International Journal of Application on Sciences, Technology and Engineering (IJASTE)
Volume 1, Issue 1, 2023.ISSN:2987-2499

Numerical Analysis of Single Segmental Baffles Cut Angle of 0^0, 15^0 and 30^0

Harto Tanujaya[1,a)], Steven Darmawan[1,b)], and Jason Prathana[1,c)]

[1]*Mechanical Engineering Study Program, Faculty of Engineering, Universitas Tarumanagara*

[a)] *Corresponding author: hartotan@ft.untar.ac.id*
[b)]*stevend@ft.untar.ac.id*
[c)]*jason@student.untar.ac.id*

Submitted: November-December 2022, Revised: January 2023, Accepted: February 23, 2023

Abstract. A heat exchanger (HE) is usually used as one of the equipment in the manufacturing process. The efficiency of the HE is improved to reduce the operating cost. This research examined the baffles with 0^0, 15^0, and 30^0 angle cutting shapes. Parameters are used to calculate temperature (K), velocity (m/s), and pressure distribution (Pa). The fluids that are used in the system of one phase and liquid (water) – liquid (water). The purpose of the study was to obtain the phenomena of the velocity and pressure distribution with the variation of the baffles with angle cutting shape. The velocity of the fluid of shell detects highest when the fluid pass at each baffle. The eddy current surrounds the baffle lowest using baffles with a cut angle of 30^0. The phenomena and distribution of the fluid have the same condition in the 3D model of HE with the full model and symmetric model one

INTRODUCTION

Heat exchanger (HE) is one of tools to transfer the energy in the form of the heat, between two fluids with difference temperatures. The system can use the gas or liquid fluids. HE is widely used in the industrial manufacturing to support the production. HE is one of the equipment that are influence the smoothness of the production, because if the system or the equipment has a problem will cause the operational production problems. One type of the HE usually used in the industry is Shell and Tube Heat Exchanger (STHE). Design of the STHE is a non-compact heat exchanger, the surface area of heat transfers per unit volume of 50 to 100 m^2/m^3. Baffle is one of the important parts in the HE. The baffles are used to increase the heat transfer with the streamlines between the shell side and the tube side and also to support the construction and decrease the vibrations of the system. The type of baffles are plate type and rod type [1]. Commonly, the plate type consists of single segmental baffle, double segmental baffle, and triple segmental baffle. The single segmental baffle is the common use in wide area.

Many researchers around the worlds have investigated to increase the performance and effectiveness the HE. Missirlis et al. [2] investigate the heat transfer and flow field of the heat exchanger designed for aero engine applications using experimental study and CFD computation. Tanujaya and Sukania [3] investigate the performance and effectiveness of the prototype of shell-and-tube heat exchanger using stationary-head with ring rubber clamp, using single segmental baffle type. Tanujaya and Darmawan [4] also investigates the shell-and-tube heat exchanger (STHE) with disc-and-doughnut baffles type and 40% cut segmental baffles using numerical method. This study will analyze and examine the baffles which cut tilt 15^0 and 30^0 angle cutting shape.

THEORY, DESIGN, MATERIAL AND METHODS

The theory of heat transfer is used to calculate the phenomena of conduction, convection, and thermal radiation also the turbulent flow in the system, also the variation of them or in collaboration with other physical property [5]. The conservation law is used that complete the continuum mechanics theory; the law of conservation of mass, conservation of linear momentum, and conservation of angular momentum [6]. In the system, two kinds of flow, inside the tube (hot fluid) and outside the tube – inside the shell (cold fluid). Inside the tube is calculated based on the research result of

https://doi.org/10.24912/ijaste.v1.i1.204-209

Dittus-Boelter using automobile radiators of tubular type for internal flow, with n = 0.4 (shell) for heating and n=0.3 (tube) for cooling [7].

$$0 = \frac{\rho}{t} \ (\rho u) \qquad (1)$$

$$\rho \frac{u}{t} + \rho(u \ )u = \ \ +Fv \qquad (2)$$

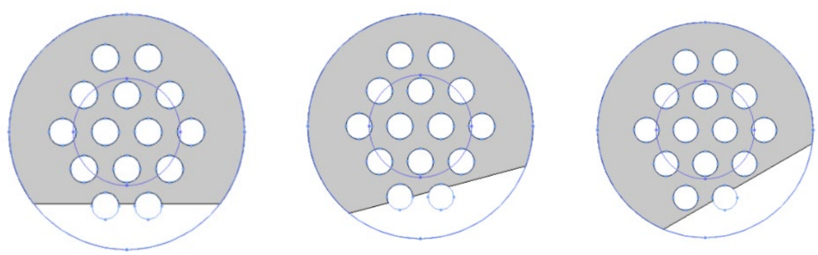
$$^{T} = \qquad (3)$$

The HE equipment used in this study is STHE. The simulation model design using laboratory type scale. Dimension of the STHE, the diameter of the shell is 55 mm, with plexiglass material (acrylic). The diameter of the tube is 6.35 mm with copper material. The total length of the STHE is 743 mm. the number of the tubes are 14. The diameter of inlet and outlet shell and tube are 25 mm. The tube arrangement uses a triangular arrangement with a rotation of 30^0. Both the fluids are water, the inlet temperatures of the shell and tube are maintained and set of 278.15 K and 373.15 K, respectively as shown in Table 1. The velocity of the fluid entering the shell is 5 m/s, and the velocity of the fluid entering the tube is at a speed of 5 m/s. This type of fluid flow calculation uses the principle of turbulent k-ε model. Fluid characteristics using the fluid properties of water.

TABLE 1. Characteristic of fluid

	Tube	**Shell**
Fluid	water	water
Temperature inlet (K)	373.15	278.15
Convective heat transfer coefficient (W/m^2K)	535	535

The geometry model of the baffles using baffles modification, 8 baffles with cutting angle of 0^0, 15^0, and 30^0, as shown in Figure 1.



(a) (b) (c)

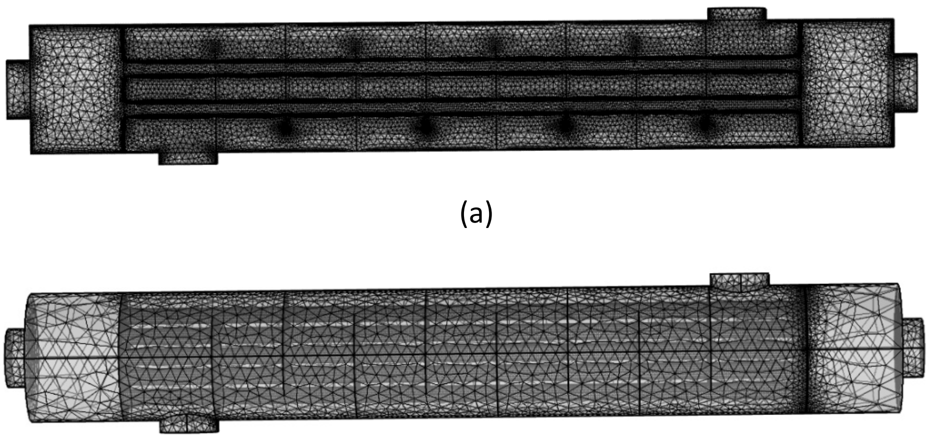
FIGURE 1. Baffles cutting angle of (a) 0^0, (b) 15^0, and (c) 30^0

The distribution of temperature, velocity and pressure was analyzed using COMSOL 5.2a software. Iteration for each case of different flow rates takes between 56 minutes for geometric models with symmetrical cuts and 2 hours, 30 minutes for geometry models without it. The inlet velocity of shell and tube are 5 m/s, and calculate using a 10th generation Pentium i7 Processor, 16 GB of RAM. The geometry meshes a free tetrahedral type with a 15^0 cut angle baffle arrangement symmetrically, as shown in Figure 2. The number and size of the meshes are,

- Number of vertex elements: 702
- Number of edge elements: 14341
- Number of boundary elements: 114504
- Number of elements: 1010232
- Free meshing time: 23.47s
- Minimum element quality: 0.00438
- Number of vertex elements: 702

https://doi.org/10.24912/ijaste.v1.i1.204-209

- Number of edge elements: 8716
- Number of boundary elements: 53102
- Number of elements: 232567
- Free meshing time: 10.78s
- Minimum element quality: 0.003954
- Number of vertex elements: 702
- Number of edge elements: 4813
- Number of boundary elements: 18886
- Number of elements: 68641
- Free meshing time: 5.84s
  Minimum element quality: 0.002646



(a)

(b)

FIGURE 2. The complete geometry of free tetrahedral (a) symmetrical cut, (b) full model

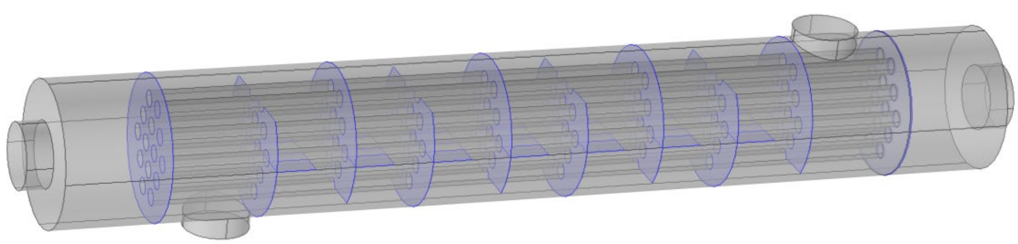


FIGURE 3. Baffles 0^0 cut angle

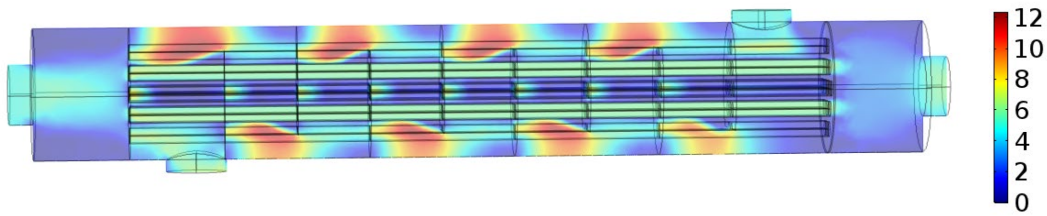
Figure 3 show the full model design and the position of the baffles with 0^0 cut angle. The amounts of baffle are 8. Domain of the tube consist of 14 tubes that are connect with stationary head on the left and right side of the shell. The shell envelopes the all of the tubes. The distance from one side to the other side of the pipe with baffle is 60 mm.

RESULT AND DISCUSSION

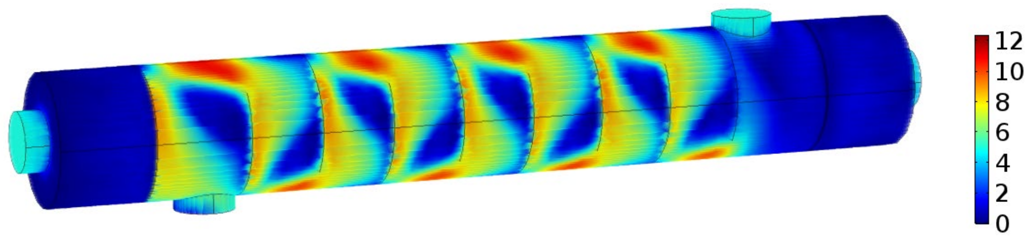
Figures 4 to 6 show the HE using the baffles with cut angle of 0^0, 15^0, and 30^0, respectively. In the Figure 4(a), 5(a), and 6(a), the velocity distribution using the model that is symmetrical cut. The velocity of the fluid of shell shows highest when the fluid pass at each baffle. There are some eddy current surrounds the baffle, which are decrease the heat transfer in the shell. The eddy current at Figure 6 (a) lowest than the other. This indicate that using baffles with

https://doi.org/10.24912/ijaste.v1.i1.204-209

cut angle 30^0 will increase the turbulence phenomena in the shell. The phenomena and distribution of the fluid has not same condition at the 3D model of HE with full model as show at Figure 4(b), 5(b), and 6(b). The Figure using 3D full model show almost same detail the phenomena of the velocity distribution at the system in the shell, but the difference phenomena shown at the bottom of the shell, at the Figure 6(b) the turbulence and high velocity of the fluid look clearer. The difference of illustration between figure with symmetrical cut 4(a), 5(a), and 6(a) with figure with full model 4(b), 5(b), and 6(b) are caused by the cutting of the baffles with cut angle of 0^0, 15^0, and 30^0 are not symmetry form of the left and right side.

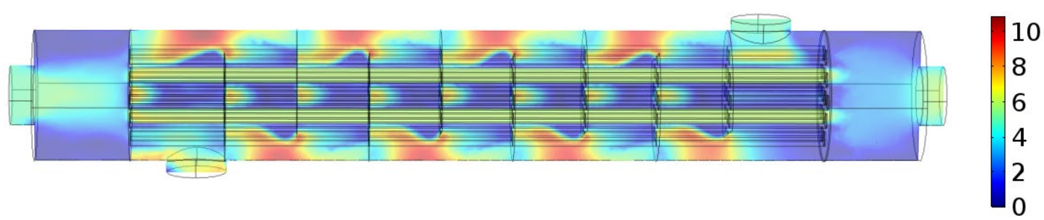


(a)

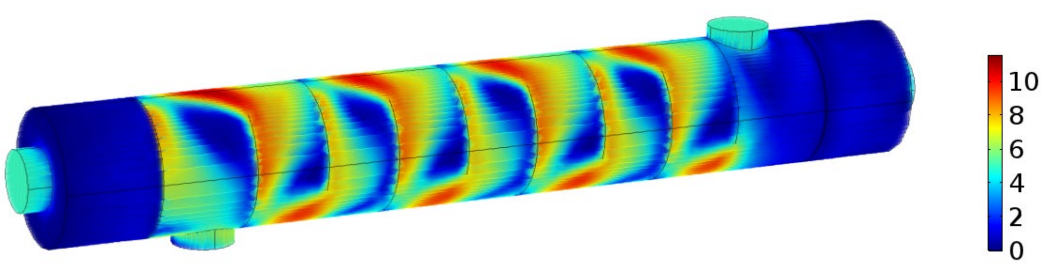


(b)

FIGURE 4. Velocity distribution with baffle cut angle of 0^0 (a) symmetrical cut, (b) full model



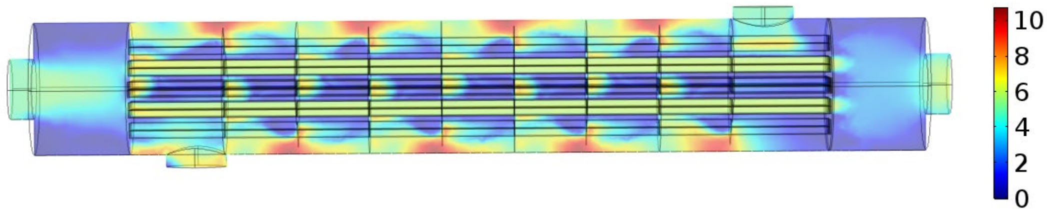
(a)



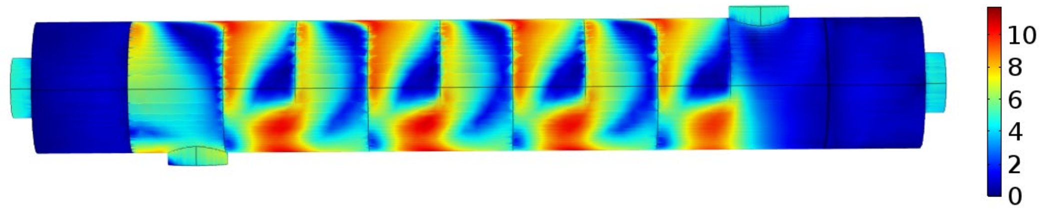
(b)

FIGURE 5. Velocity distribution with baffle cut angle of 15^0 (a) symmetrical cut, (b) full model

https://doi.org/10.24912/ijaste.v1.i1.204-209

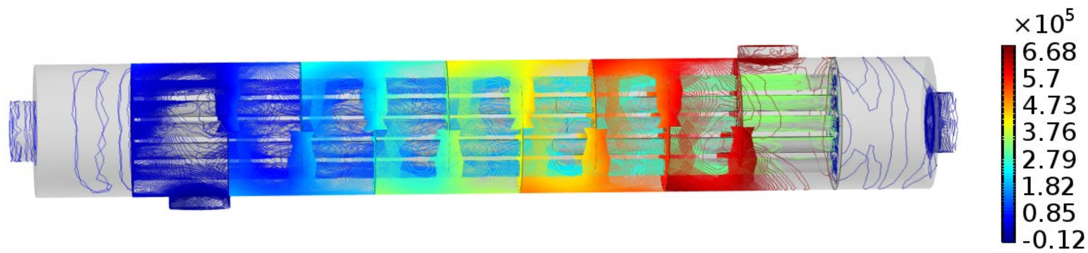


(a)

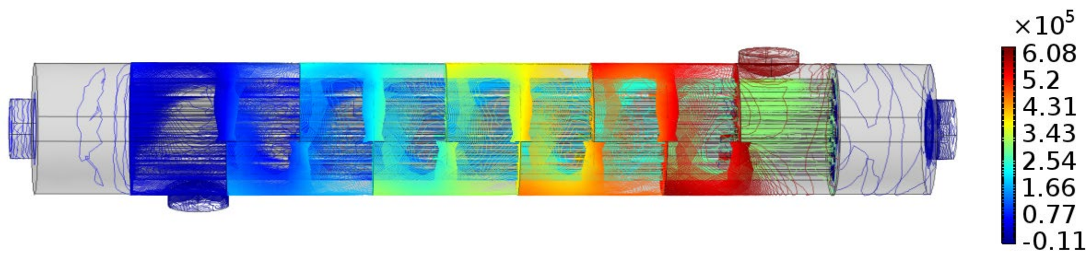


(b)

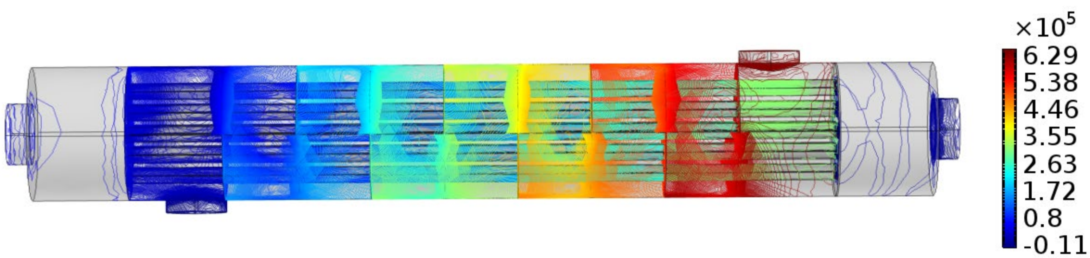
FIGURE 6. Velocity distribution with baffle cut angle of 30^0 (a) symmetrical cut, (b) full model



(a)



(b)



(c)

FIGURE 7. Pressure distribution symmetrical cut with baffle cut angle of (a) 0^0, (b) 15^0, and (c) 30^0

Figure 7 show the pressure distribution of symmetrical cut with baffle cut angle of 0^0, 15^0, and 30^0. The pressure increases when the fluid hits and enter pass through the baffle. At the outlet side of the shell for baffle cut angle 30^0 show the line of pressure distribution has lower than the baffle cut angle of 15^0, but higher than the baffle cut angle of

https://doi.org/10.24912/ijaste.v1.i1.204-209

0^0. The highest pressure detect using the baffle cut angle of 0^0 is 6.68 x 10^5 Pa and the lowest pressure detect using the baffle cut angle of 15^0 is 6.68 x 10^5 Pa.

CONCLUSION

The Heat exchanger (HE) performance improvement needs to be done. The velocity of the fluid of shell detects highest when the fluid pass at each baffle. The eddy current surrounds the baffle lowest using baffles with cut angle of 30^0. The phenomena and distribution of the fluid has same condition at the 3D model of HE with full model and symmetric model one.

ACKNOWLEDGMENTS

This work is supported and funded by Institute of Research and Community Engagement (LPPM) Universitas Tarumanagara, Indonesia. The authors wish to thank all of the participating personnel for their help, support and suggestions.

REFERENCES

1. Bergman, T. L., Lavine, A. S., Incropera, F. P. & Dewitt, D. P. *Fundamentals of Heat and Mass Transfer*. (John Wiley & Sons, 2011).
2. Missirlis, D., Flouros, M. & Yakinthos, K. Heat transfer and flow field investigation of a heat exchanger for aero engine applications. *International Journal of Heat and Technology* **29**, 57–64 (2011).
3. Tanujaya, H. & Sukania, I. W. Experimental Study of Stationary-Head/Channel Cover STHE Prototype Using ε-NTU Method. *Experimental Techniques* **43**, 645–655 (2019).
4. Tanujaya, H. & Darmawan, S. Investigation of flow of the disc-and-doughnut baffles and 40% cut segmental baffles. *International Journal of Heat and Technology* **39**, 1541–1548 (2021).
5. Multiphysics, C. Heat Transfer Module User's Guide. *Module* **COMSOL 5.2**, 1–512 (2016).
6. Holmann, J. P. *Heat transfer*. (McGraw-Hill Series in Mechanical Engineering, 2010).
7. Dittus, F. W. & Boelter, L. M. K. Heat transfer in automobile radiators of the tubular type. *International Communications in Heat and Mass Transfer* **12**, 3–22 (1985).

https://doi.org/10.24912/ijaste.v1.i1.204-209