Numerical Study Of The Influence Of Air Flow Through Rectangular Elbow 90° With Triangle Inlet Body Disturbance

Luke Ezra Faradis[(1)], Nur Fatowil Aulia*[(2)], Ahmad Hamim Su'udy[(3)], Yanuar Mahfudz Safarudin[(4)], Mulyono[(5)], Baktiyar Mei Hermawan[(6)], Bayu Sutanto[(7)]
[1,2,3,5,6]*Department of Mechanical Engineering, Politeknik Negeri Semarang*, Semarang, Indonesia
[4]*Department of Electrical and Communication Engineering, United Arab Emirates University, Al Ain, Uni Emirat Arab*
[7]*Department of Mechanical, Aerospace, and Civil Engineering, University of Manchester, Manchester, United Kingdom*
Email address : ***nurfatowil.aulia@polines.ac.id**

***Abstract*— This research is to determine the effect of air flow flowing through a 90° square elbow with the additional shape of a triangle inlet disturbance body. Simulations were carried out using the Computational Fluid Dynamics (CFD) method to analyze air flow characteristics and changes in flow patterns due to the presence of additional triangular shapes in the flow channel. Numerical simulations are carried out by taking the 90° square elbow geometry as the basic model and adding an additional triangle inlet disturbance body shape to it. The simulation results show that the triangle inlet disturbance body significantly influences the air flow inside the elbow. This effect can increase turbulence producing different pressure and velocity contours along the elbow. The effect of flow velocity on the flow in the elbow results in a higher velocity if the form of disturbance is also greater. This research could provide greater understanding of the influence of additional components on fluid flow in channels with similar geometries, opening up potential applications across a wide range of industries.**

***Keywords*— Air flow simulation, Triangle Disturbance, Pressure, Speed**

I. INTRODUCTION (*HEADING 1*)

Along with technological developments and the increasing population, vertical development has become an option today. In big cities throughout the world you can find many skyscrapers built and used for various purposes. Likewise in Indonesia, big cities have many skyscrapers that function as office centers, hotels, and so on. Buildings built vertically like this certainly require air conditioning ducts[1-5].

Air ducts (ducting systems) in the industrial world are not only in the form of straight pipes, but also have fittings in the form of branching ducts, merging ducts, or bending ducts. Examples of fittings used in air ducts are 90° elbows and dampers (valves). The use of a 90° elbow will cause a pressure drop due to friction loss, separation loss and secondary flow that occurs after passing the 90° elbow. To reduce separation loss and secondary flow, add a guide vane to the 90° elbow. [6-8]

The addition of disturbance to a 90° elbow as per research [6] at a low Reynolds number is able to reduce the pressure drop, but at a higher Reynolds number it fails to reduce the pressure drop. Furthermore, a new problem can be discovered, namely by combining the addition of disturbance to the 90° elbow which is filled with fluid at various sizes. [9-10]

The disturbance is expected to provide information regarding the pressure drop in the rectangular cross-section air duct. An effort to reduce the pressure drop that occurs in the 90° elbow is by adding disturbance to the 90° elbow and a triangle shaped disturbance body before the 90° elbow inlet. The addition of disturbance is intended to minimize the effect of flow separation on the elbow wall.[11-13]

By adding disturbance, it is hoped that the possibility of secondary flow formation at the elbow can also be reduced. Meanwhile, the addition of a triangle disturbance inlet body is aimed at delaying the separation point and making the flow have a strong turbulence intensity. The stronger the turbulence intensity causes the flow momentum to become stronger so that it is able to resist the adverse pressure gradient.[14-15]

The triangle-shaped disturbance body or what is called the triangle disturbance inlet body (TDIB) is placed in the upstream duct at a distance of 12.5 mm from the inlet elbow, gap distance (g/Dh) = 2.5 in the direction of the disturbance, and the elbow is 90° with R/Dh = 125 mm with the addition of a single disturbance. Next, it was varied with a flow velocity of 8 m/s-1 or a number ReDH = 6.37 x 104, so this research used turbulent flow (Re > 4000). The phenomenon of flow interaction in the air duct related to these variations can be displayed by the pressure drop in the entire air duct as well as visualization of the velocity contour. By reducing drag force, there will be a decrease in minor head loss so that the pressure drop value that occurs will also be smaller. Several approaches were made to observe the behavior of air fluid flow in 90° elbow channels.

II. METHODS

This research was carried out with the help of fluent 19.2 software using the standard k-ε turbulence model. Near Wall Treatment used uses Standard Wall Function. The differences in variations between the various disturbance dimensions are then analyzed and compared in the discussion. The data analyzed includes: Pressure Drop of air flow in the 90° elbow pipe and visualization of the velocity contour in the 90° elbow pipe.

https://jurnal.polines.ac.id/index.php/eksergi

ISSN 0216-8685 (print); 2528-6889 (online)

In this experiment, the range contours were global. The global range is a measurement parameter between minimum and maximum which will automatically be read by the simulation results without rounding restrictions. Determining the global range countours was carried out by experimenting with 3 variations of disturbance size, after which the minimum and maximum pressure points were found in the simulation results.

This numerical research has a ducting shape with a square cross-section (rectangle), divided into three large connected parts, namely the upstream duct, 90° elbow and downstream duct. At the upstream duct, a triangular inlet disturbance body is installed. The specifications of the test section of this research can be described as follows:

Table 1. Dimension Object Simulation

Dimension	
Upstream duct length (L1)	7 Dh
Downstream duct length (L2)	15 Dh
Rectangle duct side	125 x 125
Imaginary axis distance (R)	250
Elbow radius of curvature 90° (R/Dh)	2
Hydraulic diameter (Dh)	125
Size of triangle disturbance body I	10
Size of triangle disturbance body II	15
Size of triangle disturbance body III	20
Gap (g)	2.5
Distance between triangle and inlet elbow (l)	12.5

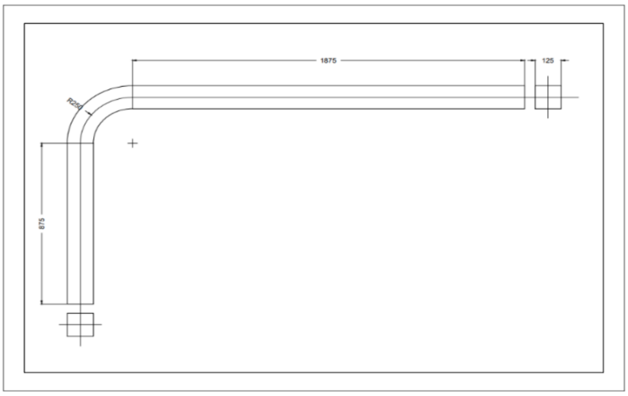


Fig. 1. Geometri of Elbow 90°

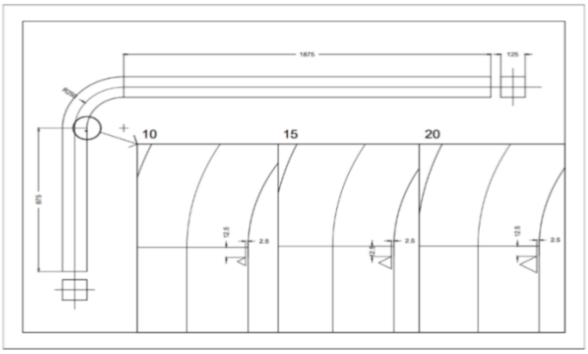


Fig. 2. Detail position of triangle inlet disturbance body

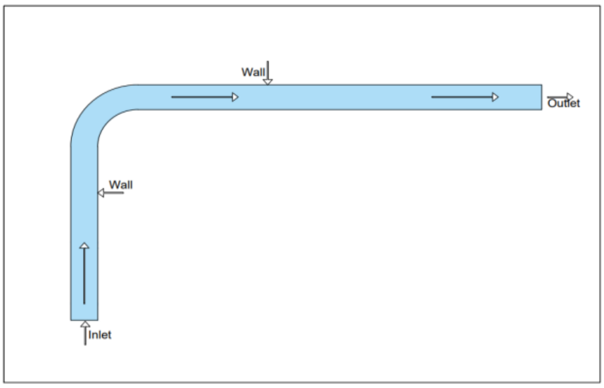


Fig. 3. Boundary Condition of Model

Defining boundary conditions is determining the parameters and limitations that may occur in the flow. The inlet boundary condition is the inlet velocity and the outlet boundary condition is the outflow. In this meshing simulation, quadrilateral is used because the number of sides is greater, making quadrilateral meshes tend to have faster computing and convergence processes, because the greater the number of data transfer meshes that occur during the computing process, the faster it will be. The meshing volume used is quadrilateral type. The statistics show that nodes are 25229 while elements are 24418. this is shown in the fig.5 .

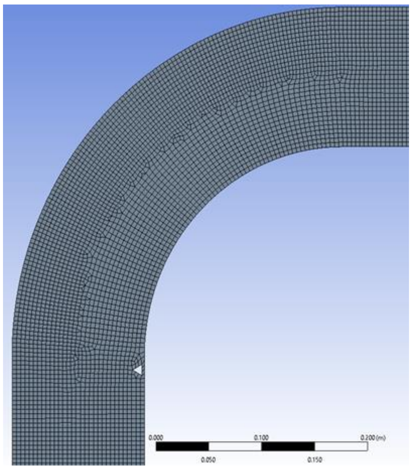


Fig. 4. Meshing details on channels with 90° elbows with disturbance

https://jurnal.polines.ac.id/index.php/eksergi

ISSN 0216-8685 (print); 2528-6889 (online)

III. Results and Discussion

The analysis results are shown as follows :

A. *Grid independence test*

Grid independence is needed to obtain data accuracy in the post processing step. The calculation results that have been obtained can be compared with existing experiments. If the modeling results are close to the patterns and values of the experimental data, it means that the input is appropriate. If it does not match or is far from the experimental results, then the modeling input can be corrected.

Table 2. Result of Grid Independence Test

Turbulent Model (k-ε Standard)				
Mesh	Jumlah Mesh (cells)	y+ max	Pressure Drop (pa)	Error of Eksperimen (%)
Eksperimen	-	-	46.950	-
Mesh A	19920	23.41	48.858	4,063%
Mesh B	21823	14.43	48.905	4,164%
Mesh C	22568	17.69	48.011	2,259%
Mesh D	24418	15.97	47.206	0,545 %
Mesh E	26786	19.78	49.121	5,925%

As a result of the grid independence that has been carried out, data is obtained from the five variations in mesh density, namely in the form of pressure drop data and the number of mesh cells. This data is then compared with the pressure drop results from the experiment.

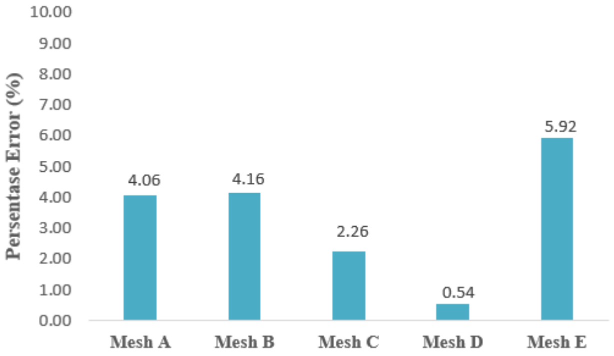


Fig. 5. Meshing *Test of* Grid Independence Test

From the turbulence model used, namely k-ε standard, error data was obtained from each mesh variation, where the smallest error was found in the D mesh variation with an error value of 0.545%, thus to analyze this numerical study, the D model meshing variation was used.

B. *Result of Pressure Drop*

The simulation results of the pressure drop are shown in the figure 6. By varying the size of disturbance on the bend pipe. So that it affects the results of the contour values and conditions

The simulation results on elbows without disturbance show that the outer elbow experiences quite strong pressure in the range of 42.24 Pa to 47.21 Pa. Meanwhile, the centerline elbow experienced a decrease in pressure as shown by yellow flow with a range of 32.30 Pa to 39.75 Pa. The air flow on the inner elbow side decreases gradually so that it can be seen in the simulation in green, light blue and dark blue in the range of 2.48 Pa to 29.81 Pa.

The simulation results accompanied by a disturbance measuring 10 show that the pressure point at the outer elbow is greater, namely 40.28 Pa to 51.84 Pa. On the centerline side of the elbow the pressure is 36.43 Pa to 21.03 Pa. Furthermore, on the inner elbow side it is 17.18 Pa to 1.77 Pa.

Furthermore, the 15 size disturbance variation shows that the pressure point on the outer elbow is greater, namely 38.99 Pa to 57.52 Pa. On the centerline side of the elbow the pressure is 20.46 Pa to 34.36 Pa. Furthermore, on the inner elbow side it is 15.83 Pa to 1.93 Pa.

With a variation of 20, the simulation results show that the pressure point on the outer elbow is greater, namely 39.55 Pa to 65.99 Pa. On the centerline side of the elbow the pressure is 13.36 to 34.27 Pa. Furthermore, on the inner elbow side it is 7.84 to 2.55 Pa. This causes the flow momentum produced by adding TIDB to be greater to counter the adverse pressure that occurs due to the curvature of the elbow so that the resulting pressure drop is smaller.

The presence of a disturbance causes the pressure drop value to decrease, this happens because with the disturbance the flow velocity at the elbow increases and the momentum of the flow increases which makes the flow separation smaller so that the pressure drop is reduced (Bimantoro, 2017). The pressure drop value without TIDB is smaller than using TIDB, the highest pressure drop occurs at a variation of 20 mm and will be higher as the disturbance size value increases.

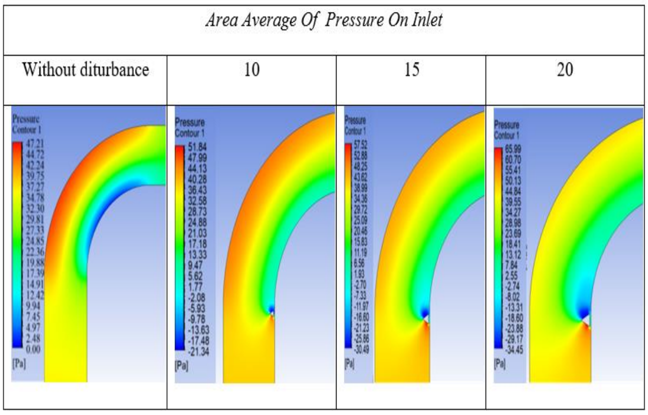


Fig. 6. Result CFD of Pressure Drop

In Figure 7, it can be seen that if the pressure drop value is reviewed for each existing section, it can be seen that the addition of disturbance can cause a decrease in the pressure drop. The sections that will be reviewed include the upstream, outer elbow, inner elbow and downstream areas.

https://jurnal.polines.ac.id/index.php/eksergi

ISSN 0216-8685 (print); 2528-6889 (online)

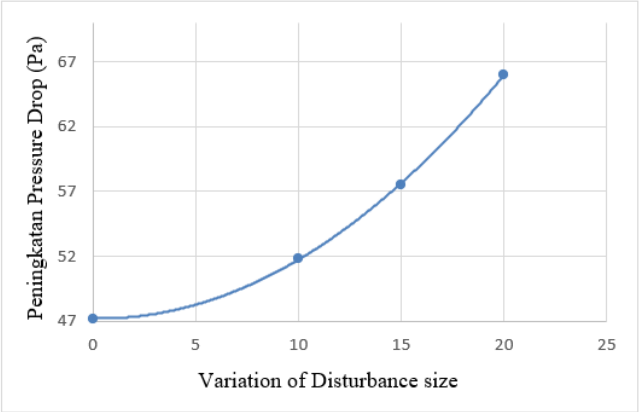


Fig. 7. Graph of the relationship between variations in disturbance size and pressure drop

C. *Result of Velocity Contour*

The simulation results of the Velocity Contour are shown in the figure 8. By varying the size of disturbance on the bend pipe. So that it affects the results of the contour values and conditions.

The simulation results of velocity contour visualization without disturbance show that the outer elbow pressure that is passed is in the range of 4.23 m/s to 7.40 m/s. On the centerline side to the inner elbow there was an increase with a value ranging from 8.45 m/s to 10.04 m/s. In the inlet elbow that passes through the ducting without disturbance, there is a change, namely the speed at the inner wall position is greater than the outer wall side, the speed value is constant or constant at 8 m/s, the speed contour experiences differences on the inlet elbow side and the outlet elbow side. On the inlet side of the contour the speed range is in the range of 7.40 m/s to 8.45 m/s. Meanwhile at the outlet elbow there was an increase in speed in the range of 7.93 m/s to 9.40 m/s. In the simulation without disturbance, there is no visible backflow in the horizontal or vertical plane. This is confirmed by the color gradation shown by the speed contour, where in this section there is only a decrease in speed

Simulation experiments to visualize velocity disturbance measuring 10 on a 90° elbow pipe shown with detailed contours including variable velocity resulted in a minimum velocity of 0 m/s, while a maximum velocity of 10.385 m/s. In the flow towards the outer wall side the flow speed is lower in the range of 3.83 m/s to 7.11 m/s while the flow towards the centerline wall side is higher, 8.75 to 10.39 then at the inner wall there is a significant decrease in speed. shown in yellow to light blue in the range of 57.11 to 2.19 due to additional disturbance. The addition of this triangle-shaped disturbance also creates a backflow, this is due to the effect of the gap between the disturbance and the wall ducting.

In the visualization simulation of velocity disturbance measuring 15 on a 90° pipe elbow with detailed contours including variable velocity, the minimum velocity measurement results were 0 m/s, the maximum velocity measurement was 10.0395 m/s. In the flow towards the outer wall, the flow speed is lower in the range of 3.83 m/s to 7.11 m/s. The flow on the centerline wall experienced an increase in speed in the range of 8.72 m/s to 10.46 m/s then on the inner wall there was a decrease in speed as shown in yellow to light blue in the range of 7.55 m/s to 2.32 m /s. At size 15, this shows that the flow speed decreases after adding disturbance. The addition of the disturbance triangle makes the flow calmer.

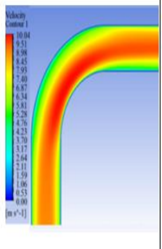
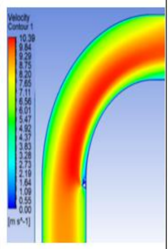
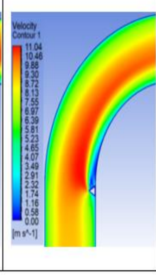
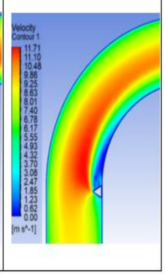
Area Average Of Pressure On Inlet			
Without disturbance	10	15	20
			

Fig. 8. Result CFD of Velocity Contour

Furthermore, with a variation of 20, the minimum velocity measurement result is 0 m/s, while the maximum velocity measurement is 11.7141 m/s. Then for color variations, use contours 400. In the flow towards the outer wall, the flow speed is lower in the range of 4.93 m/s to 9.25 m/s. Meanwhile, when disturbance is added to the elbow, the shape of the speed contour shows the presence of backflow. This happens because the damper leaves little space for flow to pass in the outer and inner wall areas. On the centerline wall side there was an increase in speed in the range of 9.86 m/s to 11.71 m/s then on the inner wall there was a decrease in speed which was shown in green to dark blue in the range of 7.40 m/s to 0.62 m/s. s. In this simulation, the flow velocity decreases after adding disturbance. With the addition of the disturbance triangle at 20, this produces better results from the inner and outer walls. The high air flow speed is actually on the centerline side which makes the elbow better due to reducing the level of friction on the outer and inner elbow.

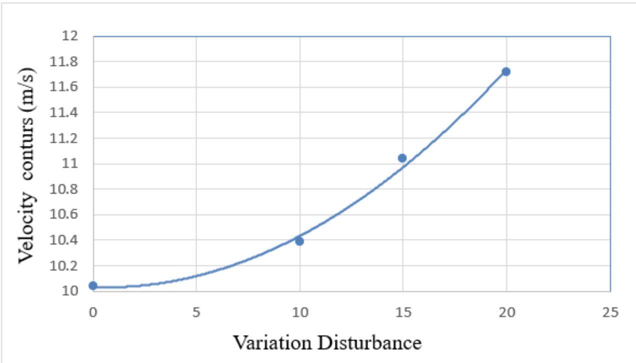


Fig. 9. Graph of the relationship between variations in disturbance size and velocity conturs

In graphic Figure 9, the addition of disturbance in the form of a triangle to the inlet elbow has an influence on the visualization of the velocity contour in the air duct with a 90° rectangle elbow. This shows that the flow in the elbow pipe with the addition of the triangle inlet disturbance body has greater momentum than the flow in the ducting without the triangle inlet disturbance body. So that flows that have greater

https://jurnal.polines.ac.id/index.php/eksergi

ISSN 0216-8685 (print); 2528-6889 (online)

momentum are able to reduce the effects of shear stress from disturbances. As a result, the losses that occurred due to additional disturbances could be slightly resolved

IV. Conclusion

Based on the simulation results, the following conclusions are obtained:

1. There is the addition of TIDB (Triangle Inlet Disturbance Body) to the pathline contour that is formed in each different variation, where the effect of adding disturbance turns out to make the base vortex formed stronger so that the pressure drop that occurs is greater. On the outer wall the highest pressure is at a variation of size 20 , then on the centerline side the pressure is highest at a disturbance variation of 10 mm and on the inner wall the pressure is highest at a disturbance variation of size 10.

2. From the simulation results of the velocity contour visualization, it is concluded that the simulation calculation contours of variations are 0: 10,039 m/s, 10 : 10,385 m/s, 15 : 11,039 m/s and 20: 11,714 m/s . Meanwhile, for a constant speed of 8 m/s, the additional air flow disturbance to speed (velocity) is stronger towards the outer side (wall) of the elbow which is caused by the curvature of the elbow.

References

[1] Bimantoro, Abdullah. 2017. Studi Numerik Aliran melalui Square Duct dan Square Elbow 90° dengan Square Disturbance Body pada Inner Upstream Duct. *Surabaya, Teknik Mesin Jurnal Teknik ITS, 3(13). https://doi.org/10.12962/u23376634.v24i0.74553*

[2] Cheng, D.Y. 1994. Laminar Flow Elbow System and Method. U.S. *Journal Patent Documents, No. 5,323,661.*

[3] Dutta, P., & Nandi, N. (2015). Effect of Reynolds number and curvature ratio on single phase turbulent flow in pipe bends. *Journal of Mechanics and Mechanical Engineering*, *19*(1), 5–16.

[4] Faila, R. N., & Sutardi. (2018). Studi Numerik Karakteristik Aliran Fluida Melalui Rectangular Elbow 90 derajat dengan Diamond Inlet Disturbance Body. Teknik Mesin Jurnal Teknik ITS, 21(3). https://doi.org/59.92872/l23745434.v14i9.9843

[5] Halwan, (2016). Studi eksperimen aliran melalui square duct dan square elbow 900 dengan single guide vane pada variasi sudut bukaan damper, tm 091585(Air flow ducting), *Jurnal Fakultas teknologi industri institut teknologi sepuluh nopember surabaya 1-102. https://doi.org/-Undergraduate_Thesis.pdf*

[6] Jaya Nazar, A., & Aries Widodo, W. (2017). Studi Eksperimen Aliran Melalui Square Duct dan Square Elbow 90° dengan Double Guide Vane pada Variasi Sudut Bukaan Damper. *Jurnal Teknik ITS*, *5*(2). https://doi.org/10.12962/j23373539.v5i2.20360

[7] Mahir, N. (2009). Three-dimensional flow around a square cylinder near a wall. *Journal Ocean Engineering*, *36*(5), 357–367. https://doi.org/10.1016/j.oceaneng.2009.01.002

[8] Ozgoren, Muammer. 2006. Flow Structure in the Downstream of Square and Circular Cylinders. Turkey : Department of Mechanical Engineering.Putera, N. F. A. F. (2018). Studi Numerik Aliran Melalui Square Duct dan Square Elbow 90° Single Guide Vane dengan Square Disturbance Body pada g/Dh = 0,5 dengan Variasi Jarak Longitudinal. *Institut Teknologi Sepuluh November 2*(21).

[9] Rup, K., Malinowski, Ł., & Sarna, P. (2011). Measurement of flow rate in square sectioned Duct Bend. Journal Of Theoretical And Applied Mechanics, 49, 301–311.

[10] Yudhatama, I. W., & Hidayat, M. I. (2018). Simulasi Computational Fluid Dynamics (CFD) Erosi Partikel Pasir dalam Aliran Fluida Gas Turbulen pada Elbow Pipa Vertikal - Horizontal. *Jurnal Teknik ITS, 7(2), 134–139.*

[11] Yalin Li, Xikun Wang, Shouqi Yuan, Soon Keat Tan. 2016. “Flow development in curved rectangular ducts with continuously varying curvature”, Experimental Thermal and Fluid Science, 75 1-15.

[12] G.-D. Xia, X.-F. Liu, An investigation of two-phase flow pressure drop in helical rectangular channel, Int. Commun. Heat Mass Transfer 54 (2014) 33–41.

[13] T.T. Chandratilleke, N. Nadim, R. Narayanaswamy, Vortex structure-based analysis of laminar flow behavior and thermal characteristics in curved ducts, Int. J. Therm. Sci. 59 (2012) 75–86

[14] J. Guo, M. Xu, L. Cheng, Second law analysis of curved rectangular channels, Int. J. Therm. Sci. 50 (2011) 760–768.

[15] H. Fellouah, C. Castelain, A. Ould El Moctar, H. Peerhossaini, The Dean instability in power-law and Bingham fluids in a curved rectangular duct, J. Non-Newton Fluid 165 (2010) 163–173.

https://jurnal.polines.ac.id/index.php/eksergi

ISSN 0216-8685 (print); 2528-6889 (online)