Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 6- Issue 2, August 2023
Paper : 20

Optimization of Heat Transfer Fluids In Ribbed Tubes For Enhanced Performance

[1] Ganugapenta Ramesh
Associate Professor
Department Of Mechanical Engineering
Vemu Institute of Technology
Chittoor,Andhra Pradesh,INDIA.
ganuga.ramesh303@gmail.com

[2] Vooribindi Teja
UG Scholar
Department Of Mechanical Engineering
Vemu Institute of Technology
Chittoor,Andhra Pradesh,INDIA.
tejaroyalofficial@gmail.com

[3] Dodapaneni Rajesh
UG Scholar
Department Of Mechanical Engineering
Vemu Institute of Technology
Chittoor,Andhra Pradesh,INDIA.
rajeshdodapaneni055@gmail.com

[4] Kongara Lokesh
UG Scholar
Department Of Mechanical Engineering
Vemu Institute Of Technology
Chittoor,Andhra Pradesh,INDIA.
lokeshkongara99@gmail.com

[5] Kummaragunta Syam Sundar Rao
UG Scholar
Department Of Mechanical Engineering
Vemu Institute of Technology
Chittoor,Andhra Pradesh,INDIA.
syamsundarrao0000@gmail.com

[6] Cheekala Sai Charan
UG Scholar
Department of Mechanical Engineering
Vemu Institute of Technology
Chittoor,Andhra Pradesh,INDIA.
saicharan21308@gmail.com

***Abstract*— This approach aimed to analyze the optimal performance of Heat Transfer Fluid for improving performance of different liquid phase heat transfer fluids in ribbed tubes. The optimal performance analysis of four heat transfer fluids viz Molten salt, Therminol 66, ethylene glycol and water was conducted to investigate the flow pattern of fluids inside the ribbed tube and the heat transfer coefficient for these fluids are to be estimated.**

Along with optimal performance analysis like structural, and computational fluid Dynamics analysis, the present work also focused on performing modelling tasks to system to evaluate the temperature fluctuations that happen in the evaporator tubes. Furthermore, ribs parameters like height, passage flow, angles and skewness of the directional flow were studied.

Keywords—Ribbed tube, Therminol 66, Molten salt, Water, Ethylene glycol, Skewness

I. INTRODUCTION

The need for using more efficient energy systems was brought on by the recent decade's continuously rising cost of energy. This repeatedly inspired academics and researchers in the field of enhancing heat transfer in heat exchangers. Ribbing is regarded as a potent heat transfer tool among the many techniques identified for the study of heat transfer enhancement. Improvements in design techniques for heat transfer intensification are important and essential for better performance across a variety of engineering applications. The most widely applied, straightforward, and dependable heat transfer improvement technology in circular tubes is flow swirling. It is commonly used in nuclear power plant ducts, fridges, heat exchangers, airplanes, radiators, and space equipment so that the tube inner wall appropriate design will boost the flowing water heat transfer; as a result, it is one of the key criteria for its effective usage in boilers. Ribbed tubes are used in place of smooth walled tubes to improve heat transfer and reduce inner tube wall damage.

In contrast to steam, Therminol heat transfer fluids are less expensive to install, operate, and maintain. The capital expenses of low-pressure thermal liquid systems using Therminol fluids could be greatly reduced. Moreover, there is very little chance of corrosion and fouling with Therminol fluids. The problems associated with direct fired heating are eliminated by heat transfer systems using Therminol heat transfer fluid. Furthermore, it eliminates hot spots that can boil delicate process materials while providing accurate and close process temperature control. According to Yao (2018), a heat exchanger is an energy exchange device that moves heat from one working medium to another. It is commonly used in the HVAC refrigeration industry, the petrochemical industry, the aerospace industry, and many other industries. To achieve energy conservation, production cost reduction, and energy consumption reduction, the process industry places a great deal of emphasis on the effective functioning and optimal design of heat transfer networks and heat exchangers. The resistance of the fluid will often increase with the addition of heat transfer equipment and a larger heat transfer surface, which will increase the pressure drop.

II. LITERATURE REVIEW

Siavash Hosseini [2021] In order to achieve the best structure for predicting the overall heat transfer coefficient of a ribbed triple-tube heat exchanger in terms of the rib pitch, rib height, and nanoparticle concentration, four nature-inspired optimizers are combined with a multilayer perceptron neural network in this paper. A hybrid nanofluid made of graphene nanoplatelets and Pt nanocomposite powder is used in the heat exchanger. Artificial Bee Colony

(ABC), Ant Colony Optimisation (ACO), Ant Lion Optimizer (ALO), and Biogeography-Based Optimisation (BBO) are among the algorithms used. Computational methods offer the necessary data. Due to its greater accuracy, the BBO algorithm is shown to be the best technique for predicting the outcome. The BBO performs best when there are 450 people in the population. For the training data and testing data, respectively, root mean square errors of 0.030 and 0.025 are used to estimate the overall heat transfer coefficient. Additionally, among all the approaches, the ACO algorithm has the shortest computational time. In order to forecast the overall heat transfer coefficient of the ribbed tube, this work analyses and models the ribbed tube in a single phase using a hybrid nanofluid. For this purpose, the homogeneous nanofluid, insignificant natural convection, negligible viscous heating, steady and incompressible flow, Newtonian nanofluid, and negligible thermal radiation are taken into consideration when solving the set of governing partial differential equations. The numerical analyses, which are conducted at four different nanoparticle concentrations (0, 0.02, 0.06, and 0.1%), yield the necessary data sets. 70% and 30%, respectively, of the data are randomly split into training and testing sets. Each suggested optimizer is run through 1000 iterations and tested with various population sizes. Four optimizer algorithms were coupled with the MLP neural network in order to reduce mistakes and improve ANN performance. A population size of 450 and 1000 repetitions gave the BBO its highest performance. For the training and testing data samples, the suggested model's output was calculated with root mean square error percentages of 0.030 and 0.025, respectively. The weakest method for estimating the overall heat transfer coefficient was the ABC algorithm which had a root mean square error percentage of 0.086 and 0.132 for the training and testing data, respectively.

Mehdi Bahiraei et al [2020]. In order to create an ideal network and reduce mistakes for estimating the heat transfer rate of a ribbed triple-tube heat exchanger operating with a graphene nanoplatelets-based nanofluid, eight optimizer approaches are integrated with a perceptron neural network in this study. The optimization methods include the Grey Wolf Optimizer (GWO), the Whale Optimization Algorithm (WOA), the Ant Colony Optimization (ACO), the Ant Lion Optimizer (ALO), the Harris Hawks Optimizer (HHO), the Ant Colony Optimization (ACO), and the Ant Lion Optimizer (ALO). Numerical simulations are utilized to provide the necessary data. Different rib pitches and heights are used to take the structural factors into account. The best technique for estimating the output is the ALO algorithm. A population size of 350 gives this algorithm its optimum performance. By using this approach, the Root Mean Square Error (RMSE) values for the training and testing data samples of the heat transfer rate estimation are around 0.0310 and 0.0385, respectively. The heat transfer analysis of the nanofluid flow inside the RTTHE coincides with the current paper. The nanofluid is thought to behave like a homogeneous fluid with Newtonian properties.

The biological interplay in brain systems serves as the inspiration for the Artificial brain Networks (ANNs) used in this. An effective and powerful tool for prediction and optimization in a variety of engineering challenges is the artificial neural network (ANN). The multilayer perceptron neural network with three neurons in its biases of the unreinforced ANN is combined with the eight optimizer algorithms, which include the Harris Hawks Optimization (HHO), Grey Wolf Optimizer (GWO), Whale Optimization Algorithm (WOA), Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), Ant Lion Optimizer (ALO), Biogeography-Based Optimization (BBO), and Dragonfly Algorithm (DA). The finite volume technique is the foundation of the modern numerical analysis. The pressure-based solver is chosen to carry out the simulations, and the SIMPLE technique is used to couple pressure and velocity.

In order to create an optimal network and reduce errors for predicting the heat transfer rate of a ribbed triple-tube heat exchanger working with a graphene nanoplatelets-based nanofluid, the present investigation's primary goal is to combine eight optimizer algorithms with a multilayer perceptron neural network. The output of the WOA-ANN and the simulated data agree well, and the high value of R2 indicates a strong correlation between the simulated and WOA-ANN-predicted data.

Nima Mirkhani et al [2018] The hydraulic and thermal capabilities of internally ribbed tubes are investigated numerically in this article for both sub-critical and supercritical water flows. To compare and validate the findings with the experimental data, a real-world case has been used. Under various fluid enthalpies, heat transfer behaviour and pressure drop features have been examined. The water flow inside the ribbed tube is simulated by applying pressures of 15 and 25 MPa. Results show that computational methods can deliver a solid foundation capable of foretelling the performance of ribbed tubes. The spiral flow has been contained inside the tube in supercritical flow. Also resolved is the heat transfer amplification brought on by the water's pseudocritical thermophysical characteristics, his paper numerically investigates the hydraulic and thermal performances of internally ribbed tubes under both sub-critical and supercritical water flows. A real case has been adopted to compare and validate the results with the experimental data. Heat transfer behaviour and pressure drop characteristics have been analyzed under different fluid enthalpies. 15 and 25 MPa pressures are used to simulate the water flow inside the ribbed tube. Results indicate that computational method can provide a reliable framework which is capable of predicting the ribbed tubes performance. In supercritical flow, the spiral flow has been captured inside the tube. In addition, the heat transfer enhancement due to the pseudocritical thermophysical properties of the water is resolved. It should be noted that the model was created, the geometry was meshed, and the issue was resolved using ANSYS Workbench 16 modules. A personal PC with an Intel® CoreTM i7-4820K processor and

32 GB of RAM is used to run the simulations. The flow regime, or whether it is subcritical or supercritical, primarily determines the average run time for each operational point. Each simulation takes an average of 50 hours for the subcritical pressure and 50 hours for the supercritical pressure. The unusual behaviours found inside internally ribbed tubes in both the sub-critical and supercritical zones are said to be well captured by computer investigations.

III. METHODOLOGY

A. *Identification Of Need*

Heat transfer fluids are commonly used in various industrial applications to transfer heat energy from one point to another. In many cases, heat transfer fluids are circulated through ribbed tubes to enhance their performance. Ribbed tubes are tubes with ribs or fins on their inner or outer surfaces, which increase the heat transfer surface area and improve the fluid turbulence. However, the performance of heat transfer fluids in ribbed tubes can be affected by several factors, such as the fluid properties, tube geometry, and flow conditions. Therefore, it is important to identify the need for optimization of heat transfer fluids in ribbed tubes to enhance their performance.

One of the key reasons for optimizing heat transfer fluids in ribbed tubes is to increase their heat transfer rate. Heat transfer rate is a measure of how efficiently heat energy is transferred from the fluid to the tube or vice versa. By optimizing the heat transfer fluid properties, such as thermal conductivity, viscosity, and specific heat capacity, and the tube geometry, such as rib height, pitch, and angle, the heat transfer rate can be improved significantly.

B. *Overview*

In this study four heat transfer fluids were used for the optimal performance analysis in order to examine the flow pattern of fluids inside the ribbed tube. They were heat transfer fluids namely Therminol 66, Molten Salt, Water and Ethylene glycol liquid phase heat transfer fluids. In this, thermal, flow and structural analysis was performed with the motive to improve the temperature fluctuations that occurred within the evaporator tube using ANSYS software. Ansys started with a significant promise in the modelling of several thermodynamics based on the applications related to heat transfer fluid motion. One of the most exciting prospects is its application in coupled problems such as fluid-structure interaction, in thermomechanical. The focus of this paper is to enhance the heat transfer coefficient of the fluid which increases the overall performance in a ribbed tube by using numerical simulation. Heat transfer fluid selection is considered to be an important factor in maximizing heat transfer by minimizing pressure drop. The size and weight of heat transfer equipment should be considered to be lesser in the design of the heater. It is noted that heat transfer and resistance coefficient of a fluid increases with the increase of its rib height. The major enhancement required here is to improve the heat transfer coefficient which is going to improve the overall performance.

C. *CATIA V5*

CATIA V5 is a powerful computer-aided design (CAD) software developed by Dassault Systems. It is widely used in industries such as aerospace, automotive, and manufacturing for designing complex parts, assemblies, and products. CATIA V5 offers a wide range of tools and features for creating 3D models, 2D drawings, and simulations. It has a user-friendly interface that allows designers to create and modify models with ease. The software supports a variety of file formats, including IGES, STEP, and STL, which makes it compatible with other CAD software and 3D printing.

D. *Design of Helical Ribbed Tube In CATIA V5*

Designing a helical ribbed tube in CATIA V5 involves several steps, including creating a sketch of the cross-section of the tube, defining the helical path, and creating the rib profile. Here is a brief overview of the design process:

- Start by creating a new part file in CATIA V5 and switch to the Sketcher workbench.
- Create a 2D sketch of the cross-section of the tube using the available sketching tools.
- Extrude the sketch to create a 3D tube using the Pad tool.
- Switch to the Wireframe and Surface Design workbench and create a helical path using the Helix tool.
- Create a new sketch on the XY plane and draw the profile of the rib.
- Use the Sweep tool to sweep the rib profile along the helical path.
- Boolean subtract the ribbed helix from the original tube to create the final helical ribbed tube.

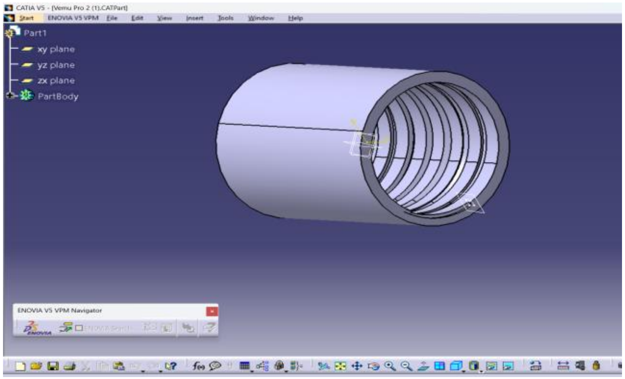


Fig 1 Ribbed Tube Model By CATIA V5

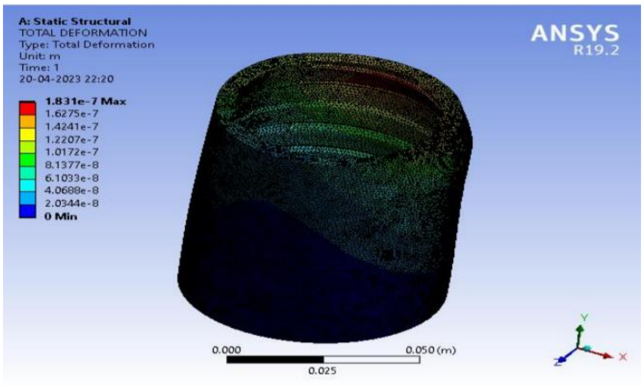
Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 6- Issue 2, August 2023
Paper : 20

E. *ANSYS Workbench*

The software offers a wide range of features and tools, such as mesh generation, solver options, and post-processing capabilities.

Some of the key features of ANSYS Workbench include:



- **Geometry Modeling:** Allows engineers to create or import geometries and modify them using various tools.
- **Mesh Generation:** Generates a mesh of the geometry using various meshing techniques.
- **Solver Options:** Provides access to a variety of solvers for different simulation types, such as structural, thermal, and fluid analysis.
- **Post-Processing:** Provides various visualization and analysis tools to view and interpret simulation results.

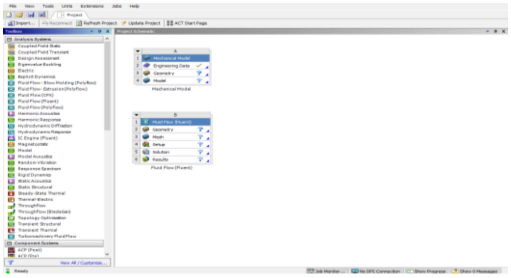


Fig 2 ANSYS Workbench Interphase

F. *Structural Analysis*

In this type of analysis, the fluid flow and heat transfer characteristics of ribbed tubes are simulated using computational fluid dynamics techniques. The aim is to optimize the design of the ribbed tube for enhanced heat transfer performance by analyzing various geometrical and operational parameters, such as the rib height, pitch, Reynolds number, and flow rate.

Fig 3 Deformation Test on ANSYS

To perform deformation tests in ANSYS, you would need to create a 3D model of the ribbed tube and heat transfer fluid, define the material properties and boundary conditions, and then run the simulation to calculate the deformation under various conditions. This information can then be used to optimize the design of the ribbed tube and heat transfer fluid for enhanced performance.

Total Deformation, Directional Deformation, Shear stress and Elastic Strain were Tested for the Ribbed tube in the Structural Analysis enhanced performance, such as increased heat transfer rates or reduced pressure drop.

G. *Computational Fluid Dynamics Analysis*

The purpose of this analysis is to investigate the performance of different heat transfer fluids in ribbed tubes for enhanced heat transfer. The heat transfer coefficient in a ribbed tube can be significantly improved by selecting the appropriate fluid, which can result in increased efficiency and reduced costs for many applications in various industries such as chemical, power, and aerospace.

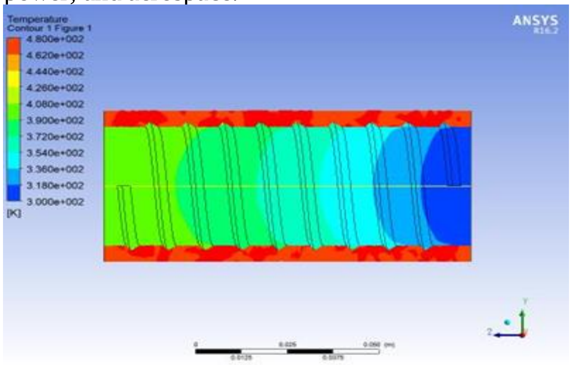


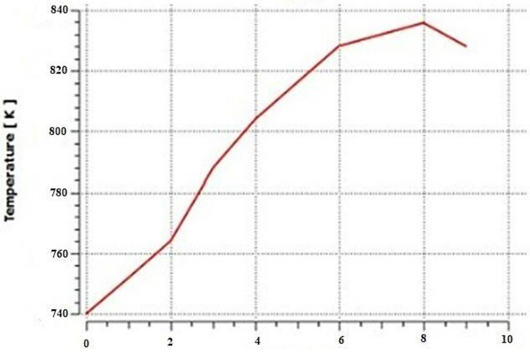
Fig 4 CFD Analysis For Molten Salt

Blue: At low temperatures, the fluid appears blue in the ribbed tube. This indicates that the fluid is in a liquid state and has not reached its boiling point.
Clear: As the temperature increases, the blue color fades and the fluid becomes clear which indicates that the fluid is still in liquid state but not approaching its boiling point.
Yellow: As the fluid reaches its boiling point, it turns yellow in the ribbed tube. This indicates that the fluid is in a two-phase state with both liquid and vapor present.
Red: If the temperature is further increased, the fluid may turn red in the ribbed tube. This indicates that the fluid is overheating and may be experiencing thermal

Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 6- Issue 2, August 2023
Paper : 20

degradation.



Graph: Molten Salt (Temp vs Len)

It is observed that the temperature of the Molten Salt Heat transfer fluid at inlet is 740K and increase in temperature takes place accordingly to the length. As per the results generated by ANSYS software the maximum Working temperature of Molten Salt is 838.15K.

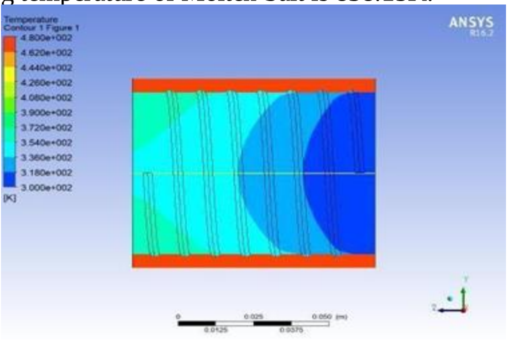
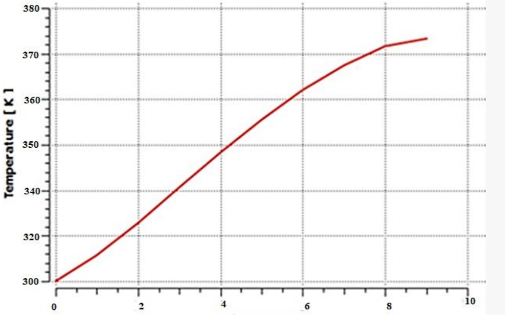


Fig 5 CFD Analysis For Molten Salt



Graph: Water (Temp vs Len)

It is observed that the temperature of the Water as Heat transfer fluid at inlet is 300K and increase in temperature takes place accordingly to the length. As per the results generated by ANSYS software the maximum Working temperature of Water is 373.15K.

IV. CONCLUSION

A. Structural Analysis

The following Conclusions were observed from the results of Structural Analysis:

TABLE I. STRUCTURAL ANALYSIS RESULTS

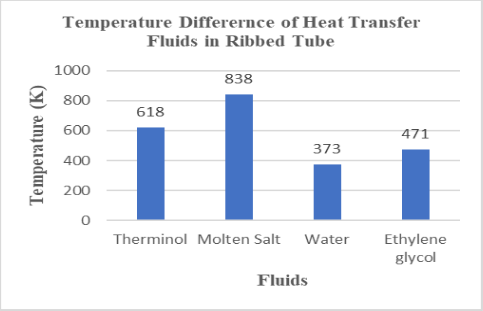
S No	Structural Analysis	Minimum Value	Maximum Value
1	Total Deformation	-3835.2nm	-767.09 nm
2	Directional Deformation	-83.113 nm	80.534 nm
3	Elastic Strain	6161.2 nm	0.08339 nm
4	Shear Stress	0.01768 N/mm2	0.08839 N/mm2

B. Thermal Analysis

The following Conclusions were observed from the results of Steady state Thermal Analysis:

TABLE II. ANSYS TEMPERATURE RESULT

S. No	Heat Transfer Fluids	Temperature Observed from Graph (K)
1	Therminol 66	618
2	Molten Salt	838
3	Water	373
4	Ethylene glycol	471



GRAPH I TEMPERATURE RANGES OF HTF

Water is a weaker heat transfer fluid among them with a temperature range of 373K and Molten Salt results as a good Heat Transfer Fluid with a Working Temperature range to 838K..

ACKNOWLEDGMENT

We would like to express my deep gratitude to all those who helped directly or indirectly to transform an idea into our working Project.

We would like to thank our parents and friends, who have the greatest contributions in all my achievements, forthe great care and blessings in making as We are thankful to our guide Dr. G . RAMESH, Associate Professor for his valuable guidance and encouragement. His helping attitude and suggestions have helped in the successful completion of the Project.

REFERENCES

1. Mehdi Bahiraei, Loke Kok Foong ,Siavash Hosseini, Nima Mazaheri. Predicting heat transfer rate of a ribbed triple-tube heat exchanger working with nanofluid using neural network enhanced by advanced optimization algorithms. Elsevier Volume 381, March 2021, Pages 495-476.

2. Dabiao Wanga, Ran Tianc , Lanlan Lid , Xiaoye Daib , Lin Shi. Heat transfer of R134a in a horizontal internally ribbed tube and in a smooth tube under super critical pressure. Elsevier Volume 173, 5 June 2020, 115208
3. Mehdi Bahiraei, Loke Kok Foong, Siavash Hosseini, Nima Mazaheri. Neural network combined with nature-inspired algorithms to estimate overall heat transfer coefficient of a ribbed triple-tube heat exchanger operating with a hybrid nanofluid. Elsevier Volume 174, April 2021, 108967.
4. Bin Zoua, Yiqiang Jiang, Yang Yao, Hongxing Yang. Thermal performance improvement using unilateral spiral ribbed absorber tube for parabolic trough solar collector. Elsevier Volume 183, May 2019, Pages 371-385.
5. Nima Mirkhani, Alireza Taklifi, Pedram Hanafizadeh, Abbas Aliabadi. Numerical study on the hydraulic and thermal performance of internally ribbed tubes in supercritical pressure and sub-critical two-phase flows. Elsevier Volume 136, 2018, Pages 21-28.
6. Weiguo Xu, Shuyan Wann, Lu Huang, Qiang Wang, Qinghong Zhang, Huilin Lu .Thermo-hydraulic performance of Therminol liquid phase heat transfer fluid in a ribbed tube of solar heater. Elsevier Volume 101, February 2017, page 919-929.
7. Xu Weiguo, Wang Shuyan , Lu Huang, Wang Qiang, Zhang Qinghong, Lu Huilin. Thermo-hydraulic performance of liquid phase heat transfer fluid (Therminol) in a ribbed tube. Elsevier Volume 72, April 2016, page 149-160.
8. Keke Xu, Lijun Tang, Hua Meng. Numerical study of supercritical-pressure fluid flows and heat transfer of methane in ribbed cooling tubes. Elsevier Volume 84, may 2015, page 346-358.
9. Lixin Cheng, Tingkuan Chen. Study of vapor liquid two-phase frictional pressure drop in a vertical heated spirally internally ribbed tube.Elsevier Volume 62, 2007, Pages 783-792.
10. Shengqiang Liu a , Baoyu Wang, Investigation of cold drawing process of thin-walled ribbed steel tube, Volume 366-368