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Performance Analysis In Cross Flow Plate Fin Type Heat Exchanger

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***Abstract**: The compact heat exchanger refers to heat exchanger design in which large heat transfer surface area are provided in a small space as possible. The heat transfer surface area is increased by fins to increase the surface area per unit volume. The main reasons for the good performance of compact heat exchangers are their special design which includes turbulent which in turn use high heat transfer coefficient and resists fouling, and maximum temperature driving force between the hot and cold fluids. Plate fin heat exchangers form one of the main categories of compact heat exchangers designed to pack a high heat transfer capacity into small volume. The complexity of compact heat exchanger design equations results from the exchanger's unique ability to transfer heat between multiple process streams and a wide array of possible flow configurations. This research work is aimed to study the performance analysis in cross flow plate fin heat exchanger by determining the overall heat transfer coefficient, fin effectiveness, surface effectiveness and exchanger effectiveness using Water-Water system, Water- Carboxyl Methyl Cellulose (CMC) system (0.01, 0.05 and 0.1 %) and Water- Sodium Alginate (SA) system (0.01, 0.05 and 0.1 %) with various compositions on volume basis.*

***Keywords**: Overall heat transfer coefficient, surface effectiveness, exchanger effectiveness, Fin effectiveness, CMC and Sodium Alginate.*

I. INTRODUCTION

Heat exchangers used in cryogenic applications need to have very high effectiveness to preserve the refrigerating effect produced. Normally the heat exchangers used in liquefiers have the effectiveness of the order of 0.95 or higher. Heat Exchanger is process equipment designed for effective transfer of heat energy between two fluids (a hot fluid and a cold fluid). Many types of heat exchangers are used in industry, such as shell and tube, double pipe, compact heat exchangers etc, which vary both in application and design. Heat Exchangers may be classified according to their flow arrangement. In parallel flows, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flows the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. Simulation studies on cross flow heat exchanger were carried by using miscible systems. Steam is the hot fluid, whereas Water and Acetic acid-Water miscible solution serves as cold fluid. Performance analysis of cross flow heat exchanger was carried out. by using air as one of the fluid. An approximate method for transient behavior of finned tubes cross flow heat exchangers was discussed. In the present work, focus lies on the investigation on the performance analysis in heat exchanger by determining the overall heat transfer coefficient, fin effectiveness, surface effectiveness and exchanger effectiveness using Water-Water system, Water- Carboxyl Methyl Cellulose (CMC) system (0.01, 0.05 and 0.1 %) and Water- Sodium Alginate (SA) system (0.01, 0.05 and 0.1 %) in cross flow plate fin heat exchanger.

II. MATERIALS AND METHODS

A. Experimental Setup

The Plate fin heat exchanger, in which heat transfer studies are to be carried out, was fabricated with Aluminum as the material of construction. The basic element consists of two plates, a strip of corrugated sheet and edge- sealing bars. Here, instead of the edge sealing bars, the flat plate was folded on both sides thus providing an enclosure to the corrugations. The flat plates are termed as Primary surface and the corrugations as 'secondary surface'. The corrugations were welded to the flat plates. Figure 1 shows the schematic of cross flow plate-fin exchanger.

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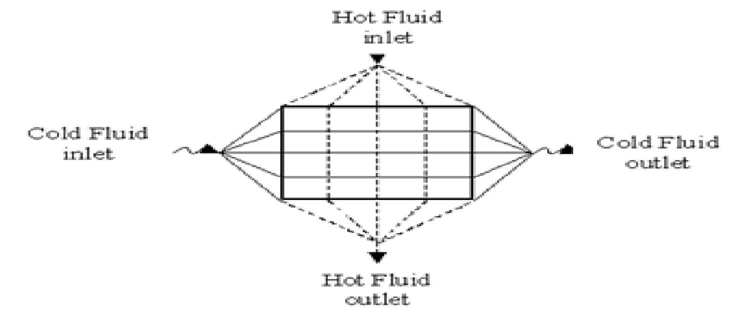

Figure1 Schematic Diagram of Cross Flow Plate Fin Heat Exchanger

B. Experimental Observations

The observations were made for the water-water system and varying the composition of Water -CMC solution system and Water-SA solution system are given in the following tables 1 and 2. The composition was taken based on volume.

Table 1 Water – Cmc System

Volumetric flow rate of cold fluid	Volumetric flow rate of hot fluid	Hot fluid		Cold fluid	
		Inlet	Outlet	Inlet	Outlet
Lpm	Lpm	ºC		ºC	
0.01%CMC-Water System					
2	4	120	90	26	48
3	4	120	88	26	47
4	4	120	87	26	47
5	4	120	87	26	46.5
6	4	120	87	26	46
0.05%CMC-Water System					
2	4	120	89	26	47
3	4	120	88.5	26	46.5
4	4	120	87.5	26	46
5	4	120	87	26	45
6	4	120	86	26	44
0.1%CMC-Water System					
1	4	120	87	26	54
2	4	120	86.5	26	53
3	4	120	85	26	52
4	4	120	85	26	51
5	4	120	84.5	26	50

Table 2 Water-Sa System

Volumetric flow rate of cold fluid	Volumetric flow rate of hot fluid	Hot fluid		Cold fluid	
		Inlet	Outlet	Inlet	Outlet
Lpm	Lpm	ºC		ºC	
0.01%SA-Water system					
2	4	31	46	60	51
3	4	31	43	60	50
4	4	31	41	60	49
5	4	31	40	60	48
0.05%SA-Water system					
2	4	31	44	60	52
3	4	31	42	60	50
4	4	31	41	60	48
5	4	31	39	60	47
0.1%SA-Water System					
2	4	31	43	60	52
3	4	31	41	60	53
4	4	31	40	60	50
5	4	31	38	60	48

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III.RESULTS AND DISCUSSION

A. Graphical Analysis

The performance characteristics of cross flow plate fin type heat exchanger for water-CMC and water-SA systems with different compositions are summarized in above tables 1 & 2. The overall heat transfer coefficients, surface temperature effectiveness, fin temperature effectiveness of cold and hot fluid and exchanger effectiveness are represented with respect to Reynolds's number of cold and hot fluid.

Overall Heat transfer coefficient Vs Reynolds number The Reynolds Number for different compositions of CMC and SA is plotted against Overall Heat transfer coefficient to find the effect of varying flow rate, composition of non-Newtonian fluid in figures 2 to 5.

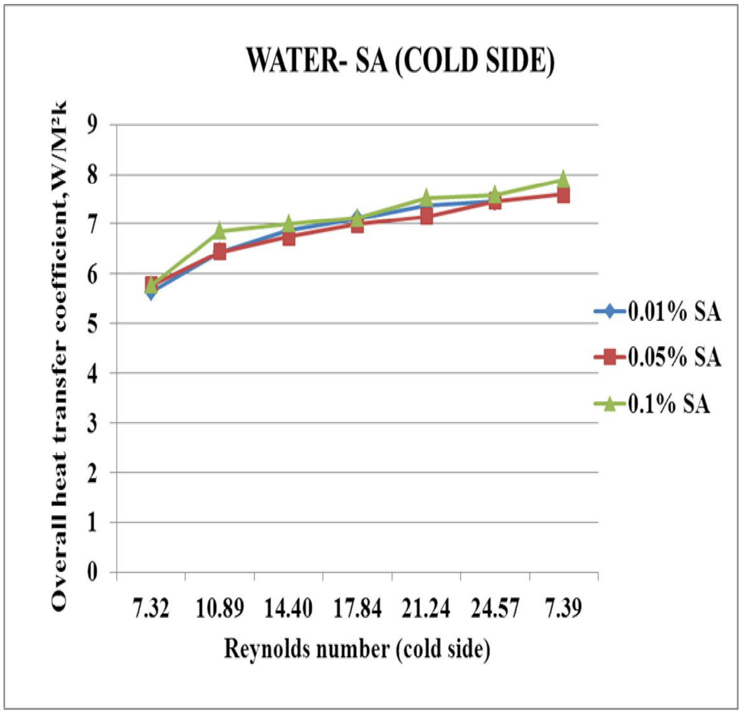

Figure 2 Overall Heat transfer coefficient Vs Reynolds number (cold side) for water – SA system

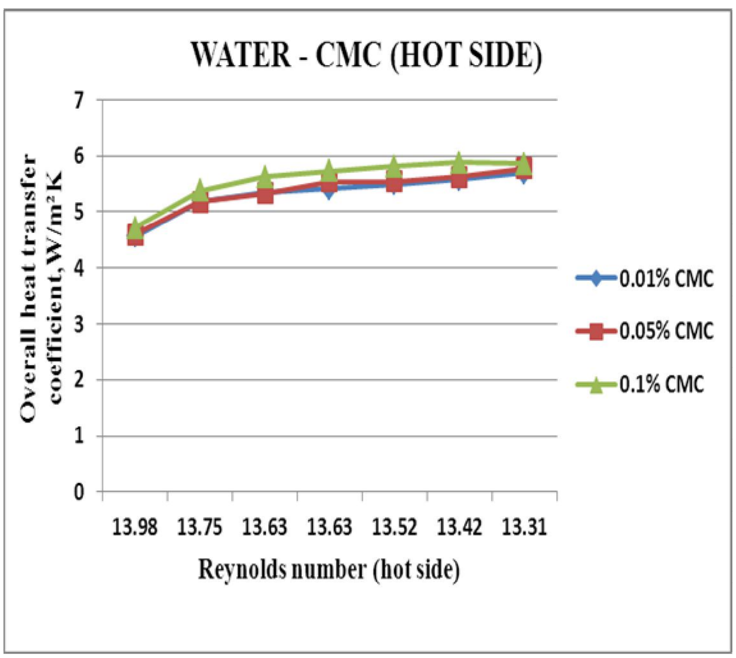

Figure 3 Overall Heat transfer coefficient Vs Reynolds number (hot side) for Water-CMC system

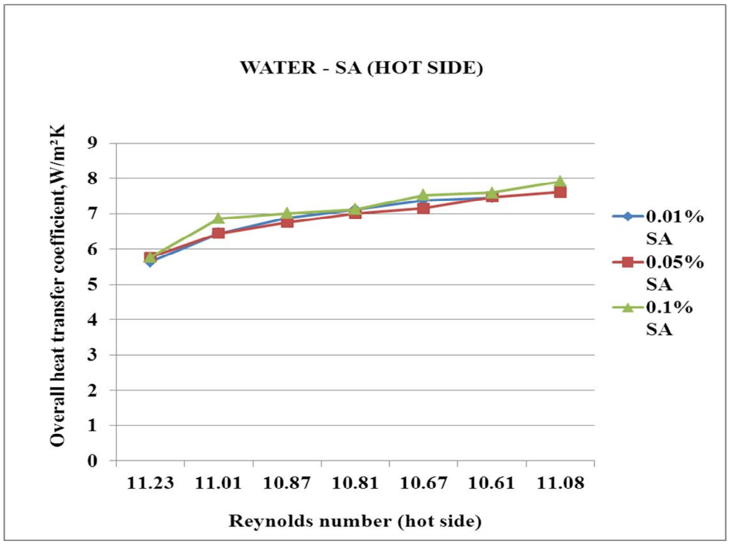

Figure 4 Overall Heat transfer coefficient Vs Reynolds number (hot side) for Water-SA system

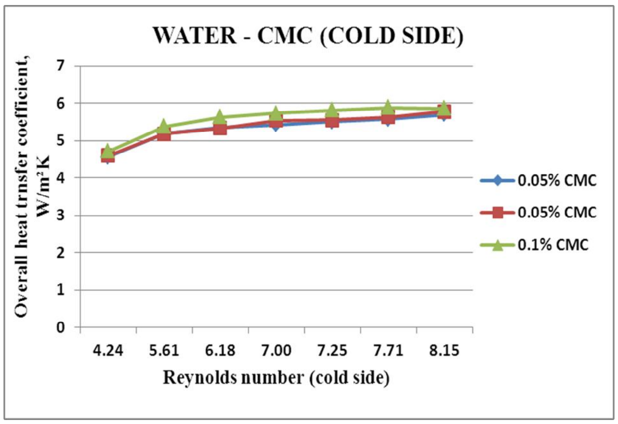

Figure 5 Overall Heat transfer coefficient Vs Reynolds number (cold side)for Water-CMC system

B. Fin Effectiveness vs Reynolds Number (Cold)

The variation of Reynolds Number (cold) for different composition of CMC and SA on fin temperature effectiveness to indicate effect of flow rate and composition of non-Newtonian fluid in figures 6 to 9.

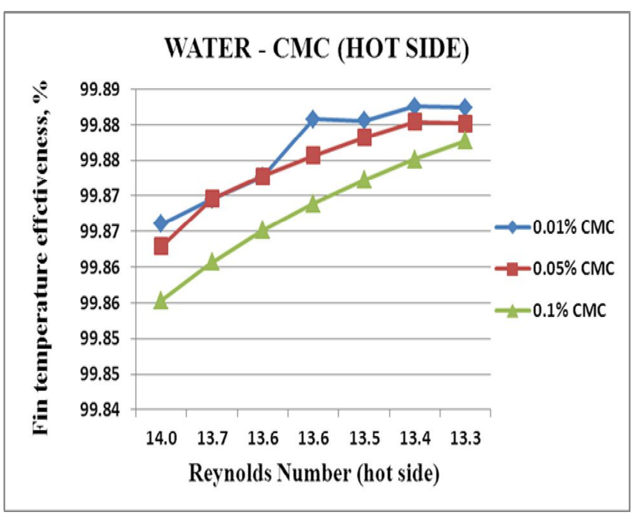

Figure 6 Fin effectiveness Vs Reynolds number(hot side) for Water-CMC system

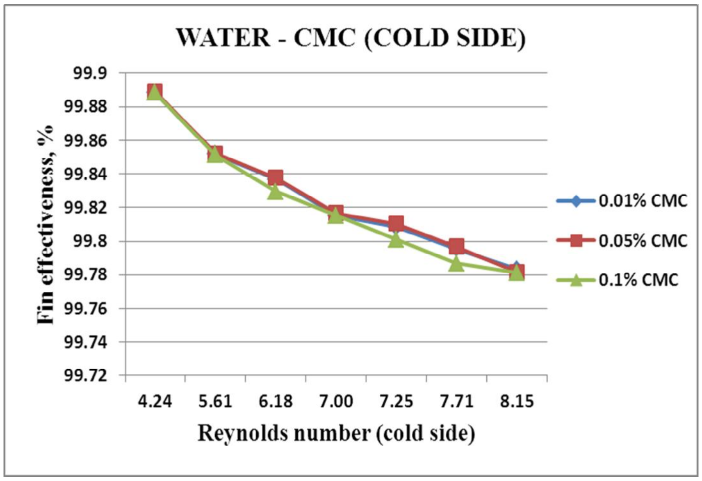

Figure 7 Fin effectiveness Vs Reynolds number(cold side) for Water-CMC system

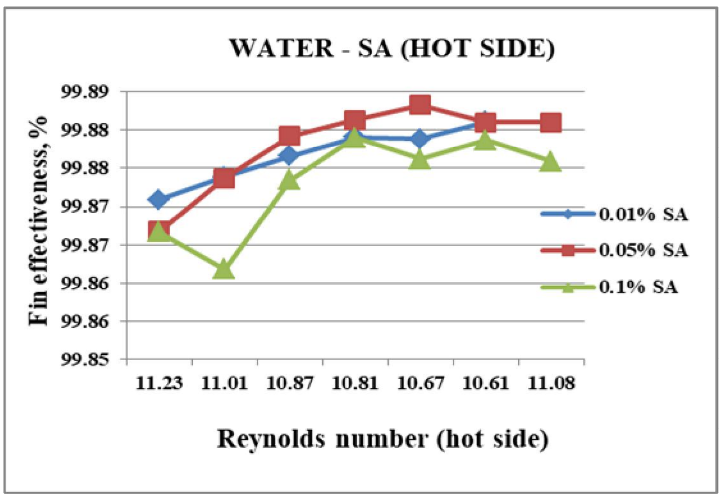

Figure 8 Fin effectiveness Vs Reynolds number(hot side) for Water – SA system

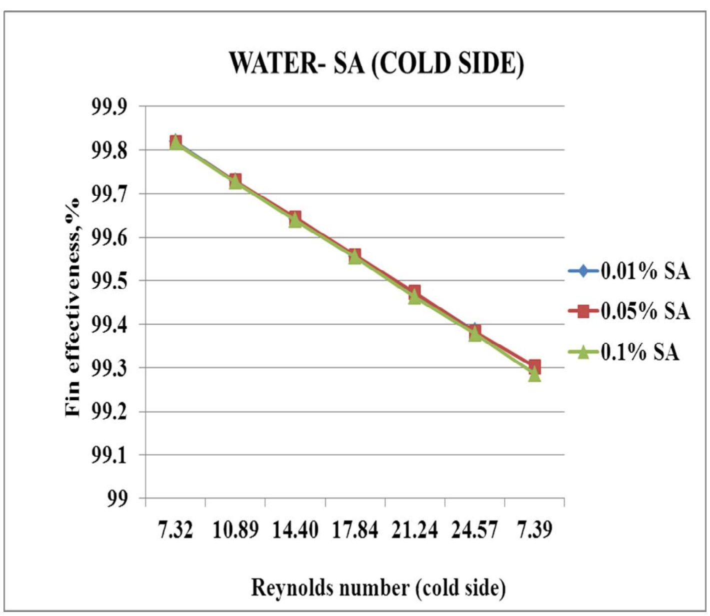

Figure 9 Fin effectiveness Vs Reynolds number(cold side) for Water – SA system Surface Effectiveness vs ReynoldsNumber

The variation of Reynolds Number for different composition of CMC and SA (hot and cold side) on fin temperature effectiveness to indicate effect of flow rate and composition of non-Newtonian fluid in figures 10 to 13.

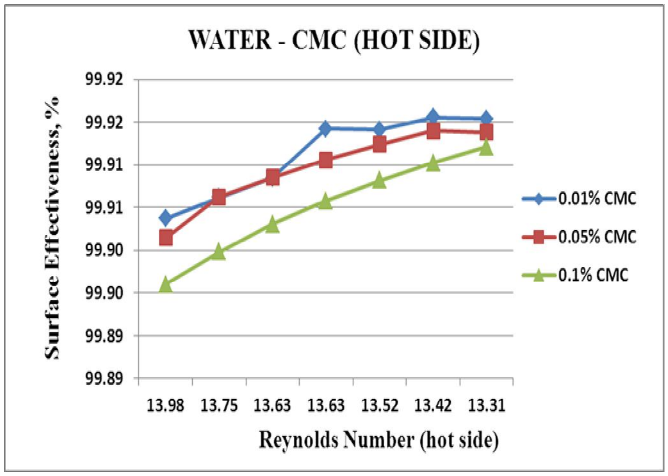

Figure 10 Surface effectiveness Vs Reynolds number(hot side) for Water – CMC system

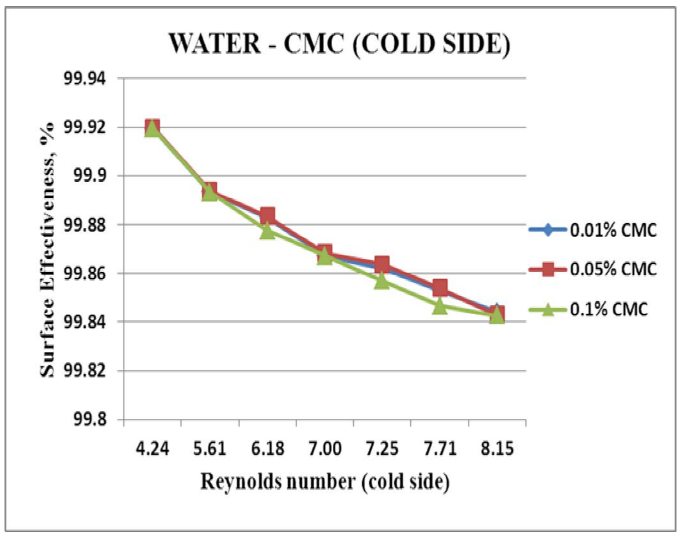

Figure 11 Surface effectiveness Vs Reynolds number(cold side) for Water – CMC system

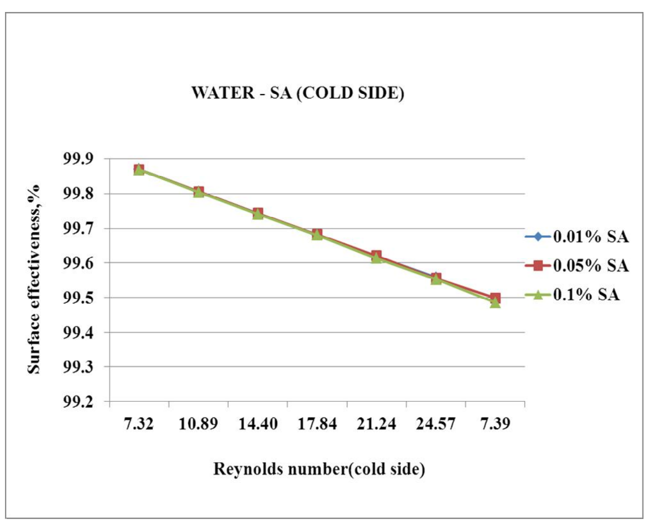

Figure 12 Surface effectiveness Vs Reynolds number(cold side) for Water – SA system

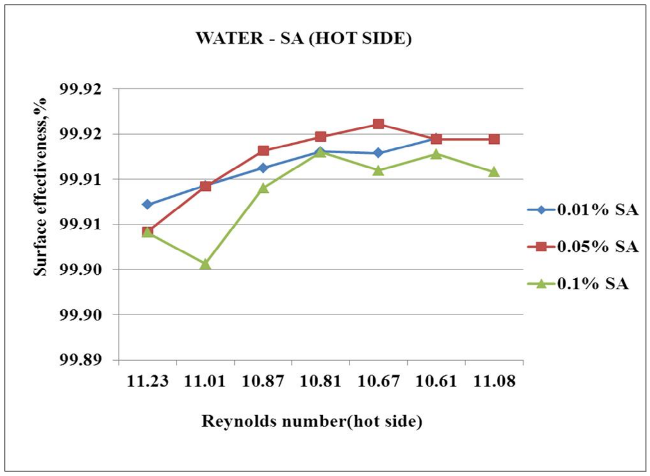

Figure 13 Surface effectiveness Vs Reynolds number(hot side) for Water – SA system

C. Exchanger Effectiveness Vs Reynoldsnumber

The variation of Reynolds Number for different composition of CMC and SA (hot and cold side) on Exchanger effectiveness to indicate effect of flow rate and composition of non-Newtonian fluid in figures 14 to 17.

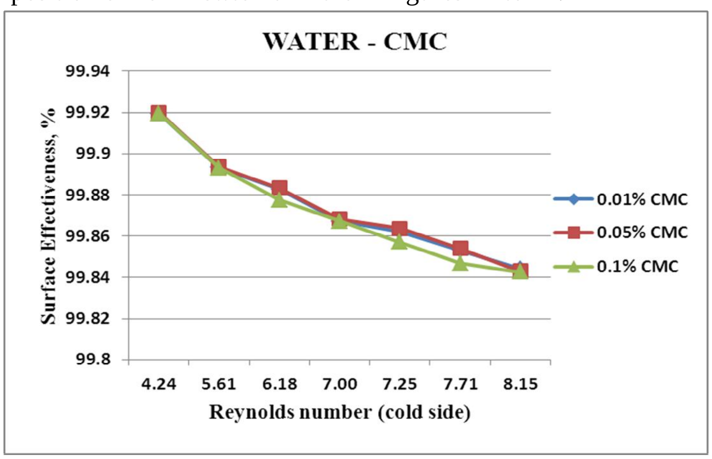

Figure 14 Exchanger effectiveness Vs Reynolds number (cold side) for Water – CMC system

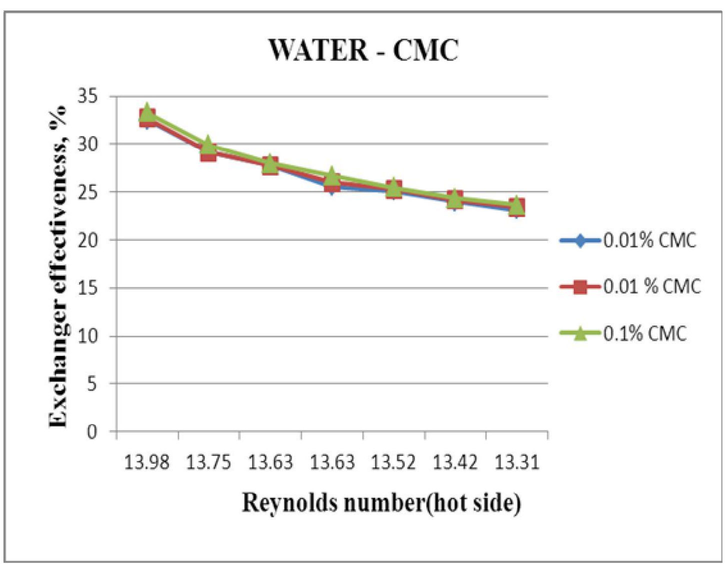

Figure 15 Exchanger effectiveness Vs Reynolds number (hot side) for Water – CMC for system

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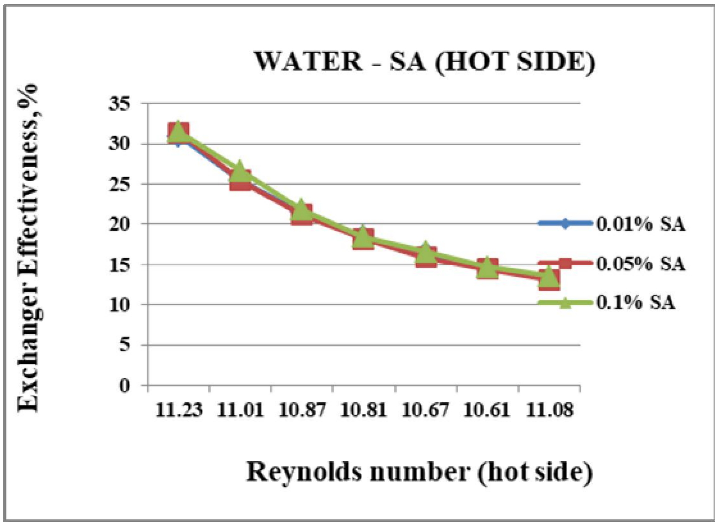

Figure 16 Exchanger effectiveness Vs Reynolds number(hot side) for Water – SA for system

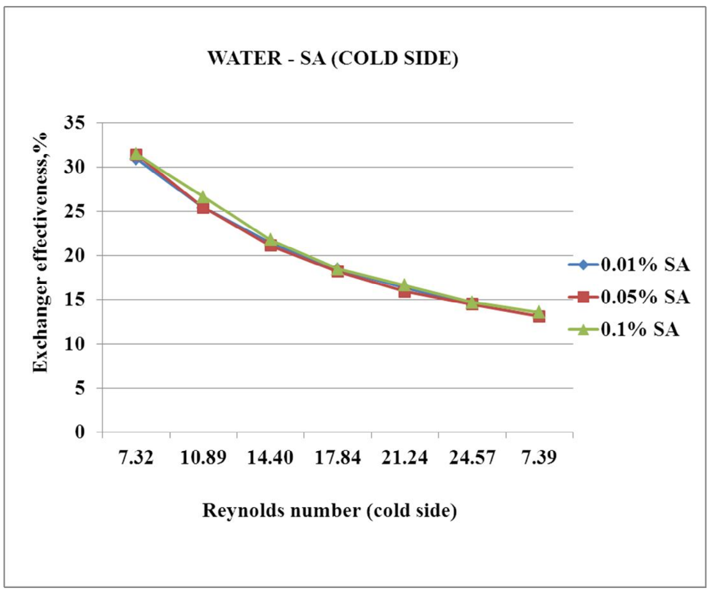

Figure 17 Exchanger effectiveness Vs Reynolds number(cold side) for Water – SA for system

D. Comparison of CMC and SA

Figure 2 to 18 .shows plot between Nusselt Number experimental vs Reynolds Number for base fluid-water system, 0.01%nanofluid system, 0.05% nanofluid system for parallel and counter flow. It clearly shows that Sodium Alginate has higher Nusselt Number for a particular Reynolds Number compared to CMC. For Water-SA system system as Reynolds number decreases with individual heat transfer coefficient, also decreases for (hot side) and Reynolds Number increases with individual heat transfer coefficient also increases for (cold side).

E. Comparison with respect to Effectiveness

The effectiveness of the cross flow plate fin heat exchanger was calculated for water-cmc and water- sa on various compositions. The effectiveness of the WATER-CMC system for (hot side) marginal value is higher than that of WATER-SA system for (hot side) and the effectiveness decreases with decreases in reynolds number and increases with increases in concentration of Non-Newtonian fluids.

Exchanger effectiveness decreases with increases in reynolds number for WATER-CMC system in cold side.

Exchanger effectiveness decreases with reynolds number increases for WATER-SA system in cold side.

Exchanger effectiveness decreases with reynolds number decreases for WATER-SA system in hot side.

From the above performance analysis, it clearly shows that carboxy methyl cellulose has higher exchanger effectiveness for particular reynolds number compared to SA.

IV. CONCLUSIONS

The experiments have been conducted on a cross flow plate fin heat exchanger with different mass flow rate and compositions 0.01%, 0.05% and 0.1% for Water-CMC and Water-SA systems on volume basis of cold fluid to study the performance of cross flow plate fin heat exchanger. The effect of mass flow rate of cold fluid and compositions on the cold outlet temperature, hot outlet temperature, Individual and overall heat transfer coefficients, fin temperature effectiveness, total surface temperature effectiveness, exchanger effectiveness are also studied.

From the performance analysis, following conclusions are made.

A. It can also be observed that for a given Reynolds number, the heat transfer coefficient decreases with increase in non-Newtonian fluid concentration

B. Finally, Carboxy Methyl Cellulose shows better exchanger effectiveness compared to that of Sodium Alginate.

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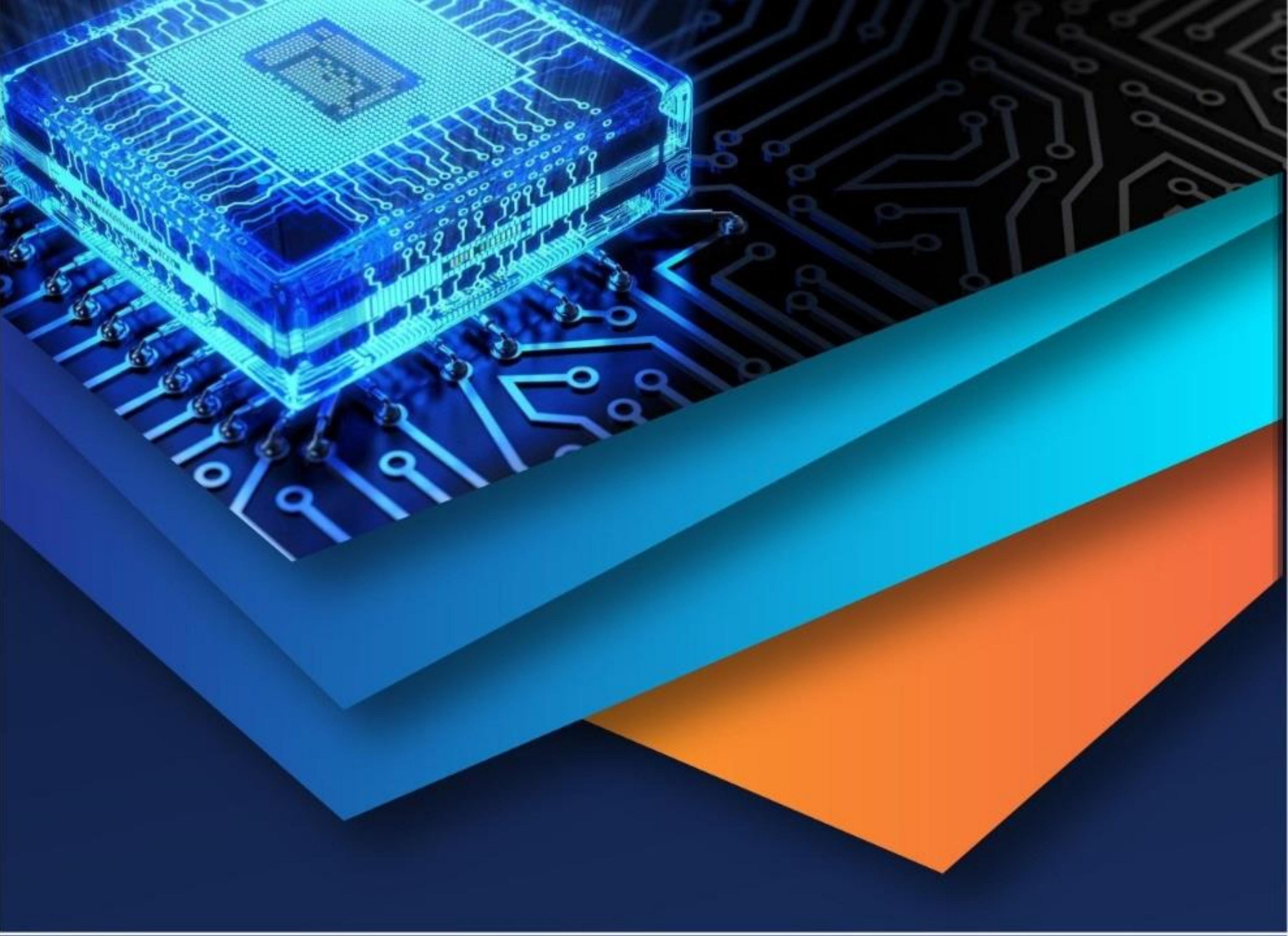

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