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EXPERIMENTAL INVESTIGATION ON SHELL AND STRAIGHT PIPE WARMTH EXCHANGER WITH PARAMETER AND VALIDATE THE RESULT WITH TAGUCHI METHOD

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Abstract- From the beginning of human advancement, warmth and work are two significant variables influencing the development of any ventures. Warmth interchanger assume significant function for warmth and work association. Warmth trade starting with one medium then onto the next has been a significant piece of numerous cycles. This has been done either by direct warmth move additionally called recuperator, where two media trade Warmth between one another with no division, or by backhanded warmth move where the warm medium exchanges its warmth through a material that isolates it from the cool medium it might be equal, counter and in cross stream. For these reasons, Warmth exchangers are broadly utilized in the present business and they exist in different structures and sizes to fit the wide scope of their applications. This paper deals with result outcome in terms of log mean temperature difference, rate of Warmth transfer and effectiveness with varying mass pace rate, inlet warm and cold fluid temperature.

Keywords: Effectiveness, Log Mean Temperature Difference, Mass Pace Rate, Parallel and Counter Pace, Warm and Cold Inlet Fluid Temperature.

1. INTRODUCTION

The growth in population, the emergence of new materials and packaging culture, the emergence of socio-economic activities, and changes in lifestyle and consumption, have greatly favored urban waste generation [11]. Nature gives an ultimate gift "Energy" in terms of petroleum product either Solid (Coal), Liquid (crude oil) and gas (Natural gas etc.). But due to development of modern science and unexpected growth of population, this gift is lost due to limited source [3]. An electricity is a source increasing in the recent times due to the rapid growth of industry and population, at the same time the price of electricity is constantly increased [12] at the same time heat is an important factor for the growth of any industry, the cost of heat is one of the parameters that directly added into profit or loss in company [9]. The heat transfer take trim because of conduction by liquid is moving through a close by strong divider [6].

Warmth exchanger or warmth interchanger are the equipment that work like a platform for exchanging Warmth from waste Warmth reservoir and transfer to the fresh Warmth reservoir system. The transformation facilitates the transmission, storage, and control of energy [5]. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multicomponent fluid streams [1].

A number of classifications available, according to the demand of industrial needs. Shell and straight pipe warmth interchanger are most versatile type of warmth interchanger due to their simple design and fabrication, installation easy and due to straight pipe, clean of pipes are required less time, labor work and inventories. The base is designed to ensure stability of the full system [7]. This type of warmth interchanger is used in area where high TDS mixed with warm exhaust fluids and scaling is a big problem like waste Warmth recovery system, power plants, chemical industries etc. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multicomponent fluid streams [2], and the next application is a heat recovery, Heat recovery is also called co-generation system from where heat can be utilized in other area [4].

2. LITERATURE REVIEW

2.1. M. Gangil, A.K. Singh (2019)

From the beginning of human advancement, warmth and work are two significant variables influencing the development of any enterprises. Warmth exchanger assume significant function for warmth and work connection. Warmth trade starting with one medium then onto the next has been a significant piece of numerous cycles. This has been done either by direct warmth move additionally called recuperator, where two media trade Warmth between one another with no partition, or by roundabout warmth move where warm medium exchanges its warmth through a material that isolates it from the chilly medium it could be equal, counter and in cross stream. For these reasons, Warmth exchangers are broadly utilized in present business and they exist in different structures and sizes to fit wide scope of their applications.

One of the issues happens for usage of warmth exchanger is fouling. The impacts of fouling are increment Warmth misfortune and decreased energy proficiency of the framework. Truth be told, any warmth move measure has a danger of fouling on the warmth move surface. The fouling can at times be cleaned actually, artificially or consumed off; in different cases it may not be conceivable to clean the warmth exchanger and another one will be required. For those warmth exchangers that are cleaned there is typically just a specific number of times that they can be cleaned before new ones will be required. Albeit early fouling discovery might not significantly affect the lifetime of warmth exchangers it can help in forestalling the circumstance where their proficiency turns out to be low to the point that it influences the cycle the warmth exchanger is utilized in, bringing about diminished economy of activity.

2.2. V. Stephenraj, M.K. Sathishkumar (2018)

Warmth exchanger as the name shows it moves Warmth starting with one liquid then onto the next which are at various temperatures. Warmth exchangers are gadgets worked for productive warmth move starting with one liquid then onto the next and are broadly utilized in designing cycles. A few models are intercoolers, pre-warmers, boilers and condensers in power plants. The warmth move proficiency relies upon both plan of warmth exchanger and property of working liquid. Some significant plan boundaries, for example, the pitch proportion, pipe length, and cylinder layer just as bewilder separating. In this venture, the warmth move effectiveness is improved by actualizing the full perplex plan and travel pipe plan and breaking down it through CFD stream recreation to locate the estimated Warmth move rates. From the recreation results the ideal astound plan and travel pipe plan for most extreme warmth move rate is recognized. Likewise, this undertaking manages locate the appropriate liquid for greatest warmth move rate.

2.3. D. Bogale (2014)

A warmth exchanger is a gadget that is utilized to move warm energy (enthalpy) between at least two liquids, between a strong surface and a liquid, or between strong particulates and a liquid, at various temperatures and in warm contact. From various sorts of warmth exchangers, the shell and cylinder Warmth exchangers with straight cylinders and single pass is to be under investigation. Here the upgrade happens due to temperature vacillation at the ninth zone of the pasteurizer in the Harar Brewery Company. Warm and mechanical plan is run to upgrade the yield temperature of the cool liquid at the last warmth exchanger in which it is splashed on the lager prepared for client use.

In warm plan part math advancement is done through experimentation. What's more, for Mechanical plan part the normal frequency& vortex shedding of various segments of warmth exchangers are explored through overseeing conditions of vibrations under powerful liquid with in pipes. Utilizing computational liquid elements (CFD) the warmth move of the two liquid is researched utilizing FEM re-enactment programming's Gambit1.3 and Fluent6.1 and the presentation of the STHEx decided regarding factors, for example, pressure, temperature, stream rate, energy input/yield, mass stream rate and mass exchange rate that are specifically compelling in STHEx investigation.

3. METHODOLOGY AND FORMULATION

For the validation of experimental result, Taguchi method used; similarly, for design and calculation, a text book Warmth transfer 5th edition by Y.A. Cengel and A.J. Ghajar and Warmth and Mass Transfer by R.K. Rajput refer.

Secondly a Handbook of Heat Transfer by W.M. Rohsenow, J.P. Hartnett, Y.I. Cho, Volume 3, Mc Graw Hill publication used for tables of content and specification and formula used.

The formula used is as the following:

- Rate of Warmth Transfer as specific heat

$$Q = m_1 c_1 (T_{warm,inlet} - T_{warm,outlet}) = \\ = m_2 c_2 (T_{cold,outlet} - T_{cold,inlet}) \quad (1)$$

- Log Mean Temperature Difference as logarithmic mean temperature difference

$$\Delta T_{lmdt} = \frac{(T_{warm,outlet} - T_{cold,inlet}) - (T_{hot,inlet} - T_{cold,outlet})}{\ln \dfrac{T_{warm,inlet} - T_{warm,outlet}}{T_{warm,inlet} - T_{hot,outlet}}} \quad (2)$$

- Effectiveness of the Warmth exchanger

$$\varepsilon = \frac{Q}{C_{\min} x (T_{warm,inlet} - T_{cold,inlet})} \quad (3)$$

where, Q is rate of warm transfer, m_1, m_2 are mass flow rate, kg/s, c_1, c_2 are specific heat, kJ/kgK, and T is temperature of warm and cold fluid.

4. TAGUCHI METHOD

This method proposed by G. Taguchi for the optimization of result if n number of variables are available. This is a technique where minimum 3 and maximum 50 variables available and some of the variables play significant role to change the result. Analytical approach is presented for the inverse problem to manufacture [8].

5. EXPERIMENTAL SETUP

The simplified design and construction of plant layout will help the plant and also for the worker to operate the unit safely and economically because of its simplified maintenance procedure [10].

From Figure 1, there are 7 components for experiment, first is a shell and straight pipe warm exchanger, second is the reservoir of warm and cold fluid, these are work as an inlet source, third apparatus is a sink container that can store warm and cold fluid after passing from the exchanger, forth part is hose pipe that are used to connect warm exchanger either in parallel flow or counter flow.

If the hose pipe is place in same side and move in a same direction then it is called parallel flow warm exchanger and if the hose pipe connected to the opposite side and flow in opposite direction, then it is called counter flow warm exchanger, fifth part is a flask that can be used to measure the temperature by collecting sample fluid, sixth part is a tab that can help to control the fluid flow and find out the mass flow rate of the fluid flowing inside the warm exchanger.

Figure 2 shows the seventh apparatus digital thermometer, that can help for the measurement of temperature in degree Celsius. Figures 1 and 2 are the experimental setup for warm exchanger analysis.

Figure 1. Shell and straight tube warmth exchanger

Figure 2. Measurement at outlet through digital thermocouple

First of all, mark the points on the tab for different mass flow rate, first mark shows one liter of fluid fill the flask in 11 second, that means 1 kg divided by 11 second = 0.091 kg/s. when the mass flow rate fixed in both the pipe then start the warm and cold fluid tab open simultaneously that help to give equal chance for warm transformation. After some period of time take one liter of sample water from both the outlet to measure the outlet warm and cold fluid temperature. Perform the experiment 4-5 times for accuracy in the apparatus.

5.1. Copper Plate

From Table 1, Copper plate or sheets are available in a wide range from very thin sheets to very thick sheets and some time as per customer demand copper plates are made up. Ounces (per square foot), millimeters, gauge, inches. Copper plate 20 gauge (0.81 mm) of length 1200 mm and width of 204 mm is used for the formation of shell. There is a shell of the shell effective length of 1102 mm and the thermal conductivity of the copper plate is 385 W/mK.

5.2. Copper Tube

Copper tubes are used for the formation of straight tube. The total length of the tube used is 4000 mm in warmth exchanger. In the case of straight tube heat exchanger four tubes of 1000 mm each are used to transmit heat as shown in Figures 5 and 6.

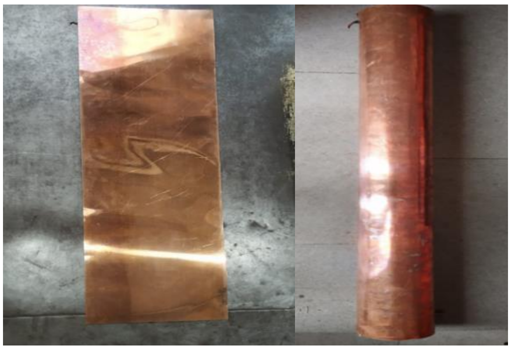

Figure 3 and 4. Copper plate and shell warm exchanger analysis

Figure 5 and 6. Copper tube and side shell warm exchanger analysis

Figure 7. Brazing of tube inside the shell

6. EXPERIMENTAL RESULTS

The detail data for design and fabrication of the warm exchanger is shown in Table 1. The observation and calculated value according to Taguchi analysis is shown in Table 2. The calculation based on formula used for obtaining at parallel and counter pace warmth exchanger in Table 3.

The parameters in Tables 1-3 are as the following:

• *LMTD* - Log Mean Temperature Difference, it is a driving force that help for warm transfer in pace system. Mostly used in warmth exchanger, this data used for the analysis of the exchanger (Figure 8).

• Warmth Transfer - This data help to know the quantity of warm or cold fluid transfer. This is a quantitative value (Figure 9).

• Effectiveness - This data help to know the ratio of actual heat transfer to the maximum possible heat transfer (Figure 10).

• T_{hi}, T_{ho} - Temperatures of warm fluid at inlet and outlet valve

• T_{ci}, T_{co} - Temperatures of cold fluid at inlet and outlet valve

Table 1. Specification and parameters of the apparatus

Type of Warmth Exchanger	Straight pipe	
Mass pace rate, $m = m_h = m_c$	0.091	kg/s
Specific Warmth of fluid, C_p	4.18	kJ/kgK
Thermal conductivity of copper, k	0.385	kW/mK
Internal Diameter of shell, D_i	0.15	m
External Diameter of shell, D_o	0.15081	m
Area of inward pipe, A_i	0.471	m²
Area of Outward pipe, A_o	0.474	m²
Inward Diameter of inner pipe, d_i	0.0125	m
Outward Diameter of inner pipe, d_o	0.0133	m
Warmth transfer area of inner pipe, a_i	0.157	m²

Warmth transfer area of outer pipe, a_o	0.167	m²
Length of pipe, l	4	m
Effective length of shell, L	1	m
Ambient Temperature, T_a	14	°C
Warmth transfer coefficient from inner surface, h_i	1.642	kW/m²K
Warmth transfer coefficient from outer surface, h_o	4.228	kW/m²K
Wall resistance, R_w	0.0064	K/kW
Total thermal resistance, R_{th}	5.4643	K/kW
Fouling resistance, R_f	0.001	K/kW
Overall Warmth transfer coefficient per unit area, U_A	0.183	kW/K

Table 2. Observation and calculated value

Taguchi Concept			Inlet Condition			Output Values			
Mass pace rate	Warm fluid temp	Cold fluid temp	Mass pace rate	T_{ci}	T_{hi}	T_{co} Parallel pace	T_{ho} Parallel pace	T_{co} Counter pace	T_{ho} Counter pace
1	1	1	0.091	25	80	36	60	41	59
1	2	2	0.091	20	70	27	61	31	54
1	3	3	0.091	15	60	21	52	24	46
2	1	2	0.076	20	80	29	69	34	61
2	2	3	0.076	15	70	22	61	24	56
2	3	1	0.076	25	60	31	52	34	46
3	3	3	0.067	15	70	23	70	26	64
3	1	1	0.067	25	80	35	61	43	55
3	2	2	0.067	20	60	27	51	41	34

Table 3. Result obtained at parallel and counter pace warmth exchanger

LMTD		Warmth Transfer				Effectiveness	
Parallel Pace	Counter Pace	*P* Cold Fluid	*P* Warm Fluid	*C* Cold Fluid	*C* Warm Fluid	Parallel Pace	Counter Pace
37.38	39.33	4.18	7.61	6.09	7.99	0.0293	0.0308
41.49	41.99	2.66	3.42	4.18	6.09	0.0357	0.0362
37.57	37.99	2.28	3.04	3.42	5.33	0.0360	0.0364
49.33	49.99	2.86	3.49	4.45	6.04	0.0354	0.0359
46.54	46.99	2.22	2.86	2.86	4.45	0.0364	0.0368
27.41	27.99	1.91	2.54	2.86	4.45	0.0337	0.0344
53.82	54.5	2.24	0.00	3.08	1.68	0.0421	0.0427
38.71	40.33	2.80	5.32	5.04	7.00	0.0303	0.0316
31.32	31.99	1.96	2.52	5.88	7.28	0.0337	0.0344

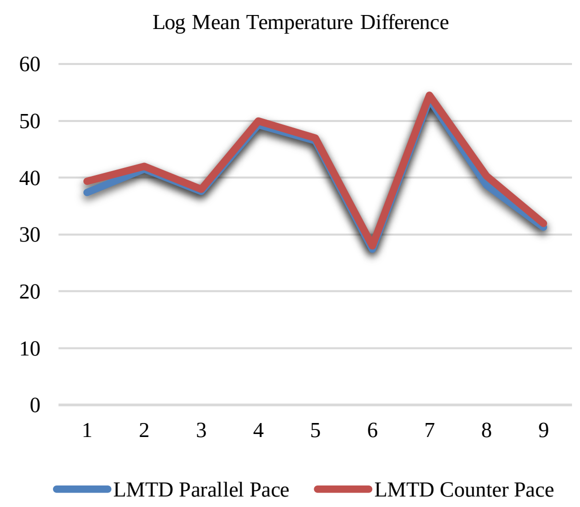

Figure 8. *LMTD* - Log Mean Temperature Difference

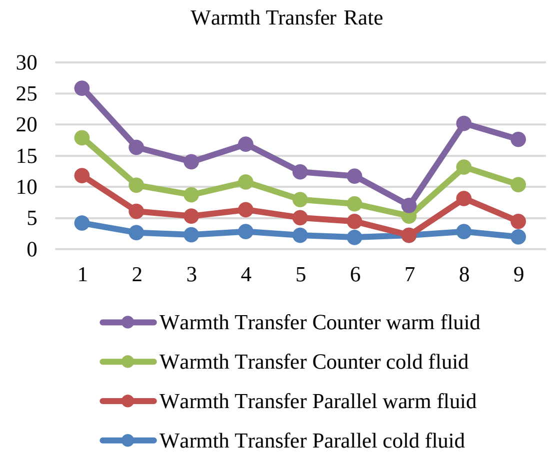

Figure 9. Warmth Transfer Rate, quantity of warm or cold fluid transfer

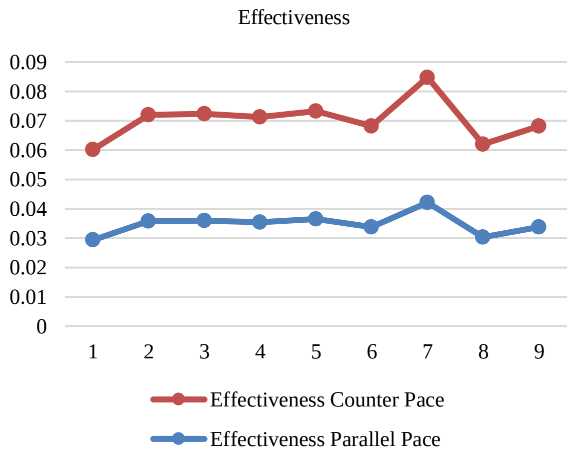

Figure 10. Effectiveness, ratio of actual heat transfer to the maximum possible heat transfer

7. TAGUCHI ANALYSIS REPORT BY MINTAB SOFTWARE

Minitab 19 is a software that can used for the analysis of the taguchi method (Figure 11). Through this software choose the level design 3 and the number of factor 3 and Design Summary of L9(3^3) that means Factors 3 and Runs 9. Table 2 is an analysis table generated by Taguchi mini-Tab software. The result of this software comes either by means or SN ratio.

This software provides Signal to Noise ratio of three different condition with mass pace rate of 0.091 kg/s, 0.076 kg/s and 0.067 kg/s with three inlet cold fluid temperature of 15 °C, 20 °C and 25 °C also with three inlet warm fluid temperature of 80 °C, 70 °C, 60 °C.

The given analysis shows Mass pace rate of 3(0.067 kg/s), warm fluid inlet temperature of 1(80 °C) and cold fluid inlet temperature of 1(25 °C) provides the maximum output as compare with other (Figure 12).

8. CONCLUSION

Log Mean Temperature Difference of counter pace is higher than that of parallel pace, this is due to effective temperature of counter pace cover 80% of the whole length but in parallel pace between 40%-50% of pipe length play a role.

Due to large effective temperature of counter pace, rate of warmth transfer of cold/warm water of counter pace is 20% to 40% higher than parallel pace, depending upon the length of the tube.

Effectiveness identified the maximum possible heat transfer by warm exchanger, effectiveness of counter pace 40%-50% higher than that of parallel pace.

Signal to Noise ratio is the value where warm exchanger gives their best or optimum value, in this case 311 shows the value where maximum outlet getting.

311 stands for, first number 3 stand for the third case of mass flow rate 0.067 kg/s, Second Number 1 stands for hot water inlet temperature of 80 °C and Third Number 1 stands for cold water inlet temperature of 25 °C.

Max. SN ratio - 311

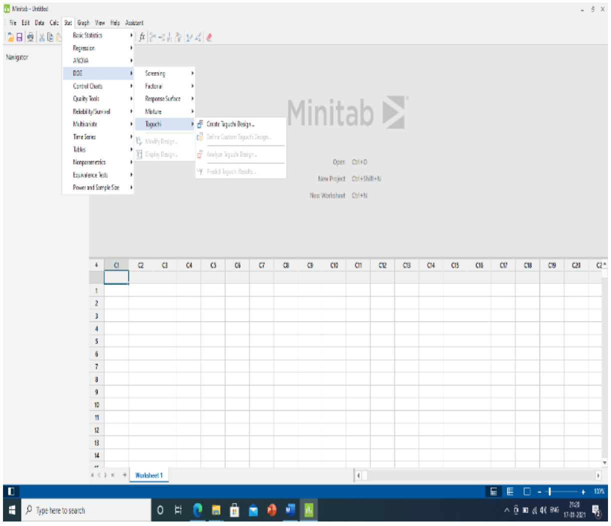

Figure 11. Minitab 19 software

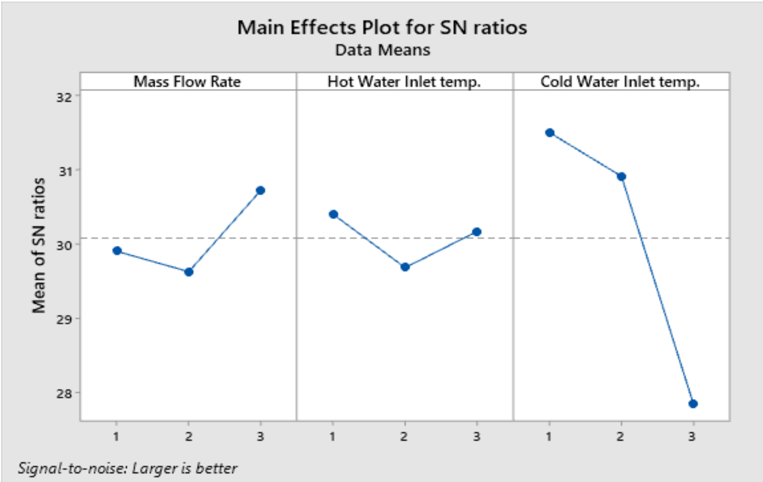

Figure 12. result obtain through Taguchi analysis

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