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Research Article

Minimizing Total Cost For Shell And Tube Heat Exchanger Using Abc, Auction, Ant Lion, Elephant, Spiral, Bacterial, Greedy, Lawlers Fireworks And Pattern Search

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ABSTRACT: The heat exchanger device usedto transferheat betweenmore than two fluids. The heat exchanger device is used in various industries. This paper captures that optimization of entire annual operating cost. Thus an effort has been made to get a group of optimum dimension of the heat exchanger subjectto given inlet and outlet conditions.Then all the parameters are collected from related industries.The elapsed time and cost to complete the problems are all compared using ABC algorithm, Auction, Spiral,Ant lion, Elephant herding, Bacterial colony, Greedy, Lawler's, Fireworks and Patterns search for these ten non-traditional methods.In this paper, we have compared the solution to minimize the total cost of shell and tube heat exchanger using ten artificial optimization method. We conclude which method gives a better solution for shell and tube heat exchanger.

Keywords: Shell and Tube heat exchanger, Bacterial colony, ABC algorithm, Cost minimization, Auction, Ant lion, Elephant herding, Spiral, Greedy, Optimization Algorithm, Lawler's, Fireworks and Pattern search.

INTRODUCTION:

The heat exchanger design Optimization approaches the output of the mathematical model (2). This structure was made by the sensitive of the planning variables in the target functions within the optimization problem (4). The heat exchanger device is employed in industrial fields for shell and tube consists of the low cost, simplicity and adaptability. These varieties of the heat exchanger are good for the pressurized operation (5). This technique is applied in process industries, power generation, oil factory and chemical industries. Within the industries they're employed in heater, oil cooler etc… During this method, the most issues are fouling. This issue is maximum founded by engineers. The fouling means undesirable materials of heat exchanger. This method decreases heat transfer rate and increasing fluid flow (3). The components of shell and tube device are shell cover, channel, tubes, channel cover, nozzles, tube sheets and baffles as shown in figure 1. Plates are baffles installed in shell side. During this system improve the nice and cozy heat transfer by fluid. This device increases the pressure drop

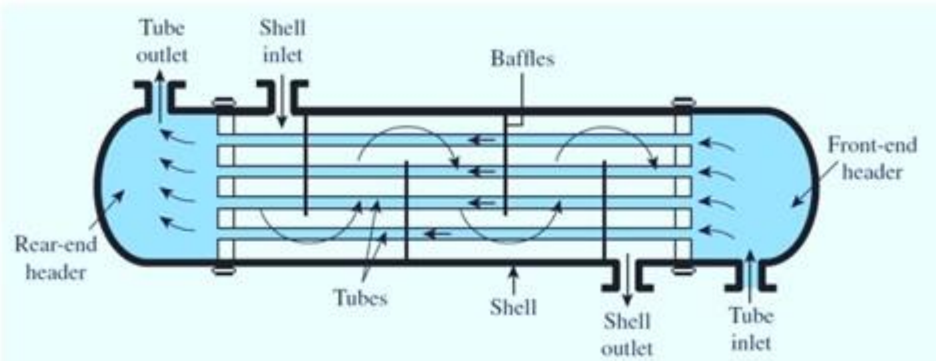


Figure 1: Flow Sheet Production

MATHEMATICAL MODEL FOR HEAT EXCHANGER:

The mathematical model for theheat exchanger is minimizing the overall annual cost within the operation device formulated and optimized. The two fluids at the inlet are known in thermal and physical properties. It's founded by device design for given outlet temperature of shell and tube fluids. Then the heat transfer place and pumping volume to desired temperature condition.

2. NOMENCLATURE

ai- numerical constant ($).
A -heat exchanger surface area (m^2).
B -baffle spacing (m).
C -numerical constant.
C_e -energy cost ($/kWh).
C_i -capital investment ($).
C_0 annual operating cost ($).
C_i -total discounted operating cost ($).
C_{tot} -total annual cost ($).

d_i -tube inner diameter (m).
d_o -tube outer diameter (m).
F-temperature difference correction factor.
H -annual operating time (hrs).
i -annual discount rate (%).
k -thermal conductivity (W/m).
L -tube length (mm) LMTD logarithmic mean temperature difference.
m_t -tube side mass flow rate (k/s).
n -number of tube passes.
n_1-numerical constant.
N_t-number of tubes.
P- pumping power (W).
R_s -shell side Reynold's number.
R_t- tube side Reynold's number.
R_{fs} -shell side fouling resistance.
R_{ft} -tube side fouling resistance.
T_{ci}-cold fluid inlet temperature (K).
T_{co}- cold fluid outlet temperature (K).
T_{hi}- hot fluid inlet temperature (K).
T_{ho}- hot fluid outlet temperature (K).
ΔP- pressure drop (Pa).
ΔP_t -tube elbow pressure drop (Pa).
ΔP -tube length pressure drop (Pa).

MATHEMATICAL MODEL:

The mathematical model is formed by considering the condition of heat transfer and mechanics. Then Bc is the baffle cut and Rbs is the quantitative. The both are related between baffle space and shell diameter. The variables are employed in the shell and tube device algorithmic program. Finally, these ideas permit the illustration of the algorithmic program. The variables are, outer tube diameter (Dt), Tube length (L) and tube passes (Ntp). Then the variables Dt, Ds, L and Ntp are assumption of the variables. The choice selection of variables of organized among the following in SDt, SDs, SL, SNtp and SRbs. The equation consisting of various constraints and parameters as follows:

A. HEAT TRANSFER

i) Tube side heat transfer efficient:

$$h_f = \left(\frac{k_t}{d_i}\right)\left(3.657 + \frac{\left(0.0677 * \mathrm{Re}_t * \mathrm{Pr}_t * \left(\frac{d_i}{L}\right)\right)^{1.33^{0.33}}}{1 + 0.1 * \mathrm{Pr}_t * \left(\mathrm{Re}_t * \left(\frac{d_i}{L}\right)\right)^{0.3}}\right)$$

(if $\mathrm{R}e_t$ <2300)

$$h_f = \left(\frac{k_t}{d_i}\right)\frac{\left(\left(\frac{f_t}{8}\right) * (\mathrm{Re} - 1000)\,\mathrm{Pr}_t\right)}{1 + 12.7\left(\frac{f_t}{8}\right)^{0.5} * \left(\mathrm{Pr}_t^{0.667} - 1\right)}\left(1 + \frac{d_i}{L}\right)^{0.67}$$

(if 2300< $\mathrm{R}e_t$ <10000)

$$h_f = 0.027 * \frac{k_t}{d_o} * \mathrm{Re}_t^{0.8} * \mathrm{Pr}_t^{0.667} * \left(\frac{\mu_t}{\mu_{wt}}\right)^{0.14}$$

(if $\mathrm{R}e_t$ >10000)

Where,

$$f_t = (1.82 \log 10^{\mathrm{Re}_t} - 1.64)^{-2}$$

$$\mathrm{R}e_t = \frac{\rho_t * v_t * d_i}{\mu_t}$$

$$v_t = \frac{m_t}{0.25\pi * d_t^2 * \rho_t} * \left(\frac{n}{N_t}\right)$$

$$N_t = c\left(\frac{D_s}{d_o}\right)^{n_1} \quad \Pr_t = \frac{(\mu_t * c_{pt})}{k_t} \quad d_i = 0.8 d_o$$

ii) Shell side heat transfer coefficient:

$$h_s = \frac{0.36 * k_t}{d_e} * \mathrm{Re}_s^{0.55} * \Pr_s^{0.33} * \left(\frac{\mu_s}{\mu_{wts}}\right)^{0.14}$$

$$d_e = 4 * \frac{S_t^2 - (\pi * 0.25 * d_o^2)}{\pi d_o}$$

$$d_e = 4 * \frac{0.43 S_t^2 - (\pi * 0.5 * d_o^2)}{0.5 \pi d_o}$$

$$A_s = D_s B\left(1 - \frac{d_o}{S_t}\right)$$

$$V_s = \frac{m_s}{\rho_s A_s} \quad \mathrm{Re}_s = \frac{m_s d_e}{A_s \mu_s} \quad \Pr_s = \frac{\mu_s C_{ps}}{k_s}$$

$$U = \frac{1}{\left(\frac{1}{h_s}\right) + R_{fs} + \left(\frac{d_o}{d_i}\right)\left(R_{ft} + \left(\frac{1}{h_t}\right)\right)}$$

iv) LMTD.

$$\text{LMTD} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln(T_{hi} - T_{co})/(T_{ho} - T_{ci})}$$

v) Correction Factor.

$$F = \sqrt{\frac{R^2 - 1}{R - 1}} * \frac{\ln((1-P)(1-PR))}{\ln\left(\left(2 - PR + 1 - \sqrt{R^2 + 1}\right) / \left(2 - PR + 1 + \sqrt{R^2 + 1}\right)\right)}$$

Where R is Correction coefficient

$$R = \frac{(T_{hi} - T_{ho})}{(T_{co} - T_{ci})}$$

And P is Efficiency

$$P = \frac{(T_{co} - T_{ci})}{(T_{ho} - T_{ci})}$$

vi)Heat-exchanger surface are

$$A = \frac{Q}{U * F * LMTD}$$

Where $Q = m_h * Cp_h * (T_{hi} - T_{ho}) = m_c * Cp_c * (T_{co} - T_{ci})$

vii) Tube Length

$$L = \frac{A}{\pi d_o N_t}$$

B. THE PRESSURE DROP

i) Tube pressure drop

$$\Delta P_t = \Delta P_{tube\_length} + \Delta P_{tube\_elbow}$$

$$\Delta P_t = \frac{\rho_t v_t^2}{2} * \left(\frac{L}{d_i} f_t + p \right) n$$

Where, p=4.5

ii) Shell pressure drop

$$\Delta P_s = f_s \left(\frac{\rho_s v_s^2}{2} \right) \left(\frac{L}{B} \right) \left(\frac{D_s}{D_e} \right)$$

Where,

$$f_s = 2b_o \operatorname{Re}_s^{-0.15} \; b_0 = 0.72$$

iii) Pumping power

$$P = \frac{1}{\eta} \left(\frac{m_t}{\rho_t} \Delta P_t + \frac{m_s}{\rho_s} \Delta P_s \right)$$

C. <u>OBJECTIVE FUNCTION</u>

$$C_{tot} = C_i + C_{od}$$

$$C_i = a_1 + a_{2A} A^{a_3}$$

For stainless steel heat exchanger

$$a_1 = 8000 \; a_2 = 259.2 \; a_3 = 0.93$$

$$C_{od} = \sum_{x=1}^{n1} \frac{C_o}{(1+i)^x}$$

$$C_o = PC_e H$$

H=7000 Hrs.

D. <u>CONSTRAINTS</u>

The condition are performing in this system are water and outlet of the shell and tube fluids. These are the equality constraints as follows :

$$g_1 : lb \le D_s \le ub \;\; g_2 : lb \le d_o \le ub g_3 : lb \le B \le ub$$

Therefore, the problem is to minimize

C_{tot} = 8000 +259.2S$^{0.93}$ +$\sum_{k=1}^{10} \frac{C0}{(1+i)k}$

Subject to the condition:

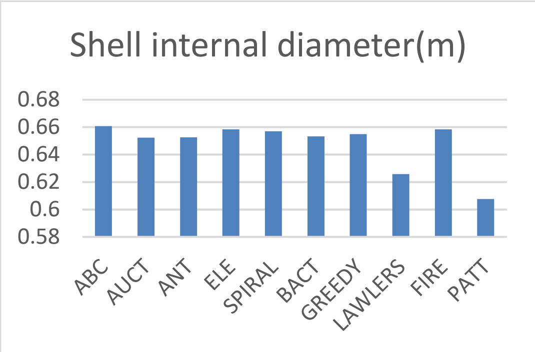
1. Shell internal diameter D_s , 0.10 m ≤ D_s ≤ 1.50 m
2. Tube outside diameter d_o ; 0.010 m ≤ d_o ≤ 0.0510m
3. Baffles spacing B ; 0.050 m ≤ B ≤ 0.50 m

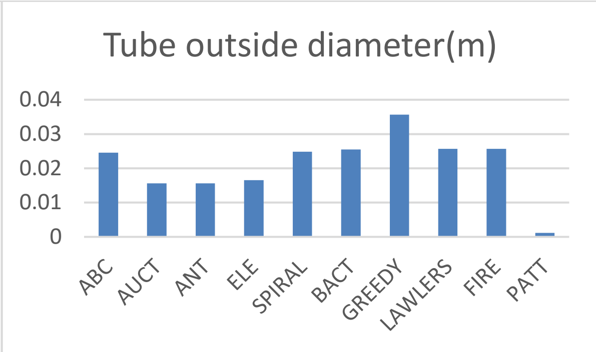
4. PARAMETERS:

The problem is solved using all the ten nontraditional optimization methods and the parameters are tabulated for comparison purpose.

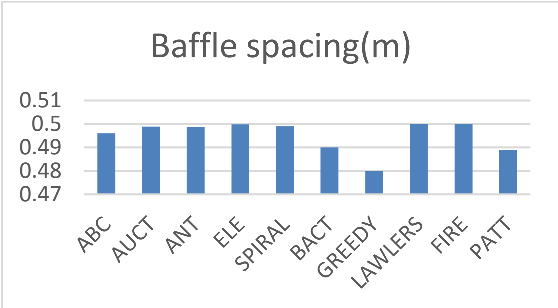
Trial No.	ABC	AUCT	ANT	ELE	SPIRAL	BACT	GREEDY	LAWLERS	FIRE	PATT
Ds(m)	0.6607441	0.65235	0.65258	0.06585	0.65699	0.65324	0.65489	0.62589	0.65844	0.607654
D_0(m)	0.02455	0.015632	0.015625	0.01654	0.02485	0.02546	0.03564	0.02563	0.02563	0.001123
B(m)	0.49606	0.4989	0.49877	0.04999	0.499	0.49	0.48	0.5	0.5	0.4889
Time(sec)	0.4745	0.45	0.4503	0.41	0.45515	0.42	0.43	0.41	0.41	0.33

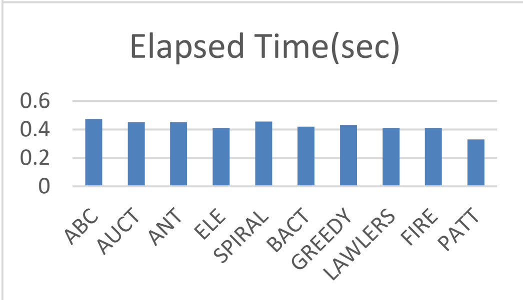
Cost($)	45731	45698	45786	45546	46000	45698	46985	44968	44481	43894



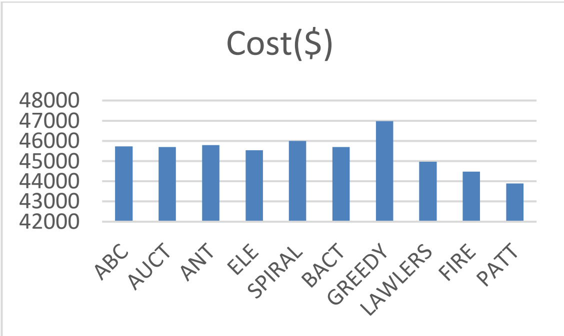


X axis = ten methods, Y axis = Internal diameterX axis = ten methods, Y axis = tube outside diameter





X axis = ten methods, Y axis = Baffle spacing X axis = ten methods, Y axis = Elapsed time (sec)



X axis = ten methods, Y axis = cost

5. RESULTS AND DISCUSSION.

The cost minimization of shell and tube exchanger problem is solved by ten nontraditional methods in optimization. All ten algorithms are implemented using MATLAB.The problem is made to run 20 trails. From the above graph we observe that shell internal diameter is less in pattern search (0.607) followed by Lawler's method (0.625m). The outside diameter is minimum in pattern search method (0.001m) followed by ANT lion algorithm (0.0156m). The baffle spacing is minimum in Greedy algorithm (0.48m) followed by pattern search algorithm (0.4889m).The elapsed time is minimum in pattern search method (0.33sec) comparing other methods. Finally the cost ($) is minimum in pattern search method (43894). From the above result we conclude that pattern search algorithm have minimum evaluation.

6. CONCLUSION

In this paper ten algorithms are proposed and applied to solve engineering design problem. The simulation results presented in ABC algorithm, Auction, Ant lion, Elephant herding, Spiral, Bacterial colony, Greedy, Lawler's, Fireworks and Pattern search these ten non-traditional optimization methods tested effectively. Then the three proposed algorithms are Lawler's (44968), firework (44481) and pattern search algorithm (43894)is provided minimum cost($).In the three methods the pattern search method is minimum (43894).The above results shows that pattern search method is better than other methods.We conclude that pattern search algorithm have minimum evaluation and minimum cost.

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