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Study and Comparison of Performance of Shell and Tube Heat Exchanger with Two Numerical Methods

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***Abstract*: The single phase shell and tube heat exchangers are widely used in process industries. The thermal design of shell and tube heat exchanger (STHE) is most important as it affects the principal cost and operating cost of the heat exchanger. In the present paper, a comparision of distilled water to raw water STHE is done using Kern method and Udayet al. method. This paper purely aims at studying and comparing the shell side heat transfer coefficients of the two numerical methods of STHE.**
***Keywords*: STHE, Heat transfer coefficient, shell and tube heat exchanger, design method for STHE, kern method**

I. INTRODUCTION

A shell and tube heat exchanger is a type of heat exchanger. Shell and tube heat type exchanger is most used and wide spread type of the heat exchanger. It is used mostly in various fields such as oil refineries, thermal power plants, chemical industries and many more. These are mostly used because of its large ratio of heat transfer area to volume and weight, easily replaceable parts, easy cleaning methods etc. It consists of some tubes through which one fluid flows. The other fluid flows through the shell which consists of the tubes and other supporting items like baffles, tube header sheets, seal strips, tie rods etc. A compact design can be achieved by minimizing the principal cost of heat exchanger [1].The shell side heat transfer coefficient plays an important role in deciding the overall size of the heat exchanger.

A. Udayet al. Method for Finding Shell Side Heat Transfer Coefficient

This method was based on actual flow pattern and heat exchanger geometry. This method consists of three sections[1].Correction factors like baffle leakage, unequal baffle spacing, bypass correction factor, fanning friction factor shell side, a fraction of tubes in one baffle window ,bypass streams and leakage streams are considered while modeling the shell side heat transfer coefficient.
Determination of heat transfer coefficient for interior cross-flow zones considering actual flow
Determination of heat transfer coefficient for window zones.
Determination of heat transfer coefficient for end cross-flow zones.
After determining the above values for different zones of the shell of heat exchanger the total shell side heat transfer coefficient, h_s is calculated by using the below equation.

$$h_s = \frac{h_c S_c (N_b - 1) + 2N_b h_w S_w + 2h_e S_e}{S_c (N_b - 1) + 2N_b S_w + 2S_e} J_\mu \quad (1)$$

B. Determination Of Interior Cross Flow Zone Heat Transfer Coefficient, h_c

To calculate the interior cross flow zone heat transfer coefficient, the following equation may be used.

$$h_c = h_{ic} J_1 J_b \quad (2)$$

Where $$h_{ic} = \frac{j_{ic} \operatorname{Re}_c \operatorname{Pr}_s^{0.33} k_s}{d_o} \quad (3)$$

According to the Bell(3), the flow is normal to tube bundle for the interior cross flow.To calculate Reynolds number Re_c ,the velocity considered is normal to the tube bundle which is taken as u_{sc}.Where as in the Udayet al.method,the flow is considered inclined to tube bundle as shown in fig 1.To calculate Re_c the inclined affect is incorporated by replacing $u_{sc}$with u_{sci} as given in equation 4.

$$Re_c = \frac{\rho_s u_{sci} d_o}{\mu_s} \tag{4}$$

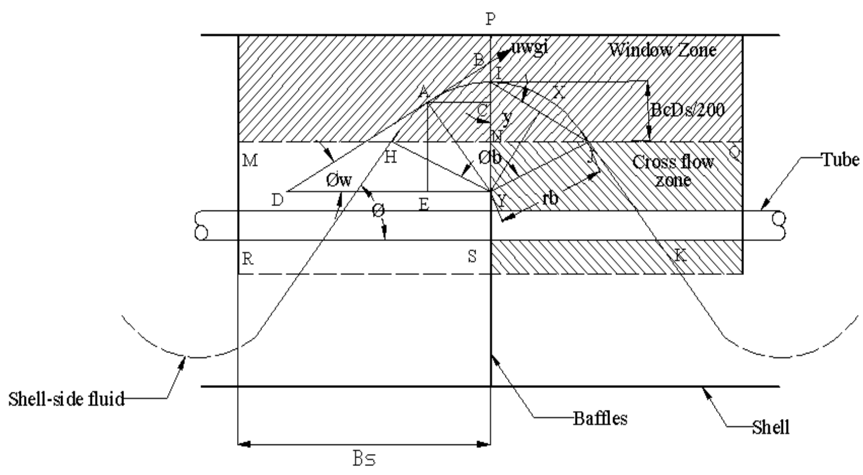

Fig 1. Actual Flow Pattern in shell side [1]

The leakage factor J_l and bundle by-pass factor $J_b$using the following equation (5) and equation (6) respectively

$$J_1 = 0.44(1 - R_M) + [1 - 0.44(1 - R_M)]\exp(-2.2R_L) \tag{5}$$

$$J_b = \exp\left[-\beta_b R_b (1 - \sqrt[3]{2R_s})\right] \tag{6}$$

β_b =a constant=1.25 for turbulent and transition flow, Re_c>100

And β_b =1.35 for laminar flow, Re_c<100

C. Determination Of Window Zone Heat transfer Coefficient, h_w

To compute the Reynolds number for window zone, the velocity is taken as the geometrical mean of cross-flowu_{sc} and window zone velocity, u_w. The geometrical mean of these two velocities is given by Eq. (7).

$$u_{wg} = \sqrt{u_w \times u_{sc}} \tag{7}$$

The equation for Reynolds number in window zone is given by Eq. (8)

$$Re_w = \frac{\rho_s u_{wg} d_o}{\mu_s \sin\theta_w} \tag{8}$$

Where $\theta_w = \dfrac{\theta_b}{4}$,

To calculate the heat transfer coefficient in window zone, we use Eq.(9)

$$h_w = h_{iw} J_1 \frac{B_c D_s}{100 B_s} \quad (10)$$

Determination of heat transfer coefficient in inlet and outlet compartment, h_e To compute the heat transfer coefficient in inlet and outlet compartment cross flow zone the equation (11) given below is used.

$$h_e = h_{ie} J_b J_s \quad (11)$$

Where $h_{ie} = \frac{k_s J_{ie} \mathrm{Re}_e \mathrm{Pr}_s^{0.33}}{d_o}$

k_s =thermal conductivity of shell side fluid

Re_e =Reynolds number of inlet and outlet cross flow zone

Pr_s = Prandtl number of shell side fluid

d_o =tube inside diameter in m

The unequal baffle spacing correction factor J_s was calculated by using the Eq. (12)

$$J_s = \frac{(N_b - 1) + \left(\frac{B_{si}}{B_s}\right)^{1-r} + \left(\frac{B_{so}}{B_s}\right)^{1-r}}{(N_b - 1) + \left(\frac{B_{si}}{B_s}\right) + \left(\frac{B_{so}}{B_s}\right)} \quad (12)$$

Where r =0.6 for turbulent flow

=1/3 for laminar flow

D. Determination Of Various Terms Used In Eq. (1)

The Surface area of the tubes S_c in the interior cross flow zone is given by Eq.(13)

$$s_c = \Pi d_o N_{tc} B_s \quad (13)$$

N_{tc} =The number of tubes in cross-flow zone

B_s =Baffle spacing in m

The Surface area of tubes lying in window zone is given by Eq. (14)

$$s_w = \Pi d_o N_{wt} B_s \quad (14)$$

Where N_{wt} = the number of tubes lying in window zone

The Surface area of tubes lying in the end compartment cross flow zone is given by Eq.(15)

$$s_e = \Pi d_o (N_t - N_{wt}) B_s \quad (15)$$

2. Kern method: It was based on experimental work on commercial exchangers with usual tolerances and will give a reasonably satisfactory prediction of the heat-transfer coefficient for preliminary designs[2]. The shell-side heat transfer and friction factors are correlated similarly to those for tube-side flow by using a hypothetical shell velocity and shell diameter. This method cannot adequately account the baffle to shell and tube to baffle leakage. The calculation of pressure drop is less satisfactory, as pressure drop is more affected by leakage and bypassing than heat transfer. The shell equivalent diameter is calculated using the flow area between the tubes taken in the axial direction (parallel to the tubes) and the wetted perimeter of the tubes. The method used by Kern is simple and more explanative. All the parameter related to the heat exchanger is obtained in well manner and brief without any complication as compared to another method, the calculation process is rather simple and detailed. Amongst all the methods, the Kern method is a simple method for calculating shell side pressure drop and heat transfer coefficient.

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II. FLUID PROPERTIES CONSIDERED

Shell side fluid properties: Hot fluid

ρ_s = 990 kg/m^3

μ_s = 0.000774 N-s/ m^2

C_{ph} = 4.187kJ/kg K

K_s = 0.6182 W/m K

Tube side fluid properties: Cold fluid

ρ_c = 990 kg/m^3

μ_c = 0.0009040 N-s/ m^2

C_{pc} = 4.187 kJ/kg K

K_c = 0.60812 W/m K

III.HEAT EXCHANGERSPECIFICATIONS:

The specifications of the heat exchanger are as follows

Shell ID	0.387 m
Tube OD	0.01905 m
Tube ID	0.01656 m
Baffle spacing	0.3048 m
Number of Tubes	160
Tube pitch	0.0238 m
Number of shell passes	1
Number of tube passes	2
Tube pattern	Triangular
Mass flow rate shell side	22.02 kg/sec
Mass flow rate tube side	33.45 Kg/sec

IV. CALCULATION OF SHELL SIDE HEAT TRANSFER COEFFICIENT USING UDAY ET AL. METHOD

A. Step 1

calculation of heat transfer coefficient in interior cross flow zone

Area of cross-flow section at centre line $A_{sc} = \left[(D_s - D_o) + \frac{(D_o - d_o)(p - d_o)}{p_t} \right]$

$$= 0.3048 \left[(0.387 - 0.356) + \frac{(0.356 - 0.01905)(0.0238 - 0.01905)}{0.0238} \right]$$

=0.0299 m^2

Cross-flow velocity at end and interior cross flow sections at shell centre line $u_{sc} = \frac{v_s}{A_{sc}}$

=0.022/0.0299 =0.7357m/sec

Inclined flow velocity $u_{sci} = \dfrac{u_{sc}}{\sin\theta}$ =0.7357/sin62.29

= 0.831 m/sec

Reynolds number $\mathrm{Re}_c = \dfrac{\rho_s u_{sci} d_o}{\mu_s}$

$$= \frac{990 \times 0.831 \times 0.01905}{0.000774}$$

=20248.524

Nusselt number for interior cross flow zone $Nu_{ic} = J_{ic}\,\mathrm{Re}_c\,\mathrm{Pr}_s^{0.33}$

$$= 0.011 \times 20248.524 \times 5.2^{0.33}$$

=385.669

Heat transfer coefficient for ideal tube tank in interior cross flow zone $h_{ic} = Nu_{ic} K_s / d_o$

$$= \frac{385.669 \times 0.6182}{0.01905}$$

=12515.528 W/m^{2}K

Actual heat transfer coefficient in interior cross flow zone $h_c = h_{ic} J_1 J_b$

$$= 12515.52 \times 0.504 \times 0.767$$

=4838.102 W/m^{2}K

B. Step 2

Determination of heat transfer coefficient in inlet and outlet compartment cross flow zone:

Reynolds number in inlet and outlet compartment cross flow zone $\mathrm{Re}_e = \dfrac{\rho_s u_{sc} d_o}{\mu_s}$

$$= \frac{990 \times 0.7357 \times 0.01905}{0.000774}$$

=17926.2715

Nusselt number for inlet and outlet compartment cross flow zone $Nu_{ie} = j_{ie}\,\mathrm{Re}_e\,\mathrm{Pr}_s^{0.33}$

$$= 0.007180 \times 17926.2715 \times 5.2^{0.33}$$

=221.779

Ideal tube tank heat transfer coefficient in inlet and outlet compartment $h_{ie} = Nu_{ie} \times k_s / d_o$

$$= 221.779 \times 0.6182 / 0.01905$$

=7197.0721 W/m^{2}K

Actual heat transfer coefficient of inlet and outlet compartment $h_e = h_{ie} \times J_b \times J_s$

$$= 7197.0721 \times 0.76 \times 0.9$$

=5469.7748 W/m^{2}K

C. Step 3

Determination of heat transfer coefficient in window zone

Reynolds number in window zone $\mathrm{Re}_w = \dfrac{\rho_s u_{wg} d_o}{\mu_s \times \sin\theta_w}$

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$$= \frac{990 \times 0.447012 \times 0.01905}{0.000774 \times \sin 25.50}$$

=25300.205

Whereas the inclined flow window velocity u_{wg} is

$$u_{wg} = \sqrt{u_{sc} \times u_w}$$

$$= \sqrt{0.7357 \times 0.2712} = 0.447012 m/\sec$$

To calculate Colburn heat transfer factor for fluids flow in window zone j_{iw}

$J_{iw} = a_1 \left(\frac{1.33}{P/d_o} \right)^{a_e} \mathrm{Re}_w^{a_2}$ whereas the values of constants for a layout 30^0 is as given below

a_1=0.593, a_2=-0.477, a_3=1.450, a_4=0.519

Substituting the above values we get J_{iw} =0.008

Nusselt number in window zone $N_{iw} = J_{iw} \times \mathrm{Re}_w \times \mathrm{Pr}_s^{0.33}$

$$= 0.008 \times 25300.205 \times 5.2^{0.33}$$

=348.734

Heat transfer coefficient for ideal tank lying in window zone $h_{iw} = \frac{Nu_{iw} \times K_s}{d_o}$

$$= \frac{348.734 \times 0.6182}{0.01905}$$

=11316.943 W/m^{2}K

Actual heat transfer coefficient window zone $h_w = h_{iw} J_1 \frac{B_c D_s}{100 B_s}$

$$= 11316.943 \times 0.504 \times \frac{25 \times 0.387}{100 \times 0.3048}$$

=1810.488 W/m^{2}K

D. Step 4

Determination of various terms

Surface area of tubes lying in interior cross flow section $S_c = \pi d_o N_{tc} B_s$

$$= \pi \times d_o \times 110 \times 0.3048$$

=2 m^2

Surface area of tubes lying in end cross flow section $S_e = \pi d_o (N_t - N_{wt}) B_s$

$$= \pi \times 0.019 \times (160 - 24.96) 0.3048$$

=2.45 m^2

Surface area of tubes lying in window flow zone $S_w = \pi d_o N_{wt} B_s$

$$= \pi \times 0.01905 \times 24.96 \times 0.3048$$

=0.454 m^2

E. Step 5

Determination of total heat transfer coefficient, h_s

$$h_s = \frac{h_c S_c (N_b - 1) + 2N_b h_w S_w + 2h_e S_e}{S_c (N_b - 1) + 2N_b S_w + 2S_e} J_\mu$$

Considering J_μ =1, and substituting the values we get h_s = 4004.277 W/m^{2}K

V. CALCULATION OF SHELL SIDE HEAT TRANSFER COEFFICIENT BY KERN METHOD:

A. *Step 1:* Area of shell side

$$a_s = \frac{D_s \times C' \times B}{P}$$

$$= \frac{0.387 \times 0.00476 \times 0.3048}{0.02381}$$

=0.0179 m^2

B. *Step 2*: Mass velocity shell side

$$G_s = w / a_s$$

$$= 22.02 / 0.0179$$

=933.03 kg/m^2 sec

C. *Step 3:* Equivalent diameter

$$D_e = \frac{4 \times \left(1/2P \times 0.86P - 1/2\pi d_o^2 / 4\right)}{1/2\pi d_o}$$ =0.0135 m

D. *Step 4*: Reynolds number shell side

$$\mathrm{Re} = \frac{D_e G_s}{\mu_h} = \frac{0.0135 \times 933.03}{0.000774}$$ =*16267.47*

E. *Step 5:*Nusselt number shell side

$$Nu = 0.027\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.33}$$

=0.027(16267.47)$^{0.8}$(5.2)$^{0.33}$

=109

F. *Step 6:*Heat transfer coefficient shell side, $h_s = \dfrac{Nu \times K_s}{D_e}$

$$= \frac{109 \times 0.618}{0.0135}$$ =4989.77 W/m^{2}K

VI. RESULT AND DISSCUSION

Shell side calculations of heat transfer coefficient for a shell and tube heat exchanger

Methods used for calculation	Shell side heat transfer coefficient, h_s
Uday et al. method	4004.277 W/m^{2}K
Kern method	4989.77 W/m^{2}K

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VII. CONCLUSION

The shell side design calculation of shell and tube heat exchanger is studied and compared between Uday et al. and Kern method. It is evident that the leakage factors and bypass factors affect the heat transfer of shell side in the shell and tube heat exchanger. Kern method which does not consider the leakage and bypass factors and provides higher values of shell side heat transfer coefficient. Thus kern method can give asatisfactory prediction of heat transfer coefficient for standard design whereas the other method gives therealistic value of heat transfer coefficient. Kern method is only accurate enough when the uncertainty in other design parameter is such that the use of the more elaborate method is not justified.

VIII. NOMENCLATURE

A_{sc}	Cross flow section area at shell centerline,m^2
B_c	Baffle cut as percentage of inside shell diameter
B_s	Interior section baffle spacing,m
C_{ph}	Specific heat of hot fluid at average temperature, J/kg K
C_{pc}	Specific heat of cold fluid at average temperature, J/kg K
C_{ps}	Specific heat of shell side fluid at average temperature, J/kg K
C_{pt}	Specific heat of tube side fluid at average temperature, J/kg K
C'	Diametral clearance between tube hole in baffle and tube outside diameter, m
D_b	Baffle diameter, m
D_e	Equivalent diameter, m
D_o	Tube bundle diameter, m
D_s	Shell inside diameter at first tube lane from shell centre line for multi tube passes ,m
d_h	Tue hole diameter in baffle, m
d_i	Tube inside diameter, m
d_o	Tube outside diameter, m
f_b	correction factor for bundle bypass stream for pressure drop
f_s	Fanning friction coefficient for shell side flow
h_c	Heat transfer coefficient for the interior cross flow section, W/m^{2}K
h_e	Heat transfer coefficient for end cross flow section, W/m^{2}K
h_{ic}	Heat transfer coefficient for ideal tube bank in the interior cross flow section, W/m^{2}K
h_{ie}	Heat transfer coefficient for ideal tube bank in the end cross flow section, W/m^{2}K
h_{iw}	Heat transfer coefficient for ideal tube bank lying in window zone, W/m^{2}K
h_s	Heat transfer coefficient of shell side fluid, W/m^{2}K
h_w	Heat transfer coefficient for the window zone flow,W/m^{2}K
J_b	Bundle bypass correction factor for heat transfer
J_l	Baffle leakage correction factor for heat transfer
J_μ	Viscosity correction factor
J_s	Heat transfer correction factor for unequal end baffle spacings
J_{ic}	Colburn’s heat transfer for ideal tube bank in interior cross flow section
J_{ie}	Colburn’s heat transfer for ideal tube bank in end cross flow section
J_{iw}	Colburn’s heat transfer factor for fluid flow in window zone
k_s	Shell side fluid thermal conductivity at average temperature, W/m^{2}K

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m_s	Mass flow rate of shell side fluid, kg/sec
N_b	Number of baffles
N_t	Total number of tubes in the shell
N_{tb}	Number if tube holes in a baffle
N_{tc}	Number of tubes in cross flow section
Nu_c	Interior cross flow section fluid Nusselt number
Nu_e	End cross flow section fluid Nusselt number
Nu_w	Window zone fluid Nusselt number
N_w	Number of tubes in window zone
P	Tube pitch, m
P_t	Transverse tube pitch, m
Pr_s	Prandtl number for shell side fluid
Re_c	shell side interior cross flow section fluid Reynolds number
Re_e	Shell side end cross flow section fluid Reynolds number
Re_w	Shell side window zone fluid Reynolds number
S_c	Surface area of tubes lying in the interior cross flow section,m^2
S_e	Surface area of tubes lying in the end cross flow section,m^2
S_w	Surface area of tubes lying in the window zone flow section,m^2
u_{sc}	Cross flow velocity at the end and interior cross flow section at shell centre line, m/s
u_{sci}	Inclined flow velocity of fluid at shell centre line, m/s
u_w	Fluid velocity in baffle window opening, m/s
u_{wg}	Geometric mean velocity of fluid in window zone, m/s

REFERENCES

[1] UdayC.. "Modeling of Single Phase Shell-Side Fluid Heat Transfer Coefficient in Shell-And-Tube Heat Exchanger", International Journal of Dynamics of Fluids/09731784, 20100601

[2] Shweta Y ,JagadishS,Manjunath "Analysis comparing of a conventional shell and tube heat exchanger using Kern, Bell and Bell Delware method", International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308

[3] YA Prasanthi,"Design and Thermal Analysis of Segmental baffle and Helical baffle in Shell and Tube Heat Exchangers using Kern method",International Journal of Advanced Engineering Research and Science (IJAERS) [Vol-3, Issue-11, Nov- 2016] ISSN: 2349-6495(P) | 2456-1908(O)

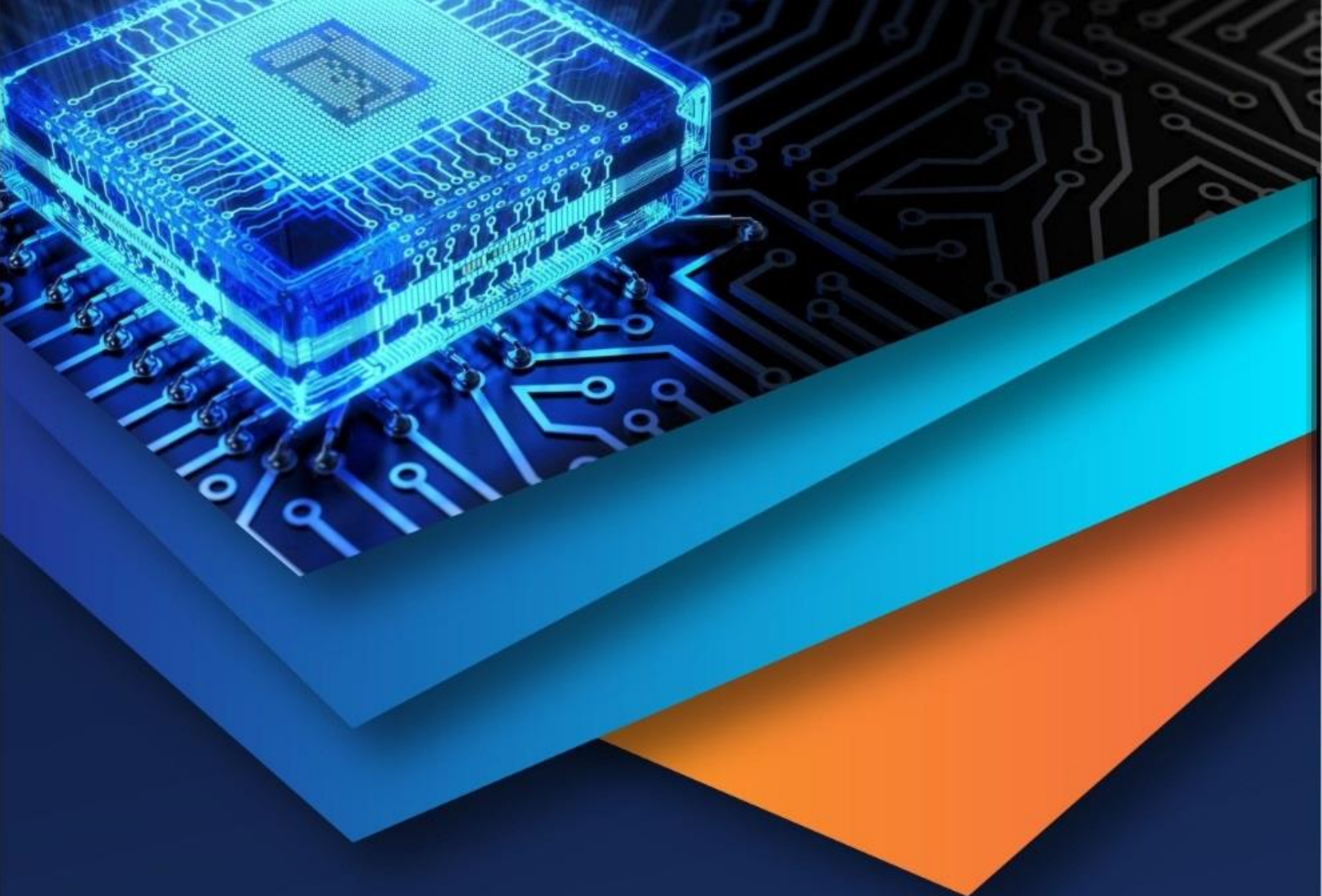
[4] Jian-Fei Zhang, Ya-Ling He, Wen-Quan Tao1, "A Design and Rating Method for Shell-and-Tube Heat Exchangers With Helical Baffles", School of Power and Energy Engineering, Xi'an Jiaotong University, Xi'an 710049, China

[5] Sandeep K. Patel, Professor Alkesh M. Mavani"Shell & tube heat exchanger thermal design With optimization of mass flow rate and baffle spacing" International Journal of Advanced engineering Research and Studies IJAERS/Vol.II/ Issue I/Oct.-Dec.,2012/130-135

[6] Yao, Ye; Zhang, Xingyu; and Guo, Yiying,"Experimental Study on Heat Transfer Enhancement of Water-water Shell-and-Tube Heat Exchanger Assisted by Power Ultrasonic". International Refrigeration and Air Conditioning Conference (2010) [11] John E Edwards

[7] Tinker t. (1951) "shell-side characteristic of shell- and-tube heat exchangers", parts ii, iii, and in: proceedings of general discussion on heat transfer, institute of mechanical engineers and american society of mechanical engineers, london, new york, pp. 89.

[8] M. Siddique, A.-R. A. Khaled, N. I. Abdulhafiz, and A. Y. Boukhary"Recent Advances in Heat Transfer Enhancements" Hindawi Publishing Corporation International Journal of Chemical Engineering Volume 2010



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