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The Software For Thermal Analysis Of Helixchanger With Modification In Kern Method

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ABSTRACT

Heat exchangers are important heat & mass transfer apparatus in oil refining, chemical engineering, environmental protection, electric power generation etc. Among different types of heat exchanger, shell-and-tube heat exchangers (STHXs) have been commonly used in Industries. The thermal analysis of conventional heat exchanger has been done using Kern method. This method is proven & has been verified by other researchers. Thermal analysis of helixchanger-a heat exchanger with helical baffles hasn't been done using Kern method.

The present work modifies the existing Kern method used for conventional heat exchanger, taking into consideration the helical geometry of helixchanger. The thermal analysis of Helixchanger using Kern method which gives clear idea that the ratio of heat transfer coefficient per unit pressure drop is maximum in helixchanger as compared to segmental baffle heat exchanger. The Helixchanger analysis for different helix angles shows that, the heat transfer coefficient decreases with increase in helix angle. This decides the optimum helix angle for Helixchanger. The Helixchanger eliminates principle shortcomings caused by shell side zigzag flow induced by conventional baffle arrangement. The flow pattern in the shell side of the heat exchanger with continuous helical baffle was forced to rotational & helical due to geometry of continuous helical baffles, which results in significance increase in heat transfer coefficient per unit pressure drop in the heat exchanger.

A software for the thermal analysis of helixchanger developed in a visual basic programming environment. Its user-friendly input format makes it an excellent tool for the teaching, learning and preliminary design of helixcanager. Design methodology is based on the open literature Kern method while calculations adhere closely to the methodology prescribed by the latest TEMA standards for industry practice. It is hoped that the software will bridge the gap between the teaching of engineering fundamentals and the existing industry practice of helixchanger design.

Keywords- Kern method, heat transfer coefficient per unit pressure drop, helical baffle heat exchanger, helix angle, increased heat transfer coefficient, reduced pressure drop and software.

I. INTRODUCTION

Heat exchangers are commonly used as oil coolers, power condensers, preheaters and steam generators in both fossil fuel and nuclear-based energy production applications. They are also widely used in process applications and in the air conditioning and refrigeration industry. Although they are not specially compact, their robustness and shape make them well suited for high pressure operations. In view of the diverse engineering applications and basic configuration of heat exchanger, the thermal analysis and design of such exchangers form an integral part of the undergraduate mechanical and chemical engineering curricula of most universities. Final year undergraduate courses often include an elective subject for thermal design of heat exchangers.

Reflecting the growing trend of using computers for design and teaching, computer software for the design and optimization of heat exchangers is needed. These softwares are written to reinforce fundamental concepts and ideas and allow design calculations for generic configurations with no reference to design codes and standards used in the heat exchanger industry.

This paper describes user-friendly computer software developed for the thermal analysis of helical baffle heat exchanger based on the open literature Kern method. The use of this software will bridge the gap between engineering practice and teaching of shell and tube heat exchanger design.

II. INTRODUCTION TO SHELL AND TUBE HEAT EXCHANGER

Shell and tube heat exchangers still take a noted place in many industrial processes. They are widely used because of their robust and flexible design. However, conventional heat exchangers with segmental baffles in shell side have some shortcomings resulting in the relatively low conversion of pressure drop into a useful heat transfer.

The helixchanger – heat exchanger with shell side helical flow eliminates principle shortcomings caused by shell side zigzag flow induced by conventional baffle arrangements. Both hydrodynamic studies and testing of heat transfer and the pressure drop on research facilities and industrial equipment showed much better performance of helically baffled heat exchanger when compared with conventional ones. The new design causes near plug flow conditions and reduces dead zones within the shell space. These results in relatively high value of shell side heat transfer coefficient, low pressure drop, and low shell side fouling. Thus the helixchanger exhibits much more effective way of converting a pressure drop in to a useful heat transfer than conventional heat transfer.[1]

Figure – 2 : Helixchanger

III. DESIRABLE FEATURES OF HEAT EXCHANGERS:

In order to obtain maximum heat exchanger performance at the lowest possible operating and capital costs without comprising the reliability, the following features are required of an exchange.

A. Higher heat transfer coefficient and larger heat transfer area:

These two factors increase the heat transfer rate for a given temperature difference and therefore improve the heat exchanger effectiveness or temperature approach.

A high heat transfer coefficient can be obtained by using heat transfer surfaces, which promote local turbulence for single phase flow or have some special features for two phase flow. Heat transfer area can be increased by using larger exchangers, but the more cost effective way is to use a heat exchanger having a large area density per unit exchanger volume. Foe some duties, such as those involving a gaseous phase, secondary heat transfer area is also useful. High area densities become economically even more attractive when an exchanger is built from expensive special materials such as titanium or nickel.

B. Lower pressure drop:

Pumping costs are dependent on pressure drop within an exchanger. Therefore the lower pressure drop means lower operating costs. Normally devices or surfaces that provide high heat transfer coefficients also give high pressure gradients i.e. the pressure drop per unit length of flow path. Exchangers designed to give enhanced performance, however require shorter flow paths to achieve a given duty. It is therefore possible that these exchangers have a high pressure gradient but not so high pressure drop.

However, the segmental baffles have some adverse effects such as large back mixing, fouling, high leakage flow, and large cross flow. In addition, segmental baffles bring on significant pressure drop across the exchanger when changing the direction of flow. Recently, a new type of heat exchanger with helical baffles has been proposed to improve the performance on the shell side [6].

Compared to the conventional segmental baffled shell and tube exchanger Helixchanger offers the following general advantages:

- ➢ Increased heat transfer rate/ pressure drop ratio
- ➢ Reduced bypass effects.
- ➢ Reduced shell side fouling.
- ➢ Prevention of flow induced vibration.
- ➢ Reduced maintenance

C. Research aspects

Research on the helixchanger has forced on two principle areas.

- Hydrodynamic studies on the shell side and
- Heat transfer and pressure drop studies on small scale and full industrial scale equipment.

Hydrodynamic studies were aimed at investigation of relation between the fluid stream momentum changes and heat transfer rate. With these tests, the influence of stagnant zones on the effective use of available heat transfer area and on the deviation from plug flow ideal could be investigated. The experimental method was based on stimulus response techniques modified for the specific purpose. Hydrodynamic studies on the helixchanger showed encouraging results- a low degree of back mixing and nearly negligible dead volume. [10]

The research program for heat transfer and pressure drop tests was guided by results of the hydrodynamic studies. Test units with optimum baffle arrangement (20°-40° helical angles) were investigated.[6]

The shell side heat transfer coefficient against the shell-side pressure drop, which offers a measure of conversion efficiency of the conventional segmental baffles as compared to that of helical baffles offer much higher conversion efficiency for converting a given pressure drop to heat transfer than the conventional segmental baffle. An interesting in figure is the dramatic improvement in conversion efficiency for the helical baffles at a helix angle of 40°. This dramatic improvement at 40° helix angle was confirmed by several repeated measurements. Recently, flow visualization tests offered some expiation for this phenomenon. The boundary layer on the tube surface follows the helical path and it appears to be fully developed just around a helix angle of 40°.

D. Design aspects:

An optimally designed helical baffle arrangement depends largely on the heat exchanger operating conditions and can be accomplished by appropriate design of helix angle, baffle overlapping, and tube layout. The cross sectional area of shell side flow channel is determined primarily by the shell inside diameter, tube outside diameter, tube layout and helix angle. A wide range of flow velocities can be achieved by variation of helix angle, analogous to variation of baffle spacing and baffle cut in segmentally baffled heat exchanger. The overlapping of helical baffles is the parameter that can substantially affect the shell side flow pattern. Especially in case where adjacent baffle touch at the perimeter, the large triangular free flow area between the baffles can cause a bypass stream with significant longitudinal flow component. In order to counter this, baffle overlapping is used to minimize the bypass stream.

In the original method an ideal shell-side heat transfer coefficient is multiplied by various correction factors for flow distribution and the non-idealities such as leakage streams, bypass stream etc. for helical baffle geometry it is suggested that some correction factor are not required; at the same time new are introduced

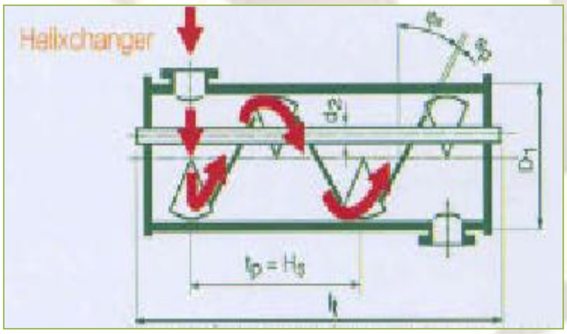


Figure - 3: Helixchanger flow pattern

Important Parameters*:*

- Pressure Drop
- Baffles pitch(Helix angle) angle (φ_S)
- Baffle space (H_s)
- Surface area (A)
- Heat transfer coeff. (h)

In designing of helixchangers, pitch angle, baffle's arrangement, and the space between two baffles with the same position are important parameters. Baffles pitch angle (φ_S) is the angle between flow and perpendicular surface on exchanger axis and H_s is space between two following baffles with the same situation. These parameters are shown in Figure - 5.1

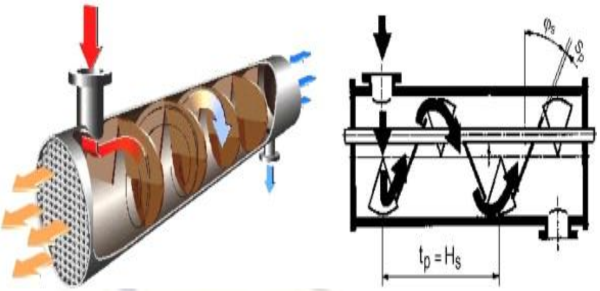


Figure - : A schematic of heat exchangers with helical baffles (left), pitch angle (φ_S) and baffle space (H_s) (right).

Optimum design of helical baffle heat exchangers is depended on operating condition of heat exchanger, and it can be followed and completed by consideration of proper design of pitch angle, overlapping of baffles and tube's layout. Changing the pitch angle in helical baffle system can create wide range of flow velocities as the baffle space and baffle cut in traditional heat exchangers. Moreover, overlapping of helical baffles is a parameter that can affect significantly on shell side flow pattern.

Heat transfer coefficients and pressure drop calculations are the main part of design of heat exchangers with a given duty. In traditional approaches such as Kern and Bell–Delaware methods a design starts with a specified primary guess for the overall heat transfer coefficient and geometry of exchanger so that at the end of one run of calculations the pressure drops are re-calculated and compare with the maximum available pressure drops given in a process.

IV. THERMAL ANALYSIS OF HELICAL BAFFLE HEAT EXCHANGER

In the current paper, thermal analysis has been carried out using the Kern's method. The thermal parameters necessary to determine the performance of the Heat Exchanger have been calculated for Segmental baffle heat Exchanger following the Kern's method, and suitable modifications made to the method then allow us to apply it for the helical baffle Heat Exchanger which is the subject area of interest. Also, the comparative analysis, between the thermal parameters of the two Heat exchangers has been carried out, that clearly indicates the advantages and disadvantages of the two Heat Exchangers.

4.1 Heat Exchanger Data at the shell side

Table 1. Input data – Shell Side

Property	**Symbol**	**Unit**	**Cold Water (Shell)**	**Hot Water (Tube)**
Specific Heat	Cp	KJ/kg. K	4.178	4.178
Thermal Conductivity	K	W/m. K	0.6150	0.6150
Viscosity	µ	kg/m. s	0.001	0.001
Prandtl's Number	Pr	-	5.42	5.42
Density	Ρ	$1\ kg/m^3$	996	996

S. No.	**Quantity**	**Symbol**	**Value**
1.	Shell side fluid		Water
2.	Volume flow rate	$(\dot{Q}_s)$	60 lpm
3.	Shell side Mass flow rate	$(\dot{m}_s)$	1 kg/sec
4.	Shell ID	(D_{is})	0.153 m
5.	Shell length	(L_s)	1.123 m
6.	Tube pitch	(P_t)	0.0225m
7.	No. of passes		1
8.	Baffle cut		25%
9.	Baffle pitch	(L_B)	0.060 m
10.	Shell side nozzle ID		0.023 m
11.	Mean Bulk Temperature	(MBT)	30 ˚C
12.	No. of baffles	(N_b)	17
13.	Shell side Mass velocity / mass flux	$(\dot{M}_F)$	kg / (m^2s)

4.2 Heat Exchanger data at the tube side

Table 2. Input data – Tube side

S. No.	**Quantity**	**Symbol**	**Value**
1.	Tube side fluid		Water
2.	Volume flow rate	$(\dot{Q}_t)$	10 lpm.
3.	Tube side Mass flow rate	$(\dot{m}_t)$	0.17 kg/sec
4.	Tube OD	(D_{ot})	0.0120 m
5.	Tube thickness		0.0013 m
6.	Number of Tubes		24
7.	Tube side nozzle ID		0.101 m
8.	Mean Bulk Temperature	(MBT)	30 ˚C

4.3 Fluid Properties

Table 3: Fluid properties

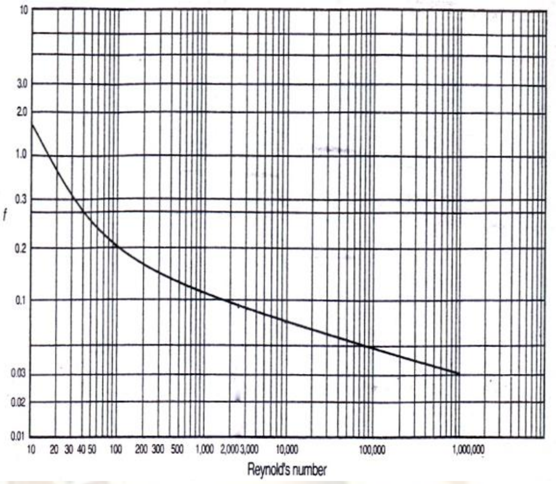


Figure - 4 plot of 'f' as a function of shell-side Reynold's number

4.4 Thermal analysis of Helical Baffle Heat Exchanger :

(Baffle Helix Angle 25˚)

1. C' = 0.0105

2. Baffle Spacing (L_b)

$L_b = \pi \cdot D_{is} \cdot \tan ф$

…(where ф is the helix angle = 25˚)

$= \pi \cdot 0.153 \cdot \tan 25$

$= 0.2241$

3. Cross-flow Area (A_S)

$A_S = (D_{is} \cdot C' \cdot L_B) / P_t$

$= (0.153 \cdot 0.0105 \cdot 0.2241) / 0.0225$

$= 0.016\ m^2$

4. Equivalent Diameter

$D_E = 0.04171$ m.

5. Maximum Velocity (V_{max})

$V_{max} = \dot{m}_s / A_s$

$= 0.001 / (0.016)$

$= 0.0625$ m/s

6. Reynold's number (Re)

$Re = (\rho \cdot V_{max} \cdot D_E) / \mu$

$= (996 \cdot 0.0625 \cdot 0.04171) / 0.001$

$= 2596.44$

7. Prandtl's no.

Pr = 5.42

8. Heat Transfer Co-efficient (α_o)

$\alpha_o = (0.36 \cdot K \cdot Re^{0.55} \cdot Pr^{0.33}) / R \cdot D_E$

$= (0.36 \cdot 0.6150 \cdot 2596.44^{0.55} \cdot 5.42^{0.33}) / 0.04171$

$= 699.94\ W/m^2K$

8. No. of Baffles (N_b)

$N_b = L_s / (L_b + \Delta_{SB})$

$= 1.123 / (0.2241 + 0.005)$

≈ 5

9. Pressure Drop (ΔP_S)

$$\Delta P_S = [4 \cdot f \cdot \dot{M}_F^2 \cdot D_{is} \cdot (N_b + 1)] / (2 \cdot \rho \cdot D_E)$$
$$= 15.52 \text{ Pa}$$
$$\mathbf{= 0.01552 KPa}$$

V. THE SOFTWARE FOR THERMAL ANALYSIS OF HELIXCHANGER

A. Introduction

A software for the thermal analysis of helixchanger developed in a visual basic programming environment. Its user-friendly input format makes it an excellent tool for the teaching, learning and preliminary design of helixcanager. Design methodology is based on the open literature Kern method while calculations adhere closely to the methodology prescribed by the latest TEMA standards for industry practice. It is hoped that the software will bridge the gap between the teaching of engineering fundamentals and the existing industry practice of helixchanger design. Reflecting the growing trend of using computers for design and teaching, computer software for the design and optimization of heat exchangers is needed. These softwares are written to reinforce fundamental concepts and ideas and allow design calculations for generic configurations with no reference to design codes and standards used in the heat exchanger industry.

B. Description of Software

The shell and tube heat exchanger design software is developed for use in the teaching of thermal design of shell and tube heat exchangers usually at the senior undergraduate level of a mechanical or chemical engineering course. It may also be used for the preliminary design of shell and heat exchangers in actual industrial applications. Developed in Visual basic programming environment, the Microsoft Windows-based Software can be compatible for personal computer with at least 250 MB of RAM and at least 2MB of free hard disk space.

C. Components of the software

The software consists of five options viz. Parameter, Calculations, Sketch, Plots and Print. The calculation option allows user to get thermal analysis of the shell and tube heat exchanger to be determined based on inputs of fluids temperatures, flow rates, helix angle and dimensional constraints. The user can call out a sketch screen showing the different geometrical configurations of helical baffle heat exchangers. Thermo physical properties of common fluids are included in the software. The existing databases of fluid properties cater for water. The software allows for user input of thermo physical properties of fluids. The inputs taken from user are in SI system. One more feature is set in this software apart from most software developed for educational applications. Firstly, it calculates different parameters like pressure drop, heat transfer coefficient of the heat exchanger for particular set of input given. Then it can be saved into excel background which can be conveniently used analysis of the heat exchanger. This feature is useful for the generation of design reports. Detailed calculation steps are also available to facilitate the understanding of concepts used in the design. This feature sets this software apart from most commercial packages which behave like black boxes and have no pedagogical use.

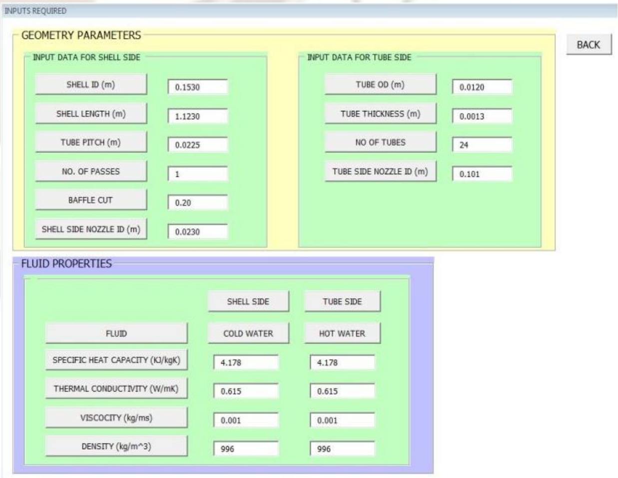
D. Tutorial

Step1:

Double click on the HXDE.xlsm file. A visual basic window will appear on the screen. It contains various tabs. After clicking on each tab a new window will appear. This new window will either takes some input from user or it shows the result. For thermal analysis of helix changer first click on the Parameters tab.

Step2:

As user clicks on the parameters tab, It will ask the user "If you want to change the previously entered input then click YES else NO". The following window will appear on the screen once you click on YES button. In this window user has to enter several input parameters which are needed for further analysis. After entering all the parameters click on the BACK button.



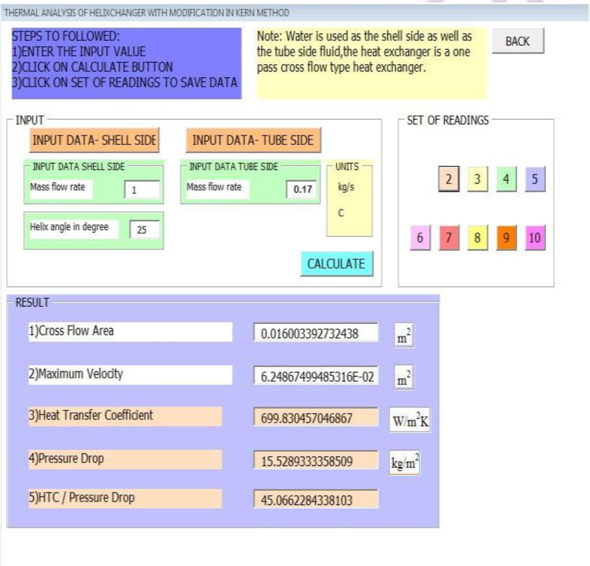
SHELL ID (m) 0.1530
SHELL LENGTH (m) 1.1230
TUBE PITCH (m) 0.0225
NO. OF PASSES 1
BAFFLE CUT 0.20
SHELL SIDE NOZZLE ID (m) 0.0230

TUBE OD (m) 0.0120
TUBE THICKNESS (m) 0.0013
NO OF TUBES 24
TUBE SIDE NOZZLE ID (m) 0.101

	SHELL SIDE	TUBE SIDE
FLUID	COLD WATER	HOT WATER
SPECIFIC HEAT CAPACITY (KJ/kgK)	4.178	4.178
THERMAL CONDUCTIVITY (W/mK)	0.615	0.615
VISCOCITY (kg/ms)	0.001	0.001
DENSITY (kg/m^3)	996	996

Step3:

As you click on the CALCULATION button, a new window will appear. Read the note which is mentioned in this window. The inputs which are varying every time are taken from the user in this step. Enter the shell side and tube side inputs in the respective boxes. The unit in which the input parameter is to be entered is shown. Helix angle also can be varied. After entering all varying inputs, click on calculation button. A new frame will appear in the same window which will give you all calculated parameters for particular input. To save this calculated results click on the button is shown in "SET OF READINGS" frame. To close this window at any instant, drag the window to the left side and then close it. After closing this window background calculation Excel sheet will appear. In this sheet user can view the calculations.



THERMAL ANALYSIS OF HELIXCHANGER WITH MODIFICATION IN KERN METHOD

STEPS TO FOLLOWED:
1)ENTER THE INPUT VALUE
2)CLICK ON CALCULATE BUTTON
3)CLICK ON SET OF READINGS TO SAVE DATA

Note: Water is used as the shell side as well as the tube side fluid,the heat exchanger is a one pass cross flow type heat exchanger.

INPUT

INPUT DATA SHELL SIDE
Mass flow rate: 1
Helix angle in degree: 25

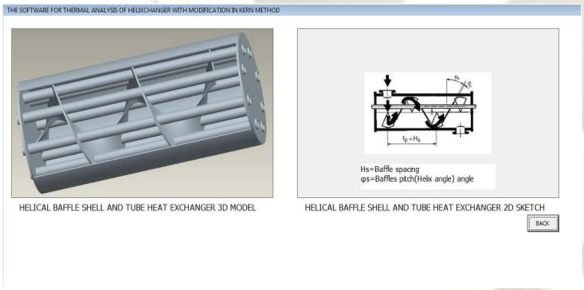
INPUT DATA TUBE SIDE
Mass flow rate: 0.17

UNITS
kg/s
C

RESULT
1)Cross Flow Area: 0.016003392732438 m^2
2)Maximum Velocity: 6.24867499485316E-02 m^2
3)Heat Transfer Coefficient: 699.830457046867 W/m^2K
4)Pressure Drop: 15.5289333358509 kg/m^2
5)HTC / Pressure Drop: 45.0662284338103

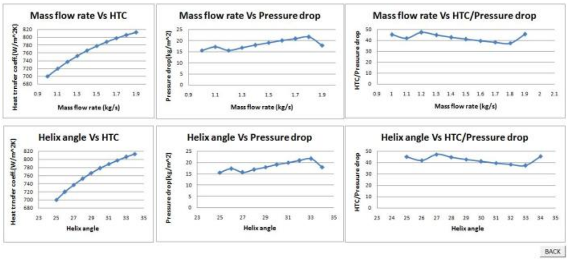
Step 4:

The sketch of helical baffle heat exchanger is shown in this window. This window will appear after clicking SKETCH button in the main window. This sketch shows the flow pattern in the helical baffle heat exchanger. The baffle which is shown in the 3-d diagram is continuous helical baffle.



Step 5:

The calculated results for varying input parameter are saved in the background. From these results various graphs are plotted. These graphs are visible to user after clicking on PLOT button in the main window.



Step 6:

Pressure drop and heat transfer coefficient is calculated for varying mass flow rate and helix angle. The calculated values are shown in table for respective mass flow rate and helix angle. From these results various graphs are plotted. User will get print for the saved data after clicking on the print button. It contains all varying parameter and calculated results for respective input parameter.

Sr no.	Mass flow rate(kg/sec)	HTC / Pressure drop	HTC(W/m^2K)	Pressure drop(Kg/m^2)	Helix angle
1	1	45.06622843	699.830457	15.52893334	25
2	1.1	41.89094899	719.4965925	17.17546653	26
3	1.2	47.2101071	736.8366028	15.60760286	27
4	1.3	44.71644118	752.16078	16.82067625	28
5	1.4	42.65912769	765.7192699	17.94971701	29
6	1.5	40.94605166	777.7164376	18.99368574	30
7	1.6	39.50983488	788.3211412	19.95252938	31
8	1.7	38.30017025	797.6742526	20.8269114	32
9	1.8	37.27883298	805.8942724	21.61801237	33
10	1.9	45.52042851	813.081595	17.86190556	34

VI. SOFTWARE UTILIZATION IN DESIGN EDUCATION

The software is suitable for teaching thermal design of shell and tube heat exchangers to senior undergraduate students in mechanical and chemical engineering and also to train new graduate engineers in thermal design. Students may be asked to use the software to undertake a few mini projects in shell and tube heat exchanger design.

VII. LIMITATIONS OF THE SOFTWARE

Since the software is developed in the college with limited manpower and financial resources, it will not have the aesthetic appearance and database of commercially developed ones.

At present, thermo physical properties of two fluids are stored in the database. It is a simple though tedious task of incorporating more fluid data into the software. This limitation does not hinder the use of the software and in fact allows the student the opportunity to search for thermo physical data of fluids encountered in engineering applications.

VIII. CONCLUDING REMARKS

Software has been developed for the thermal design of helical baffle heat exchanger based on the Kern method. Students can use it to learn the basics of helical baffle heat exchanger at their own pace.

As with the case of all software, it is always in a constant state of development. The addition of a mechanical design and optimization are some of the enhancements are needed in this software. It is hoped that the software will bridge the gap between the teaching of fundamentals and industry practice of helical baffle heat exchanger design.

Nomenclature

Symbol	**Quantity**	**Units**
A_s	Shell Area	m^2
L_B	Baffle Spacing	m
C_p	Specific Heat	kJ/kgK
D_{ot}	Tube Outer Diameter	m
D_{is}	Shell Inner Diameter	m
D_E	Equivalent Diameter	m
α_o	Heat Transfer Co-efficient	$\frac{W}{m2 \cdot}$
N_b	Number of Baffles	-
Pr	Prandtl’s No.	-
P_T	Tube Pitch	m
Re	Reynold’s Number	-
ΔP_S	Total shell side pressure drop	Pa
μ	Dynamic viscosity	$Kg \cdot s/m^2$
ρ	Fluid Density	kg/m^3
V_{max}	Maximum Tube Velocity	m/s
ϕ	Helix Angle	-

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REFERENCES

[1]. Andrews Malcolm, Master Bashir, *Three Dimensional Modeling of a Helixchanger Heat exchanger using CFD, Heat Transfer Engineering*, 26(6), (2005), 22-31.

[2]. Mukherjee R, Effectivedesign Shell and Tube Heat exchangers, *Chemical Engg Progress*, (1998), 1-8.

[3]. Gang Yong Lei, Ya-Ling He, RuiLi, Ya-Fu Gao, Effects of baffle inclination angle on flow and heat transfer of a heat exchanger with helical baffles,*ScienceDirect-Chemical Engineering and Processing*,(2008), 1-10.

[4]. Peng B, Wang Q.W., Zhang C., An experimental Study of shell and tube heat exchangers with continuous Helical baffles,*ASME Journal of Heat transfer*, (2007).

[5]. Hewitt G.F, Shires G.L., Bott T.B., *Process heat transfer*, (CRC press), 275-285.

[6]. Master B.I, Chunagad K.S. Boxma A.J. Kral D, Stehlik P, *Most Frequently used Heat exchangers from pioneering Research to Worldwide Applications*, *vol. No.6*, (2006), 1-8.

[7]. Prithiviraj, M., and Andrews, M. J, Three Dimensional Numerical Simulation of Shell-and-Tube Heat Exchangers, *Foundation and Fluid Mechanics, Numerical Heat Transfer Part A - Applications*, *33(8)*, 799–816, (1998).

[8]. Serth Robert W.,*Process heat transfer principles and application*, ISBN:0123735882, 246-270, (2007).

[9]. WadekarVishwas*Enhanced and Compact Heat exchangers – A Perspective from process industry*, 5th international conference on *Enhanced and Compact Heat exchangers: Science, Engineering and Technology*, 35-41, (2005).

[10]. Wang Qui, Dong Chen Gui, Xu Jing, PengJi Yan,*Second-Law Thermodynamic Comparison and Maximal Velocity Ratio Design Of Shell-and-Tube Heat Exchanger With Continuous Helical Baffles, ASME journal*, 132/101801, 1-8, (2010).