact and enhance the heat transfer coefficient.

2. LITERATURE REVIEW

Passive techniques such as twisted tapes, wire coils, and ribs have been extensively studied. While twisted tapes are effective in laminar flow, they often produce significant pressure drops in turbulent regions. Recent studies have explored novel flow divider type turbulators, showing that displacement of fluid from the central core towards the tube walls can significantly enhance the Nusselt number—by 1.33 to 1.46 times for 45° and 30° twist angles. The review identifies a lack of reported data regarding the specific heat transfer performance of tubes using a 45° clockwise and anticlockwise bipartition insert.
Consequently, the current work focuses on investigating these bipartition-type passive inserts both experimentally and numerically to improve thermal-hydraulic efficiency in plain horizontal heated tubes.

3. METHODOLOGY AND EXPERIMENTAL SETUP

The objective of this study is to increase the heat transfer coefficient and compare the results of flow through a plain tube with those using 90° and 45° clockwise bipartition inserts. The experimental setup consists of a blower, test section, heater, venturi meter, and measuring instruments. Bipartition inserts of 45° and 90° were placed inside the tube. Air was passed through the tube at varying flow rates and heat input conditions. Temperature and pressure readings were recorded to calculate performance parameters.
Inserts: Non-metallic Bakelite flow divider type inserts were used.
Flow Conditions: Air served as the working fluid, with Reynolds numbers ranging from 5,000 to 23,000 to ensure turbulent flow.
Heat Input: Varied across three levels: 50V, 75V, and 100V

Figure 1. Experimental Setup

4. RESULTS AND DISCUSSION

The results show that Nusselt number increases with Reynolds number for all cases. The bipartition inserts significantly enhance heat transfer compared to the plain tube. For 50V

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input, enhancement of 106% was observed, while for 75V and 100V inputs, enhancements of 87% and 102% were recorded respectively. The experimental data indicates a substantial improvement in thermal performance when using clockwise bipartition inserts compared to a plain tube.

- **At 50V**: The Nusselt number and heat transfer coefficient increased by 106%.
- **At 75V**: An 87% increase was observed.
- **At 100V**: Performance improved by 102%.

Overall, the 4-4 45° and 90° clockwise bipartition inserts effectively provided higher Reynolds numbers and Nusselt numbers across all tested voltages.

5.3.1 Plain tube observation table of V=50volts, head difference =10mm

Temp	15 min	30min	45min	60min
T1	45.60	50.90	53.20	54.50
T2	43.80	48.40	50.70	51.70
T3	43.20	47.40	49.60	50.80
T4	43.00	47.20	49.10	50.20
T5	43.60	47.90	49.70	50.50
T6	43.20	48.50	49.10	50.10
T7	43.50	47.40	49.00	49.70
T8	43.30	47.50	49.10	50.00
T9	44.80	49.50	51.20	52.10
T10 = Ti	30.80	31.00	31.00	31.10
T11= To	35.30	36.90	37.80	38.00
T12= Ta	29.40	28.90	29.30	29.00

5.3.2 Plain tube observation table of V=50volts, head difference =30mm

Temp	15 min	30 min	45 min	60 min
T1	50.07	50.00	49.40	49.50
T2	48.60	47.50	46.80	46.90
T3	47.70	47.20	46.10	46.40
T4	47.20	47.00	45.60	45.70
T5	47.60	46.00	46.00	46.10
T6	46.90	46.70	45.30	45.40
T7	46.60	46.30	45.10	45.10
T8	46.60	46.10	45.00	45.10
T9	48.10	47.50	46.30	46.50
T10 = Ti	31.30	31.30	31.30	31.30
T11= To	37.20	37.00	36.70	36.70
T12= Ta	29.00	29.10	29.00	29.10

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5.3.3Plain tube observation table of V=50volts, head difference =70mm				
Temp	**15 min**	**30 min**	**45 min**	**60 min**
T1	46.00	45.60	44.50	44.50
T2	44.00	43.60	42.70	42.90
T3	44.30	43.60	44.10	43.50
T4	43.60	42.90	42.20	42.10
T5	43.80	42.60	42.00	42.50
T6	46.20	43.00	42.40	42.30
T7	43.00	42.50	41.90	41.70
T8	42.80	42.30	41.60	41.60
T9	44.00	43.40	42.80	42.60
T10 = Ti	31.50	31.80	31.90	31.90
T11= To	35.70	35.30	35.00	34.90
T12= Ta	24.90	28.80	28.80	28.70

5.3.4 Plain tube observation table of V=50volts, head difference =130mm				
Temp	**15 min**	**30**	**45**	**60**
T1	43.00	42.90	42.50	43.20
T2	41.50	41.20	41.10	41.10
T3	41.40	40.80	40.90	40.70
T4	41.00	40.80	40.60	40.60
T5	41.70	41.10	41.10	41.10
T6	41.00	41.70	41.60	41.20
T7	40.80	40.60	40.40	40.50
T8	40.60	40.30	40.30	40.30
T9	41.60	41.20	41.20	41.20
T10 = Ti	32.20	32.20	31.80	31.70
T11= To	34.50	35.90	35.20	35.00
T12= Ta	28.60	29.90	28.80	29.00

5. CONCLUSION

This study demonstrates that clockwise and anticlockwise bipartition inserts effectively enhance heat transfer in turbulent flow. The method is simple, cost-effective, and suitable for industrial applications such as heat exchangers. The study demonstrates that using clockwise bipartition inserts is an effective passive method for enhancing forced convection heat transfer in turbulent flow regimes. The use of Bakelite as an insert material provides high thermal resistance and successfully augments the heat transfer coefficient by over 80% across various heat inputs.

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