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Analysis on Effectiveness of a Plate Type Heat Exchanger by CFD using Sea Water and Engine Oil

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***Abstract*—There is a wide utilization of Plate heat exchanger in the field of marine, dairy and other modern applications for its improved heat exchange attributes and conservative structure. Compact heat exchangers are most broadly utilized for heat transfer applications in ventures. Plate type heat exchangers are generally utilized for liquid-to-liquid heat transfer applications with high-density working fluids. This study is focused on the use of plate type heat exchanger for seawater and engine oil as the working fluids. This examination work manages examination of the plate-type heat exchanger with an assessment of convective heat transfer coefficient, overall heat transfer coefficient, exchanger effectiveness, output temperatures of the fluids. The enhancement of this work is finished by taking Low, medium and high Reynolds number and furthermore K-Epsilon turbulence. Completing this work comprises of thin metal welded plates of Titanium with 7mm thickness, rectangular geometry, and separation between two plates is 1mm. Tests are led by changing working parameters like mass flow rate, inlet temperatures of hot & cold fluids. The principal target of this work is to discover impacts of these parameters on the execution of performance of plate heat exchanger with parallel flow arrangement and to find the maximum effectiveness. The maximum effectiveness achieved in this analysis is 0.61. Utilization of plate type heat exchanger is more profitable than the tube type heat exchanger with the same adequacy, as it involves less space. The analysis was done using ANSYS 12 CFD methodology. Distinctive parameters are figured from the outcomes acquired and diagrams are plotted between different parameters. These charts have been investigated and talked about to discover the ideal outcome for which the plate Heat exchanger would give the best execution.**

***Index Terms*— Convective heat transfer coefficient, Effectiveness, Overall heat transfer coefficient, Plate heat exchanger, Reynolds number.**

I. INTRODUCTION

A heat exchanger may be defined as an equipment which transfers the energy from a hot fluid to a cold fluid, with greatest rate and least venture and running expense. The rate of exchange of heat relies on upon the conductivity of the dividing wall and convective heat transfer coefficient between the wall and fluids. A plate heat exchanger is a compact type of heat exchanger that uses metal plates to transfer heat between two fluids. This encourages the transfer of heat and greatly increases the speed of the temperature change [1]. Plate heat exchangers have a characteristic of higher turbulence. Such high turbulence results in a higher convection that leads to efficient heat transfer between the media [2]. It therefore means that there will be a higher heat

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transfer coefficient per unit area making the whole operation efficient. Research has shown that, when the plate has a wider pattern, the pressure drop is smaller and consequently the heat transfer coefficient will be smaller. This type of heat exchanger will therefore have a short thermal channel [3]. However, when two plates subjected to different pressing patterns are placed next to each other, the result is a mixture of characteristics of short and long channels as well as mixed characteristics in pressure drop and effectiveness. In numerous applications like power plants, petrochemical industries, air conditioning etc. heat exchangers are used. Plate heat exchanger is for the most part utilized as a part of dairy industry due to its ease of cleaning and thermal control. The plate heat exchangers are worked of thin metal heat transfer plates and pipe work is used to carry streams of fluid. Plate heat exchangers are generally utilized as a part of the liquid to liquid heat transfer and not appropriate for gas to gas heat transfer due to high pressure drop [4].

This paper focuses on effectiveness and overall heat transfer coefficient of plate heat exchanger for one pass one arrangement and Engine oil – seawater as the working fluids. Large size engines (normally diesel engines) are used in ships for propulsion and electricity generation. These large engines are having different systems, like the water system, lube oil system, fuel oil system, starting air system etc. Different types of heat exchangers play important roles for controlling temperatures of these different systems. So from over coming this problem we are using sea water and engine oil in the compact plate type heat exchanger to control the temperature of those systems.

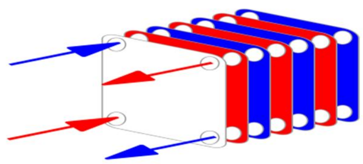


Fig.1 Flow direction of fluids

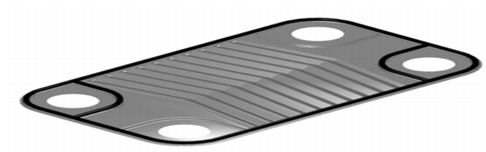


Fig.2 Plate of the heat exchanger

A. Problem Statement

Till now many studies have been done using both experimental and numerical analysis based on working fluid (water/water) which has small viscosity compared to other types of fluid [5]. In order to investigate more, fluid with higher viscosity should be used to observe the outcome of heat transfer performance [6]. By using CFD simulation, the performance of plate heat exchanger can be optimized and at the same time, it can reduce the operation cost and time when using experimental analysis [7].

B. Aim of present work

The aim of this work is to determine the heat transfer characteristics of a plate type Heat Exchanger by varying reynold's number as low, medium & high with the addition of K-ε turbulence. This research work deals with the investigation with evaluation of convective heat transfer coefficient, overall heat transfer coefficient, exchanger effectiveness, Output temperature of the fluids. An Examination has been done for Parallel flow heat exchanger utilizing ANSYS 12 programming. The effectiveness should be calculated and the different contour plots and graphs will be plotted.

II. Material selection & Methodology adopted:

The plate material for the Plate type Heat Exchanger is taken as "**Titanium**". As Titanium have high corrosion resistance capacity so it will be withstand in the plate Heat Exchanger. The material is of grade 5, also known as Ti6AI4V (or) Ti – 6 – 4, is the most commonly used alloy. It is fundamentally more grounded than commercially pure titanium while having the similar stiffness and thermal properties. This review is an incredible blend of quality, consumption protection, weld, and texture capacity. The composite is completely treatable in area sizes up to 15mm and up to around 400℃.

Basically, there are two types of fluids are to be present, one should be hot and another should be cold. As this research work is to cool the Engine oil which is generally used in the engines for cooling and lubricating purpose so the hot fluid is taken as – Engine oil (SAE 15W-40) and the cold fluid is taken as sea water.

A. K – ε Turbulence Model:

K-epsilon (k-ε) turbulence demonstrate is the most widely recognized model utilized as a part of Computational Fluid Dynamics (CFD) to reenact mean stream attributes for turbulent stream conditions. It is a two-condition show which gives a general portrayal of turbulence by methods for two transport conditions (PDEs). The first catalyst for the K-epsilon show was to enhance the blending length demonstrate, and to locate an other option to logarithmically endorsing turbulent length scales in direct to high many-sided quality streams.

TABLE I. PROPERTIES OF ENGINE OIL AND SEA WATER

Properties Name	Engine oil		Sea water	
	90℃	40℃	20℃	30℃
Dynamic Viscosity(NS/ m^2)	0.014588	0.091057	0.00108	0.00086
Density (g/ cm^3)	0.8352	0.8684	1025	1022
Thermal conductivity (w/mk)	0.1425	0.1321	0.596	0.6
Specific Heat(kj/kg k)	2.901	1.901	4.007	4.001

III. EXPERIMENTAL DETAILS AND MEASUREMENTS

First of all, we will design the heat exchanger as per the parameters which we have taken. We set the material thermal properties and give the respective conditions for the inlet and outlet. We design the heat exchanger in such way that if the hot fluid is entering to it by the 1st plate then it will not touch the 2nd plate, it will again go to the 3rd plate, similarly, the cold fluid will entering to it in the 2nd, 4th and so on. The inlet temperature of cold fluid is taken as 293k and for hot fluid 363.15k. Then we apply the boundary conditions and apply the K-epsilon turbulence. For the different values of reynold's number, we have calculated the required parameters and plot the contour plots for each fluid. Then finally we plot the graphs between the parameters to come to the conclusion and lastly, we see that how much effectiveness value we have got.

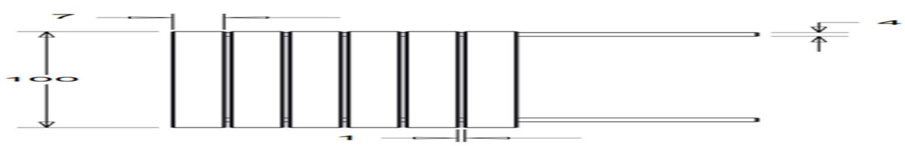


Fig.3 Plate type Heat Exchanger Modeling in 2-D

Fig 4. Mesh model and CAD model of plate type heat exchanger

The results obtained from the CFD analysis are given in the tables below:

TABLE II. LOW MASS FLOW FOR COLD AND HOT FLUID

Water inlet (Kg/sec)	**Water inlet temp(K)**	**Water outlet temp (K)**	**Reynolds number water**	**htc(cold) (w/m^2k)**	**Nu(cold)**	**Overall U**	**L.M.T.D**
0.001	293	328.15	752	229.758	1.54	90.98	4.344
0.0015	293	328.15	1171	297.313	1.99	100.12	4.344
0.002	293	328.15	1602	358.831	2.41	102.04	4.344
0.0025	293	328.15	2040	415.879	2.79	126.58	4.344
0.003	293	328.15	2486	469.264	3.14	149.25	4.344

Engine oil (Kg/sec)	**Engine oil inlet temp(K)**	**Engine oil outlet temp(K)**	**Reynolds number Engine oil**	**htc (hot) (w/m^2k)**	**Nu(hot)**	**Overall U**	**L.M.T.D**
0.009	363.15	328.15	464	140.498	3.77	90.98	4.344
0.0095	363.15	328.15	492	145.04	3.89	100.12	4.344
0.01	363.15	328.15	520	149.519	4.01	102.04	4.344
0.015	363.15	328.15	807	192.369	5.16	126.58	4.344
0.02	363.15	328.15	1102	231.487	6.21	149.25	4.344

TABLE III. MEDIUM MASS FLOW FOR COLD AND HOT FLUID

Water inlet (Kg/sec)	Water inlet temp(K)	Water outlet temp (K)	Reynolds number water	htc(cold) (w/m^2k)	Nu(cold)	Overall U	L.M.T.D
0.01	293	328.15	9079	1035.97	6.95	370.31	4.344
0.02	293	328.15	18764	1577.34	10.58	526.31	4.344
0.03	293	328.15	28491	1982.35	13.34	641.21	4.344
0.04	293	328.15	37119	2862.83	19.21	907.44	4.344
0.05	293	328.15	46439	3730.86	25.03	1020.42	4.344

Engine oil (Kg/sec)	Engine oil inlet temp(K)	Engine oil outlet temp(K)	Reynolds number Engine oil	htc (hot) (w/m^2k)	Nu(hot)	Overall U	L.M.T.D
0.1	363.15	328.15	9079	680.293	18.26	370.31	4.344
0.2	363.15	328.15	18764	1062.11	28.51	526.31	4.344
0.3	363.15	328.15	28491	1355.12	36.37	641.21	4.344
0.4	363.15	328.15	37119	1964.93	52.74	907.44	4.344
0.5	363.15	328.15	46439	2551.15	68.48	1020.42	4.344

TABLE IV. HIGH MASS FLOW FOR COLD AND HOT FLUID

Water inlet (Kg/sec)	Water inlet temp(K)	Water outlet temp (K)	Reynolds number water	htc(cold) (w/m^2k)	Nu(cold)	Overall U	L.M.T.D
0.06	293	328.15	55858	4143.97	27.81	1086.95	4.344
0.07	293	328.15	65652	4314.61	28.95	1109.87	4.344
0.08	293	328.15	74697	4953.96	33.24	1206.27	4.344
0.09	293	328.15	84117	5352.12	35.92	1260.61	4.344
0.1	293	328.15	93538	5746.54	38.56	1281.31	4.344

Engine oil (Kg/sec)	Engine oil inlet temp(K)	Engine oil outlet temp(K)	Reynolds number Engine oil	htc (hot) (w/m^2k)	Nu(hot)	Overall U	L.M.T.D
0.6	363.15	328.15	39043	2817.56	75.63	1086.95	4.344
0.7	363.15	328.15	45901	2921.02	78.41	1109.87	4.344
0.8	363.15	328.15	52251	3328.86	89.36	1206.27	4.344
0.9	363.15	328.15	58854	3580.01	96.12	1260.61	4.344
1	363.15	328.15	65457	3829.52	102.8	1281.31	4.344

TABLE V. NTU AND EFFECTIVENESS VALUES

Low Mass flow		Medium Mass flow		High Mass flow	
Effectiveness	NTU	Effectiveness	NTU	Effectiveness	NTU
0.01	0.2	0.42	0.99	0.55	0.23
0.12	0.21	0.45	1	0.56	0.24
0.24	0.22	0.48	1.8	0.6	0.3
0.3	0.235	0.509	1.9	0.601	3.2
0.38	0.41	0.52	2	0.61	4

IV. ANALYSIS OF RESULTS

Now we will plot the graphs between the parameters to see what the graphs show (in case of low mass flow). So from the graphs (fig 5 and fig 6), we observe that the overall heat transfer coefficient increases with the change in reynolds number. Then heat transfer coefficient increase constantly and then increases high with an increase in reynolds number.

Now from the graphs (fig 7 and fig 8), we observe that Overall heat transfer coefficient increases gradually and then increase suddenly high with an increase in heat transfer coefficient. Again we see that the nusselt number also increase as like same with the increase in Overall heat transfer coefficient.

From the graph (fig 9) we see that heat transfer value increases with increase in mass flow rate.

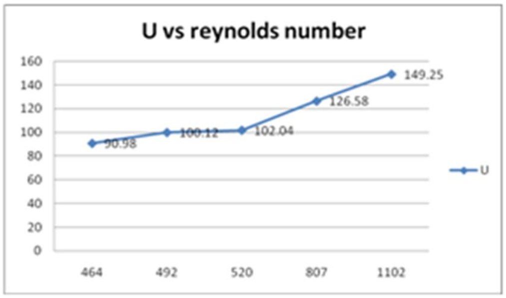


Fig.5 Graph between U Vs Reynolds No.

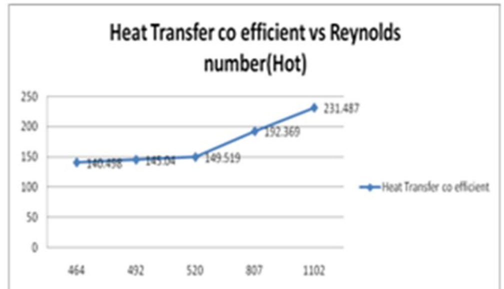


Fig.6 Graph between Htc Vs Reynolds No

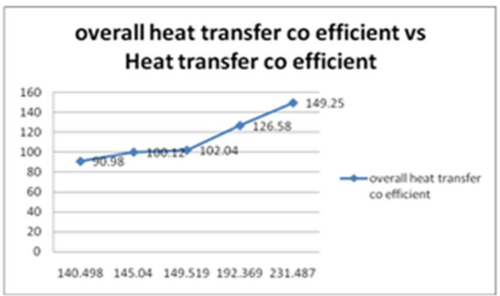


Fig.7 Graph between U Vs htc

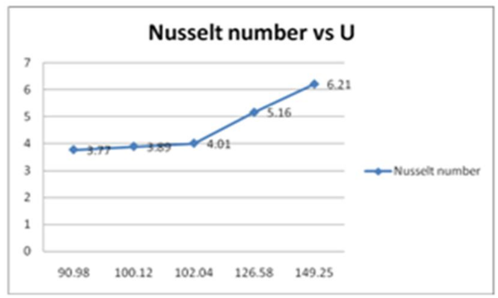


Fig.8 Graph between Nusselt No. Vs U

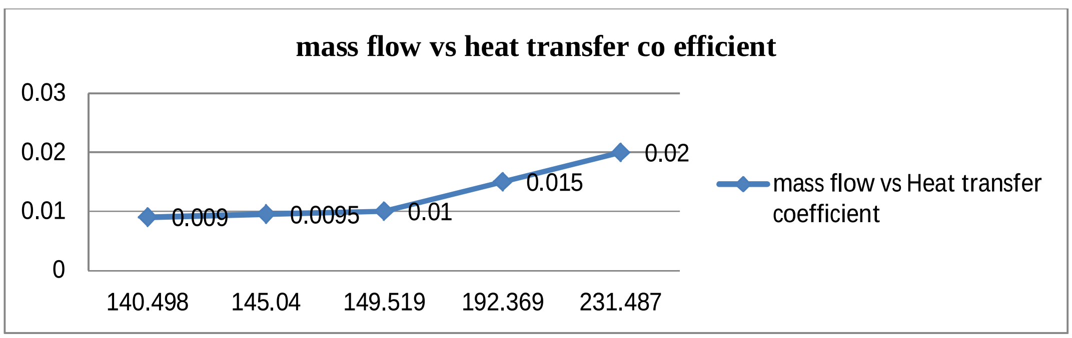


Fig.9 Graph between mass flow Vs heat transfer coefficient

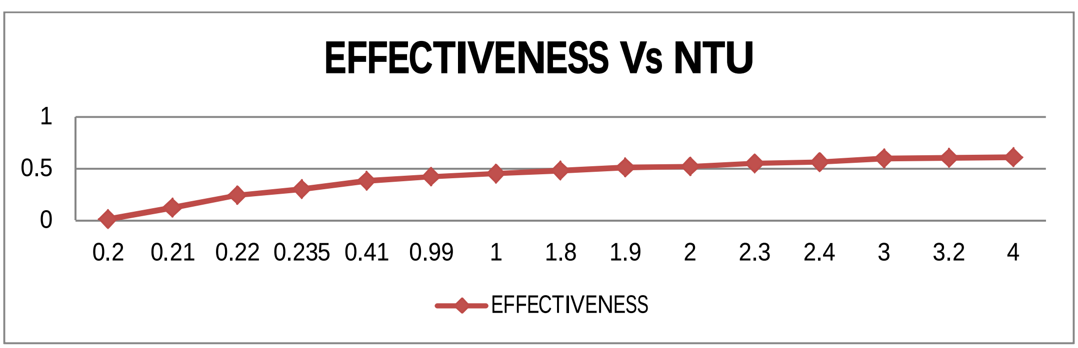
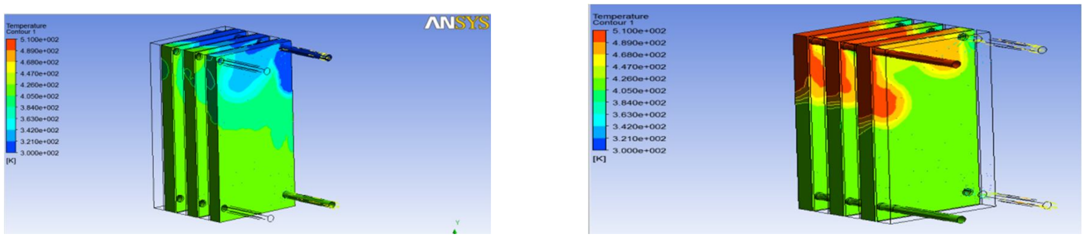


Fig.10 Overall Effectiveness Vs NTU graph

So from the above graph we see that the effectiveness values changes gradually when there is change in NTU values. The maximum effectiveness value achieve in this experiment as 0.61.



(For cold fluid) (For hot fluid)

Fig.11 Temperature contours plots from the simulation

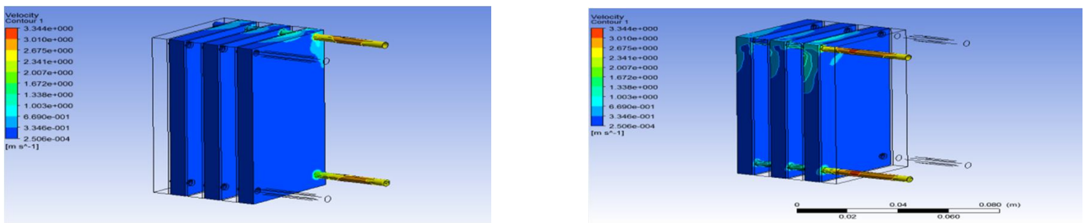


Fig.12 Velocity contours plots from the simulation

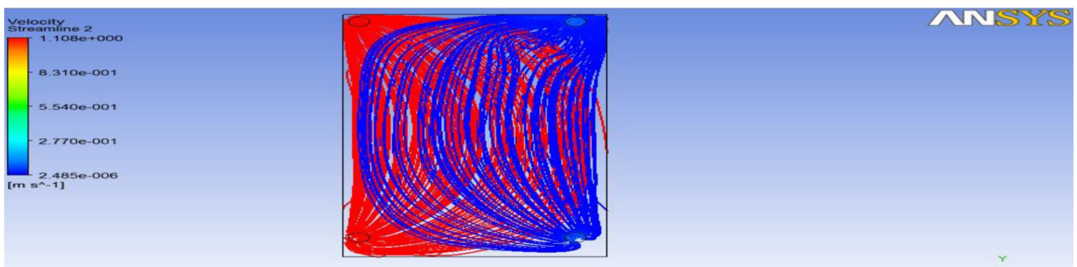


Fig.13 Velocity stream lines

The above figures are the Temperature & velocity contour plots with the velocity stream lines.

V. Conclusions

The following conclusions are drawn from the above experiment.

- The heat transfer co efficient increases with Reynolds number. Increase of Reynolds number indicates that flow is becoming more turbulent and results into higher heat transfer rates.
- Increase in mass flow rate results in increase in flow velocity so, Reynolds number increase which ultimately increases in heat transfer.
- "U" increases when Reynolds number increases, because U is directly related to h so, higher heat transfer rates.
- The nusselt number is a function of Reynolds number so, the nusselt increases with increases of overall heat transfer coefficient.
- Convective heat transfer coefficient increases with increase in mass flow rate, also overall heat transfer coefficient increases with increase in Reynolds number.
- The Effectiveness of heat exchanger changes slightly when there is a change in heat capacity ratio.
- The maximum effectiveness found in this analysis is 0.61

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