Experimental study of shell and tube heat exchanger

Cite as: AIP Conference Proceedings **2473**, 020005 (2022); https://doi.org/10.1063/5.0096706
Published Online: 11 July 2022

S. SivaChandran, R. Venkatesh, S. Baskar, et al.

Experimental Study of Shell and Tube Heat Exchanger

S. SivaChandran[1),] R. Venkatesh[2, a)], S. Baskar[3)], R. Arivazhagan[4)] and T. Maridurai[2, b)]

[1] Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai, Tamilnadu, India.
[2] Department of Mechanical Engineering, Saveetha School of Engineering, Chennai, Tamilnadu, India.
[3] Department of Automobile Engineering, Vels Institute of Science, Technology and Advanced Studies, Pallavaram, Chennai , Tamilnadu, India.
[4]Department of Mechanical Engineering, Kongunadu College of Engineering and Technology, Trichy, Tamilnadu, India.

Corresponding Author:
[a)]sivachandran.mech@sairam.edu.in
[b)]mari.durai@gmail.com

Abstract: Major components of design of an AES type heat exchanger is carried out using PV-Elite, a PC based software exclusively programmed for designing various process equipments. The objective of designing a heat exchanger using PV-Elite is to minimize the calculation time and errors. In practical, the usage of this software reduces the time consumed by about 50%.The input data required for the software are the outputs of thermal design such as working fluid, working pressure, working temperature, design pressure, design temperature, corrosion allowance, material specification, etc. The mechanical calculations such as internal pressure, external pressure, flange calculation, vessel calculation, etc. will be performed by the software and is obtained a printed format after completing the design process.

Key words: Heat Transfer, Heat Exchanger, Thermal Design, Shell and Tube

INTRODUCTION

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications. This is because the shell and tube heat exchangers are robust due to their shape. Various number of procedures were followed for deriving efficient Heat transfer from the double pipe heat exchangers irrespective of its size and dimensions at suitable pumping power. These Procedures are classified under two sections as active and passive techniques. In active method, the heat transfer is enhanced by providing energy to the fluid. In passive method, the energy of the fluid is consumed to enhance the output. These two techniques can be collectively synchronized to get efficient performance of the double pipe heat exchanger more than the performance obtained from any of the one type of this technique. This technique is termed as compound enhancement. But these techniques may result in higher pumping power due to rise in pressure drop. Hence the right method has to be chosen to obtain better efficiency. Z. Zhang et al [1]. Co related the heat transfer coefficient along the shell side and pressure drop of the heat exchanger with various helix angles. Gorman et al [2]. gives a mathematical analysis of the thermal and fluid pattern study of a double-pipe heat exchanger with the pipes having inner walls that are helically corrugated which on comparison with smooth walled double pipe heat exchanger shows better heat transfer rate and comparative pressure drop. Pourahmad and Pesteei [3] stated that there is considerable amount of enhancement in heat transfer can be achieved by piercing oscillatory stripers along its walls, with the help of mathematical study. Chamoli and Thakur [4]mathematically examined the impacts of crosswise pricked baffles enclosed to the hot wall of a rectangular channel on heat dissipation and friction factor. They noted that insertion of pricked baffles increases the heat transfer, while friction loss increases above a flat surface. Hashemian et al [5-6].

The front end of the exchanger allows the fluid to enter into the tube side and the rear end leaves the fluid for the tube side. The tube bundle comprises of tube sheets, tubes, ties roads, and baffles to hold the bundle together [7]. The shell in this exchanger has the tube bundles. This is the popular type of heat exchanger, which is made up of metals and for some special type it can also made by glass, plastics and graphite. This is a special type of exchanger, and are widely used in many applications [8]. Simulation in engineering application is widely penetrated now a days, due to its benefits these approach is followed in many filed including manufacturing [9-10]. Many simulation tools are available to analysis the graphical and behaviour of any component and machine before producing it. It loosen the effort and cost of production, and helps to predict the performance before purchasing or producing it. So for in many research the authors have simulated many applications. But they lack to use a proper machine learning technique for prediction of machine behaviour [11-12]. In some research the authors have effectively used the neural network for the forecasting the internal computation engine performance. But the prediction or forecasting of heat exchanger performance using machine learning technique is a challenging task. Hence in this paper, we are planned to propose a novel machine learning technique for the effective prediction of heat transfer rate of tube and shell heat exchanger. In 2006, Qiuwang Wang et al. [13] have initiated this idea and presented a technique using artificial neural network for the prediction of rate of heat transfer.

Heat Exchangers

A heat exchanger is a device built for efficient heat transfer from one fluid to another, where the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted. They are widely used in petroleum refineries, chemical plants, natural gas processing, refrigeration, power plants, air conditioning and space heating. One common example of a heat exchanger is the radiator in a car, in which a hot engine – cooling fluid, like antifreeze, transfers heat to air flowing through the flow arrangement.

Heat exchanger may be classified according to their flow arrangement. In parallel-flow heat exchangers, the two enter the exchanger at the same end, and travel in parallel to one another side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat. See countercurrent exchange. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger .For efficiency, heat exchanger is designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow thoroughly the exchanger. The exchanger's performance can also be affected by addition of fins or corrugation in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

The driving temperature across the heat transfer surface varies with position, but an appropriate means temperature can be defined. In most simple system this is the log mean temperature difference (LMTD). Sometimes direct knowledge of the LMTD is not available and the NTU method is used.

PROBLEM FORMATION

Due to the many variables involved, selecting optimal heat exchanger is challenging. Hand calculation is possible, but much iteration is typically needed. As Such heat exchanger is most often selected via computer programs, either by system designer, who are typically engineers, or by equipment vendors. Condition monitoring of heat exchanger tubes may be conducted through Non destructive methods such as eddy current testing. The mechanics of water flow and deposits are often simulated by computational fluid dynamics or CFD. Fouling is a serious problem in some heat exchanger. River water is often used as cooling water, which results in biological debris entering the heat exchanger and building layers, decreasing the heat transfer coefficient. Another common problem is scale, which is made up of deposited layers of chemical such as calcium carbonate or magnesium carbonate. Plate heat exchanger need to be dissembled and cleaned periodically. Tubular heat exchanger can be cleaned by such methods as acid cleaning, sandblasting, high-pressure water jet, bulled cleaning, or drill rods. In large –scale cooling water system for heat exchanger, water treatment such as purification, addition of chemicals, and testing is used to minimize fouling of the heat exchanger equipments. Other water treatment is also used in steam system for power plants, etc. to minimize fouling and corrosion of the heat exchanger and other equipments.

SHELL AND TUBES OF HEAT EXCHANGERS

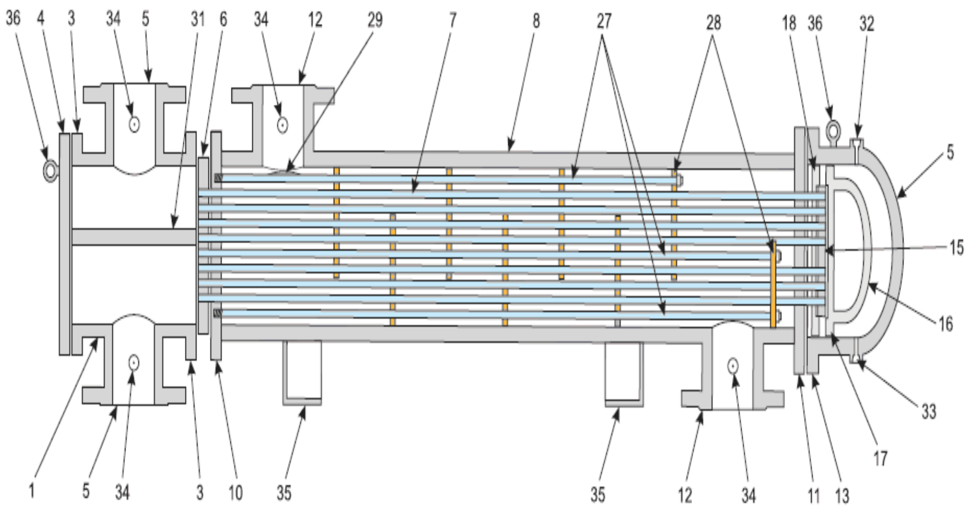

FIGURE 1. Shell And Tube Heat Exchanger(AES)

A typical heat exchanger, usually for higher-pressure applications, is the shell and tubes heat exchanger which consists of a series of tubes, through which one of the fluids runs .The second fluid runs over the tubes to be heated or cooled. The second fluids run over the tubes to be heated or cooled. The set of tubes is called tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc. The shell and Tube is the most common type of heat exchanger used in the process, petroleum, chemical and HAVC industries, it contains a number of parallel u tubes inside a shell. Shell and Tube heat exchangers are used when a process, requires large amounts of fluid to be heated or cooled. Due to their design, shell and Tube heat exchangers offer a lager heat transfer area and provide high transfer efficiency.

There are many different types or designs of shell and tube heat exchangers to meet various process requirements. Shell and Tube heat exchangers can provide steady heat transfer by utilizing multiple passes of one or both fluids. SEC shell and tube come in two (2) four (4) pass models standards, and multi-pass custom models.

Shell and tube heat exchanger use baffles on the shell-side fluid to accomplished mixing or turbulence. Without the use of baffles, the fluid can become stagnant in certain parts of the shell. If you have any questions about how shell and Tube heat exchangers will benefit your application, two fluids, of different starting temperatures, flow through the heat exchanger. Heat is transferred from one fluid to the other through the walls, either from tube side to shell side or vice versa. The fluids can be either liquids or gas on either the shell or the tube side. In order to transfer heat efficiency, a large heat transfer area should be used, so there are many tubes. In this way, waste heat can be put to use. This is a great way to conserve energy.

Heat exchanger with only one phase (liquid or gas) on each side can be called one-phase or single-phase heat exchangers. Two-phase exchangers can be used to heat a liquid to boil it into a liquid (called condenser), with the phase change usually occurring on the shell –and-tube heat exchangers. In large power plants with steam-drive turbines, Shell-and-tube surface condensers are used to condense the exhaust steam exiting the turbine into condensate water which is recycled back to be turned into steam in the steam generator. There can be many variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (sometimes called water boxes) through holes in tube sheets.

Tema Shell and Tube Nomenclature:

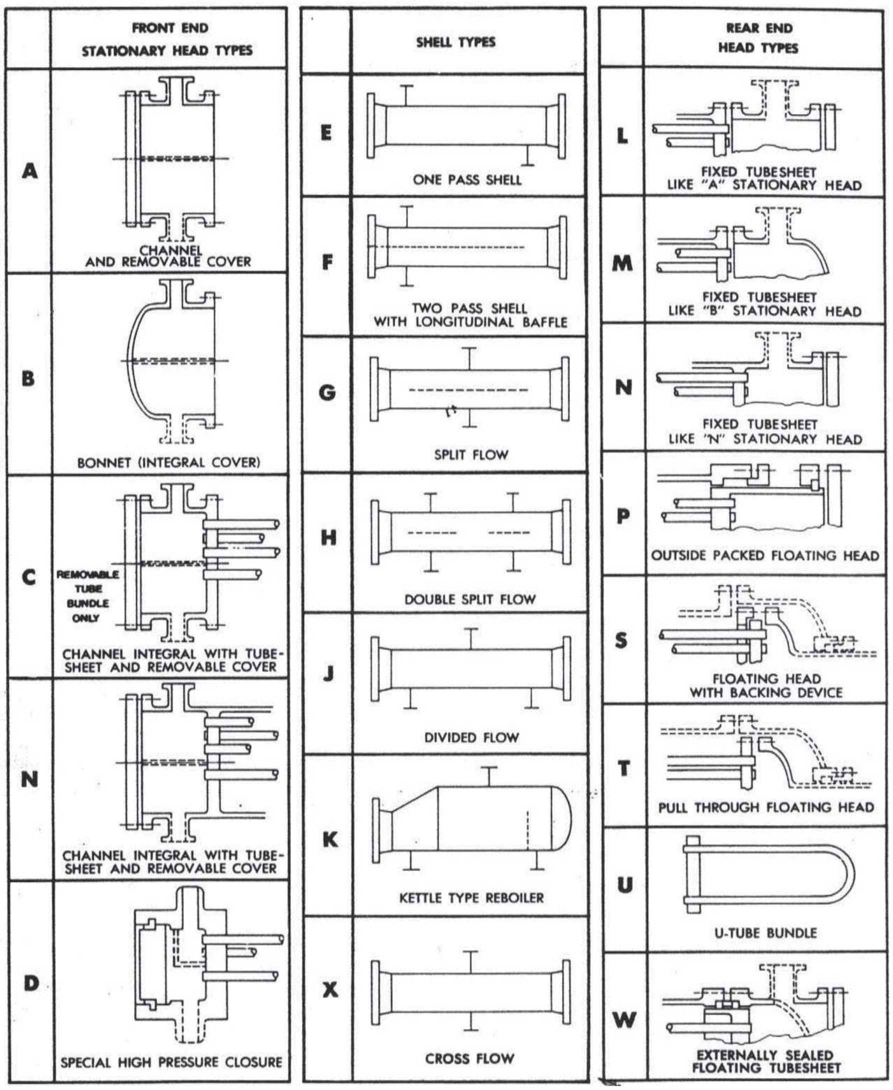

FIGURE 2. Tema Shell and Tube Nomenclature

AES Heat Transfer is a proud member of TEMA - Tubular Exchanger Manufacturer's Association. TEMA members set the standards by which Virtually all custom shell & tube heat exchangers are specified and built. Basco has been a member since the 1950's, and consequently we have a complete and comprehensive understanding of the engineering, manufacturing and testing requirements to meet this world-recognized standard. While other manufacturers may simply interpret the regulations, AES Basco has the requisite member design and fabrication capabilities to lead the industry by helping to shape and define those standards for the long-term benefit of all users.

SPECIFIC REQUIREMENTS

Design

Vendor is responsible for Mechanical detail design. All thicknesses indicated in the drawing are minimum after forming and machining. Thicknesses, weights are indicated for information only. Vendor has to confirm thicknesses, weights and is fully responsible for design. Increasing of equipment thickness and re-design of nozzles reinforcements according to applicable codes, specifications and piping loads shall not involve any extra-price. The equipment shall be designed, fabricated and tested strictly in accordance with all the specifications herein mentioned and/or listed in the CK-130-ME-08-04020001.

The Vendor shall perform the stability check due to external loads such as wind, earthquake, connected piping weight and thermal loads. Process nozzles shall be designed to withstand allowable nozzle loads. Supplier shall consider nozzle allowable loads as per CC-000-ME-40-0007 attached. Exact values of the Local loads on nozzles shall be provided during Detailed Engineering. The thickness shown in Supplier's drawings and sketches, (to be submitted by supplier after order) shall be the minimum thickness after fabrication. The selection of adequate thicknesses to compensate the thinning of materials, due to construction operations, is at supplier's responsibility. Reduction of thickness due to plates under tolerance (only if within the limits accepted by the applicable codes) is subject to Contractor's written approval.

Material certification shall be EN 10204 3.1 for pressure retaining materials and load bearing parts and EN 10204 2.2 for other materials. All the equipment shall be checked for Sea/Land transportation condition with loading factors indicated in the pressure vessel specification (D-611).In case of sour service, material & fabrication requirements shall comply with NACE MR 0103(2007) & CB&I specification CC-000-PR-42-0002, Rev 1.For Earthquake design of vessels, the below mentioned Seismic coefficients and method of analysis Substitutes those mentioned in Cl. 4.5.1.2. Of pressure vessel Specification CC-000-ME-40-0004, Rev 2.Importance factor I = 1.75 for Horizontal vessels Horizontal equipments shall be designed using Response spectrum method as per IS 1893 (Part 4).For equipments under Indian Boiler Regulations (IBR), vendor shall comply with all the requirements of IBR code and get necessary approvals for documents from CIB Tamil Nadu, India. Brackets on shell girth flange as per Annexure- A are required to lock the bundle extractor prior to pull the removable bundle.

Technical Specification

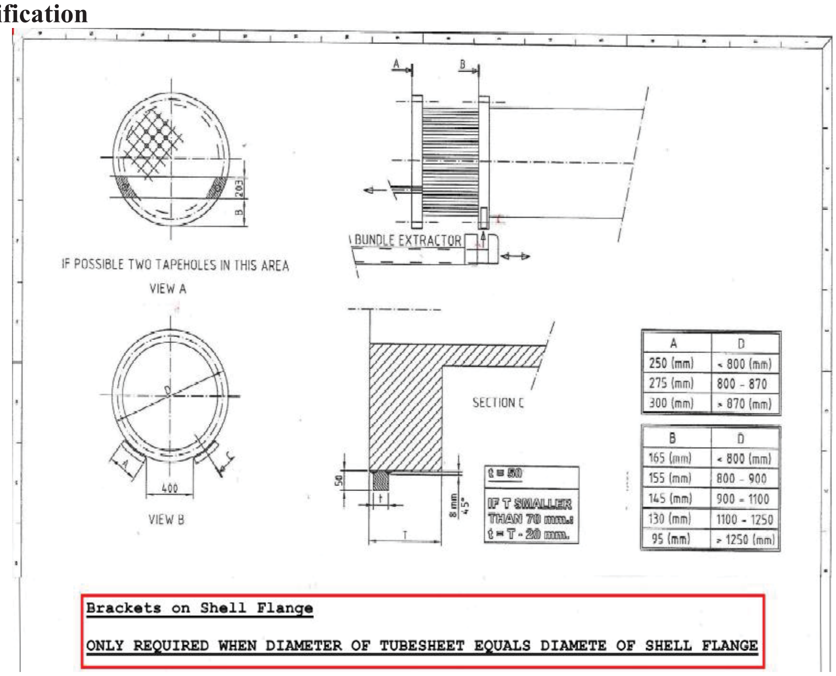

FIGURE 3. Shell and Tube Heat Exchangers

RESULT AND DISCUSSION

Testing

Heat exchanger and Hear generators are designed to contain liquids, gases and solids such that a loss of containment does not occur. Leaks or the mechanical or structural failure of these items of equipment may result in a major accident on-site.The presence of flaws in critical components may result in the integrity of such system being compromised and increase the likelihood of failure.

Non – Destructive Testing

Non – Destructive Testing (NDT) is the application of measurement techniques in order to identify damage and irregularities in materials. NDT often provides the only method of obtaining information about the current health of process plant.If done well, NDT can provide useful information to assist in the management of safety. If inappropriate NDT is applied or NDT is not applied correctly, then the result are likely to give a false impression of the integrity and safety of the plant.The types of defect / flaw and degradation that can be detected using NDT are summarized as:

- Planer defects – these include flaws such as fatigue, cracks, lack of side – wall fusion in welds, environmental assisted cracking such as hydrogen creaking and stress corrosion cracks: cold shuts in casting etc,
- Lamination – these include flaws such as rolling and forging lamination, laminar inclusions and de-lamination in composites:
- Voids and inclusion – these include flaws such as voids, slag and porosity in welds and voids in casting and forgings:
- Wall thinning – through life wall loss due to corrosion and erosion;
- Corrosion pits – these are localized and deep areas of corrosion;
- Structural deformities such as dents, bulges and ovality.

Radio graphing

Where radio graphing or spot radio graphing is specified, it shall be carried out in accordance with the requirements of paragraph UW-51 and UW-52 of the ASME code.

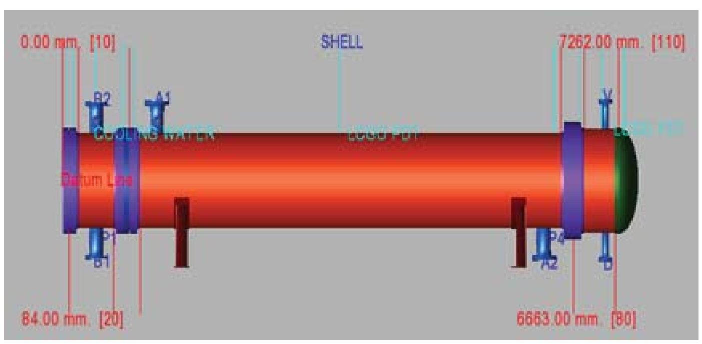

FIGURE 4. Material specification

Chemical Tests and Corrosion

Unless otherwise specified the contract specification or drawing, chemical and corrosion teats shall be conducted in accordance with test requirements set forth in this guide to specification under section developed to specific number and type of test specimens to a certificate testing laboratory approved by the owner. The chemical analysis of the specimen plate material should be forward by letter to the testing laboratory.

Hydrostatic, Hammer and Air Tests

The Test and Test Pressure Shall be in accordance with those indicated on the drawing. A general sweating of a weld under pressure shall cause rejection of the joint involved. The hammer test shall consist of striking the plate at 6 inch intervals on both sides and over the full length of all welded seams. The weight of the hammer in pounds shall be equal to the thickness of the shell in tenths of an inch and the blows shall be struck with a force equivalent an 8 foot free fall of the hammer head. The edges of the hammer shell be rounded to prevent defacing the plates. In no case shall the temperature of the vessel or the liquid be less than 500F. During the test and test pressure shell not be applied until the vessel and liquid reach this minimum temperature.

Heat Exchanger Material Constructions

The material used for the fabrication of this (ASE-type), shell and Tube Heat Exchanger are based on their specification which are given below,

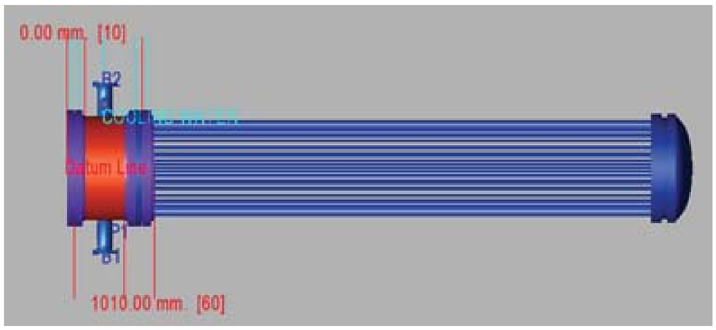

FIGURE 5. Material Constructions

Material specification will be as per ASME SEC II part –AED07

Plates: SA 516 Gr. 70
Tubes : SA 179
Baffle : SA 283 GRC
Tube sheet: SA 193 Gr. B7
Spacer: SA 179
Pass Partition Plate: SA 516 GR70
SA- Ferrous Materials
Gr. - Grade.

CONCLUSION

The research "MECHANICAL DESIGN OF HEAT EXCHANGER" is completely designed and is tested to perform well under all condition(figure 1-6). It enables to improve the operational efficiency and also meets all the requirements specified by the clients. Designing a heat exchanger using PV-Elite was to minimize the calculation time and errors. In practical, the usage of this software reduces the time consumed by about 50%.The input data required for the software are the outputs of thermal design such as working fluid, working pressure, working temperature, design pressure, design temperature, corrosion allowance and material specification.

REFERENCES

[1] Z. Zhang, Y. Ding, C. Guan, H. Yan, W. Yang, Heat transfer enhancement in double-pipe heat exchanger by means of rotor-assembled strands, Chem. Eng. Process. 60, 26–33 (2012).
[2] Gorman JM, Krautbauer KR, Sparrow EM., Thermal and fluid flow first principles numerical design of an enhanced double pipe heat exchanger. Applied Thermal Engineering, (2016). 107:194–206. 8/25/2016.
[3] Pourahmad S, Pesteei SM., Effectiveness-NTU analyses in a double tube heat exchanger equipped with wavy strip considering various angles. Energy Convers Manage, 123, 462–469 (2016).
[4] Chamoli Sunil, Thakur Narendra. Performance study of solar air heater duct having absorber Plate with V down perforated baffles. Songklanakarin Journal science and technology, 36(2), (2013).
[5] Hashemian M, Jafarmadar S, SadighiDizaji H. A comprehensive numerical study on multi-criteria design analyses in a novel form (conical) of double pipe heat exchanger. Applied thermal engineering, 102, 1228–1237 (2016).

[6] Natarajan, A , Venkatesh, R, CFD Simulation of Heat Transfer Enhancement in Circular Tube with Twisted Tape Insert by Using Nano Fluids', Materials Today Proceedings, 21(1), 572-577 (2020).
[7] Avudaiappan, T, Vijayan, V, Sundara pandiyan, S, Saravanan, M, Dinesh, S., Potential Flow Simulation through Lagrangian Interpolation Meshless Method Coding, Journal of Applied Fluid Mechanics, 11, 129-134 (2018).
[8] Godwin Antony, A., Experimental investigation of I.C Engine using various Diesel Blends, Asian Journal of Research in Social Sciences and Humanities, 6(12, 221- 235 (2016).
[9] Karthick, S., TDP: A novel secure and energy aware routing protocol for Wireless Sensor Networks, International Journal of Intelligent Engineering and Systems, 11(2), 76- 84 (2018).
[10] Venkatesh, R, Christraj, W, Performance Analysis of Solar Water Heater in Multipurpose Solar Heating System, Applied Mechanics and Materials, 1706-1713 (2014).
[11] Dinesh, S, Rajkumar, T, Sathish Kumar, G, Sureshkumar, B., Analysis and optimization of Machining parameters in through Feed centerless grinding of high Carbon steel, Journal of Mechanical Engineering and Technology 9 (13), 431-441 (2018).
[12] Vijayan, V, Vivekanandan, M , Venkatesh, R, CFD modeling and analysis of a two-phase vapor separator', Journal of Thermal Analysis and Calorimetry, (2020) https://doi.org/10.1007/s10973-020-09825-2
[13] Qiuwang Wang, et al., Prediction of heat transfer rates for shell-and-tube heat exchangers by artificial neural networks approach, Journal of Thermal Science, 15(3), 257-262 (2006).