Original Article

World Journal of Engineering Research and Technology
WJERT

SIMULATION MODELLING ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER

Rufus Ogbuka Chime*[1], Momoh Abdullah Yakubu[2], Echegi Christian Uche[3]

[1]Mechanical Engineering Institute of Management and Technology IMT Enugu.

[2]Advanced Manufacturing Process Scientific Equipment Development Institute Enugu.

[3]Chemical Engineering Institute of Management and Technology IMT Enugu.

*Corresponding Author
Rufus Ogbuka Chime
Mechanical Engineering
Institute of Management
and Technology IMT
Enugu.

ABSTRACT

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Modelling is about building representations of things in the real world and allowing ideas to be investigated; it is central to all activities in the process for building or creating an artefact of some form or other. In effect, a model is a way of expressing a particular view of an identifiable system of some kind. Analysis is the process of breaking a complex topic or substance into smaller parts in order to gain a better understanding of it. Today, finite element analysis is an integral and major component in many fields of engineering design and manufacturing. Major established industries such as the automobile, aerospace, chemical, pharmaceutical, petroleum, electronics, and communications, as well as emerging technologies such as nanotechnology and biotechnology rely on the finite element method to simulate complex phenomenon at different scales for design and manufacture of high-technology products. A Heat exchanger is an efficient device constructed for the efficacious heat transfer between two fluids of different temperature. Heat exchangers are extensively used in food processing industry, dairy industry, biochemical processing, pharmceuticals, chemical plants and petroleum plants to mention but a few. Shell and tube heat exchanger consist of series of tube containing the

fluid that must be either heated or cooled with the second fluid being circulated over the tubes that need to be heated or cooled The scope of this work includes, to design, model, simulate, and sustainability analysis of Shell and tube heat exchanger. Computer aided design uses the mathematical and graphic processing power of the computer to assist the engineer in the creation, modification, analysis, and designs many factors have contributed to CAD technology becoming the necessary tool in the engineering technical data base, series of soft wares was used in the analysis of this project.

KEYWORDS: Design, Finite Element Analysis, Shell and Tube, Heat Exchanger, Principal and Application.

INTRODUCTION

A simulation is a sampling experiment that is done on the computer (Fishman 1996). At the core of any simulation is a model that involves quantities whose values are unpredictable and therefore must be sampled from an appropriate population of observations. Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance. For instance, simulation can be used to answer questions like: What is the best design for a new product? Illustrated in fig; 5.

A Heat exchanger is an efficient device constructed for the efficacious heat transfer between two fluids of different temperatures. The media maybe separated through a solid wall, to prevent mixing, or they may be in direct contact Heat exchangers are extensively used in food processing industry, dairy industry, biochemical processing, pharmaceuticals, chemical plants and petroleum plants to name a few. The use of heat exchangers in bioprocess industry is ubiquitous; from high temperature pasteurization to low temperature freezing, Shell and tube heat exchanger – It is a type of heat exchanger which consists of a series of tubes containing the fluid that must be either heated or cooled with the second fluid being circulated over the tubes that need to be heated or cooled illustrated in fig; 7. Shell and tube heat exchangers are typically used for high pressure applications (with pressure greater than 30 bar and temperature greater than 260 °Celsius) owing to its robustness Fig. I illustrates a typical shell and tube heat exchanger. Shell and plate heat exchangers were recently introduced in the market and can withstand relatively high pressures and temperatures, as the shell and tube does. The fusion bonded plate heat exchangers (100% stainless steel) are a technology from the 21st century, these equipment being more durable than brazed plate heat exchangers.

The first patent for a plate heat exchanger was granted in 1878 to Albretch Dracke, a German inventor. The commercial embodiment of these equipments has become available in 1923. However, the plate heat exchanger development race began in the 1930's and these gasketed plate and frame heat exchangers were mainly used as pasteurizers (e.g. for milk and beer). Industrial plate heat exchangers were introduced in the 1950's and initially they were converted dairy models. Brazed plate heat exchangers were developed in the late 1970's In 1996, the total market for heat exchangers in Europe amounted to USD 3.6 billion and the plate heat exchanger had a market share of 13% (second position after the conventional shell-and-tube heat exchanger). Modern plate heat exchangers provide higher working temperatures, larger working pressures, higher resistance to chemicals, etc.. Due to this, different types of plate heat exchangers are nowadays applied in a very broad range of industrial heat exchanger needs.

CAD combines the characteristic of designer and computer that are best applicable to the design process, the combination of human creativity with computer technology provides the design efficiency that has made CAD such as popular design tool. CAD has its roots in interactive computer graphics. Before the CAD era, engineering drawings were prepared manually on paper using pencils and drafting instruments on a drafting table. The advent of interactive computer graphics replaced the drafting table with a computer monitor and the pencil with an input device such as a light pen or mouse. Instead of using physical drafting instruments, software commands and icons on the computer display are used. The drawing can be created, modified, copied, and transformed using the software tools. At the time, CAD stood for computer-aided drafting. Drafting was confined to 2D because of the paper limitation. With the computer, such limitation is removed. Three-dimensional CAD systems were developed in the 1960s. In 3D CAD, objects are modeled using 3D coordinates (x, y, and z) instead of 2D coordinates (x and y). The need for modeling parts and products with complex surfaces motivated the development of free form surface modelers shown in fig 5. CAD combines the characteristic of designer and computer that are best applicable to the design process, the combination of human creativity with computer technology provides the design efficiency that has made CAD such as popular design tool .While it is difficult to quote a date of the invention of the finite element method, the method originated from the need to solve complex elasticity and structural analysis problems in civil and aeronautical engineering. Its development can be traced back to the work by A. Hrennikoff and R. Courant in the early 1940s. Another pioneer was Ioannis Argyris. In the USSR, the introduction of the

practical application of the method is usually connected with name of Leonard Oganesyan. In China, in the later 1950s and early 1960s, based on the computations of dam constructions, K. Feng proposed a systematic numerical method for solving partial differential equations. The method was called the finite difference method based on variation principle, which was another independent invention of the finite element method. Although the approaches used by these pioneers are different, they share one essential characteristic: mesh discretization of a continuous domain into a set of discrete sub-domains, usually called elements illustrated in fig; 2. Hrennikoff's work discretizes the domain by using a lattice analogy, while Courant's approach divides the domain into finite triangular subregions to solve second order elliptic partial differential equations (PDEs) that arise from the problem of torsion of a cylinder. Courant's contribution was evolutionary, drawing on a large body of earlier results for PDEs developed by Rayleigh, Ritz, and Galerkin.

The finite element method obtained its real impetus in the 1960s and 1970s by the developments of J. H. Argyris with co-workers at the University of Stuttgart, R. W. Clough with co-workers at UC Berkeley, O. C. Zienkiewicz with co-workers Ernest Hinton, Bruce Irons and others at the University of Swansea, Philippe G. Ciarlet at the University of Paris and Richard Gallagher with co-workers at Cornell University. Further impetus was provided in these years by available open source finite element software programs. NASA sponsored the original version of NASTRAN, and UC Berkeley made the finite element program SAP IV widely available. In Norway the ship classification society Det Norske Veritas (now DNV GL) developed Sesam in 1969 for use in analysis of ships. A rigorous mathematical basis to the finite element method was provided in 1973 with the publication by Strang and Fix. The method has since been generalized for the numerical modeling of physical systems in a wide variety of engineering disciplines, e.g., electromagnetism, heat transfer, and fluid dynamics.

Applications

Heat exchangers can be used in food Industry as a process of cooling down various products in the industry. Large number of products like hazelnut paste and other types of food pastes are required to be cooled down or heated up in order to be processed further . For this process Heat exchanger can be used.

Principle

The basic principle of heat exchanger is the transfer of heat between two temperature of the two fluids will soon come to an equilibrium temperature. The energy from each fluid is

exchanged and no extra heat is added or removed. Since the heat in the process is not constant and the heat amount of the fluids is also not constant thus the Heat exchanger must be designed in a way that it is suited for alluids. Two fluids are brought in close contact with each other but are prevented from mixing by a physical barrier illustrated in fig; 2 The temperature of the two fluids will soon come to an equilibrium temperature. The energy from each fluid is exchanged and no extra heat is added or removed. Since the heat in the process is not constant and the heat amount of the fluids is also not constant thus the Heat exchanger must be designed in a way that it is suited for all the cases of heat exchange and the performance is best suited for all conditions. Also the design should be such that the heat exchange is at a particular rate required by the process.

Tube Diameter

The most common sizes used are 3/4"od and 1"od Use smallest diameter for greater heat transfer area with a normal minimum of 3/4"od tube due to cleaning considerations and vibration.1/2"od tubes can be used on shorter tube lengths say < 4ft. The wall thickness is defined by the Birmingham wire gage (BWG) illustrated in fig.

Tube Number and Length

Select the number of tubes per tube side pass to give optimum velocity 3-5 ft/s (0.9-1.52 m/s) for liquids and reasonable gas velocities are 50-100 ft/s (15-30 m/s) If the velocity cannot be achieved in a single pass consider increasing the number of passes. Tube length is determined by heat transfer required subject to plant layout and pressure drop constraints. To meet the design pressure drop constraints may require an increase in the number of tubes and/or a reduction in tube length. Long tube lengths with few tubes may give rise to shell side distribution problems

Shell Diameter

The design process is to fit the number of tubes into a suitable shell to achieve the desired shell side velocity 4ft/s (1.219m/s) subject to pressure drop constraints. Most efficient conditions for heat transfer is to have the maximum number of tubes possible in the shell to maximise turbulence. Preferred tube length to shell diameter ratio is in the range 5 to Tubes have been eliminated to provide entrance area for a nozzle equal to 0.2 times shell diameter Tube layouts are symmetrical about both the horizontal and vertical axes Distance from tube od to centre line of pass partition 7.9mm (/16) for shell id <559mm (22in) and 9.5mm (/8) for larger shells.

Applying Computers to Design

No other idea or device has impacted engineering as computers have. All engineering disciplines routinely use computer for calculation, analysis, design and simulation .Many of the individual tasks within the overall design process can be performed using a computer. As each of these tasks is made more efficient, the efficiency of the overall process increases as well. The computer is especially well suited to design in four areas, which correspond to the latter four stages of the general design process. Computers function in the design process through geometric modeling capabilities, engineering analysis calculations, automated testing procedures, and automated drafting. Illustrated in fig 1-9

Static Analysis

Determines reaction forces at the joint positions of resting when a constant load is applied fig4. As long as zero velocity is assumed, static analysis can be performed on mechanisms at different points of their range of motion. Static analysis allows the designer to determine the reaction forces on whole mechanical systems as well as interconnection forces transmitted to their individual joints. criteria set out in the problem definition. These criteria may include reliability, fatigue, and performance The data extracted from static analysis can be useful in determining compatibility with the various considerations to be analyzed through stress analysis methods. Detailed the Region with FOS (factor of safety) value less than 1 in red

Experimental Analysis

Involves fabricating a prototype and subjecting it to various experimental methods. Although this usually takes place in the later stages of design, CAD systems enable the designer to make more effective use of experimental data, especially where analytical methods are thought to be unreliable for the given model. CAD also provides a useful platform for incorporating experimental results shown in fig 5.

Why Use Simulation Modeling?

We will use the term "simulation platform" to refer to the software environment used to develop, test and run a simulation experiment. First, let's examine what features a simulation platform needs. Following is a list of the capabilities that must be available:

➢ A way to represent mathematical and logical relationships between variables in the form of computations and assignment of values, and algorithms that describe how to do a series of computations.

➢ A way to generate random numbers and use them to sample observations from various distributions.

➢ A means to repeat a series of computations, thus implementing replications. This list s minimal. All of these features are necessary for the platform to be used for simulation.

How to Design a Simulation Experiment

A simulation experiment is a test or a series of tests in which meaningful changes are made to the input variables of a simulation model so that we may observe and identify the reasons for changes in the performance measures. The number of experiments in a simulation study is greater than or equal to the number of questions being asked about the model (e.g., Is there a significant difference between the mean delay in communication, Networks A and B?, Which network has the least delay Design of a simulation experiment involves answering the question: what data need to be obtained, in what form, and how much.

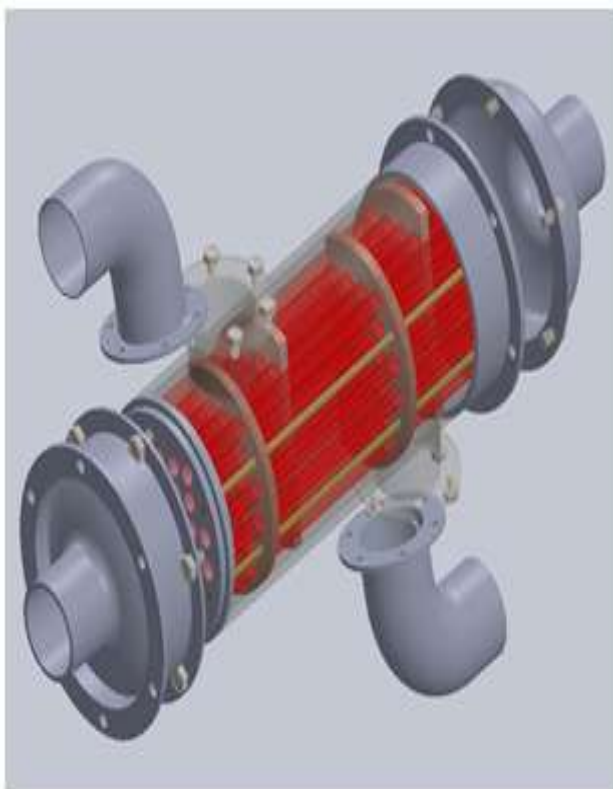**Design Analysis of Shel and Tube Heat Exchanger**

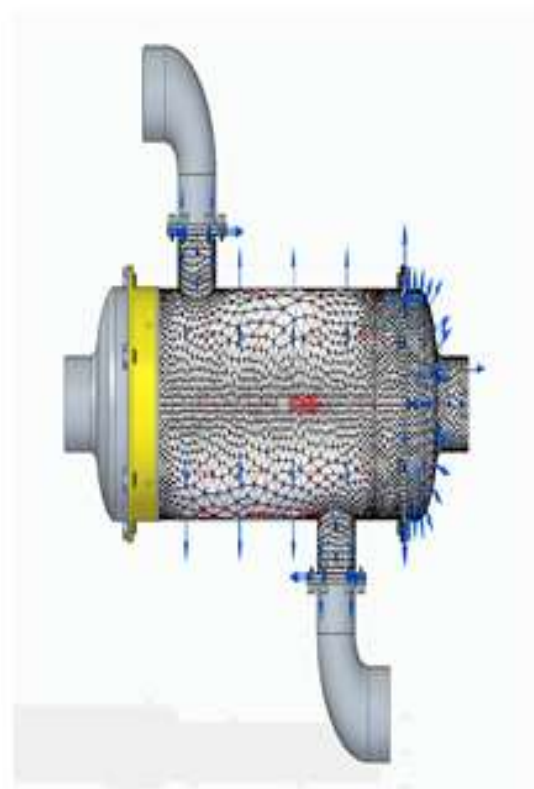**Fig. 1: Explode Views of Shell and Tube heat exchanger.**   **Fig. 2: Discretization of shell and tube Heat exchanger.**
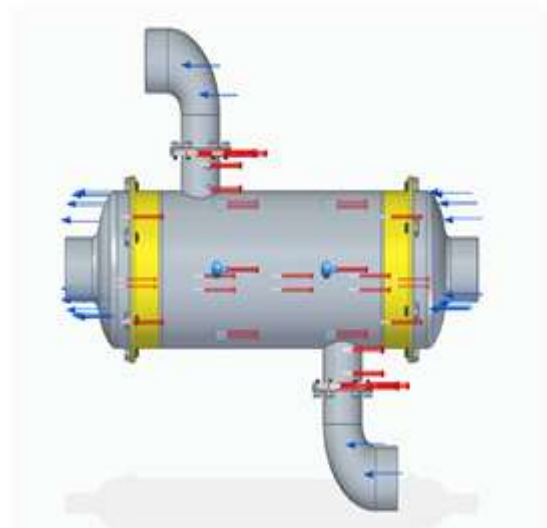
Fig. 3: Material analysis and Constrain.
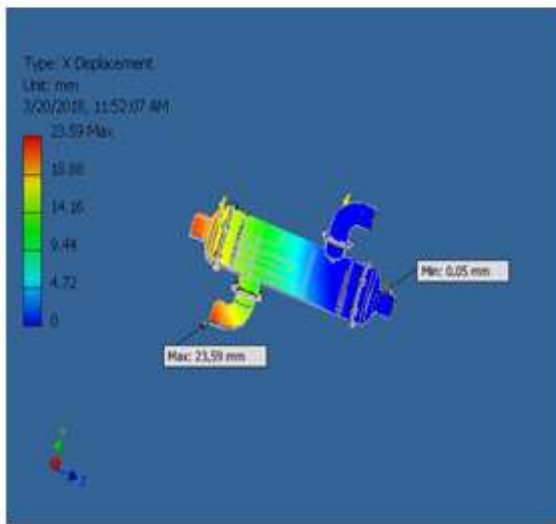

Fig. 3: Wire Frame.
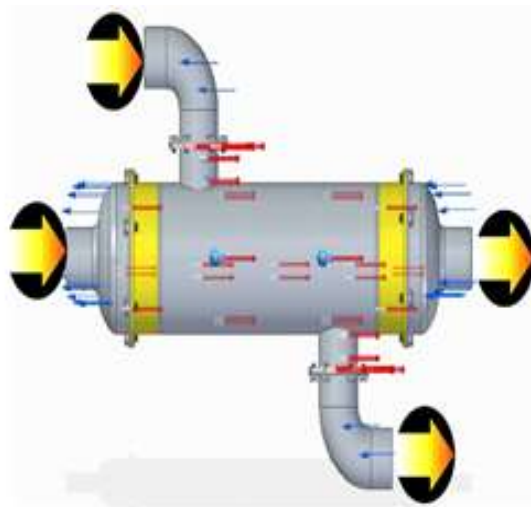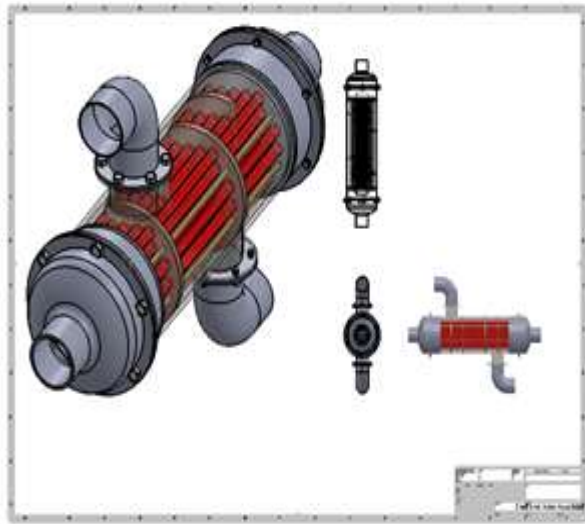

Fig. 4: Material analysis and Constrain.
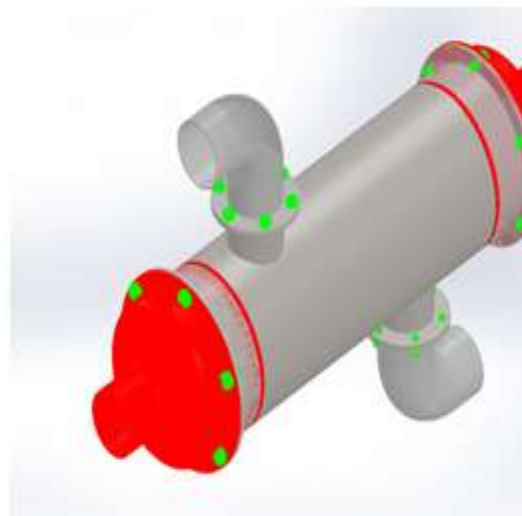

Fig. 5: Y. Displacement.

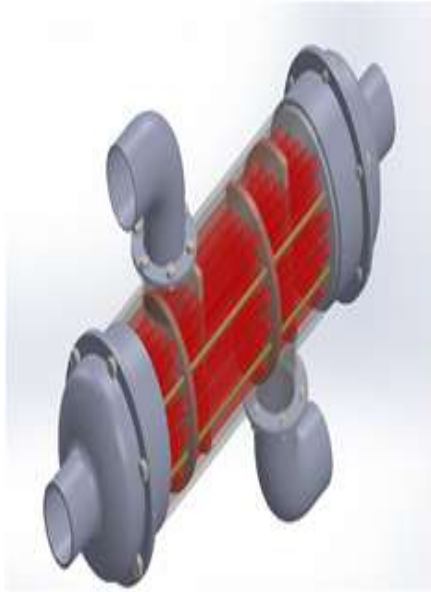

Fig. 6: Multiply Views.
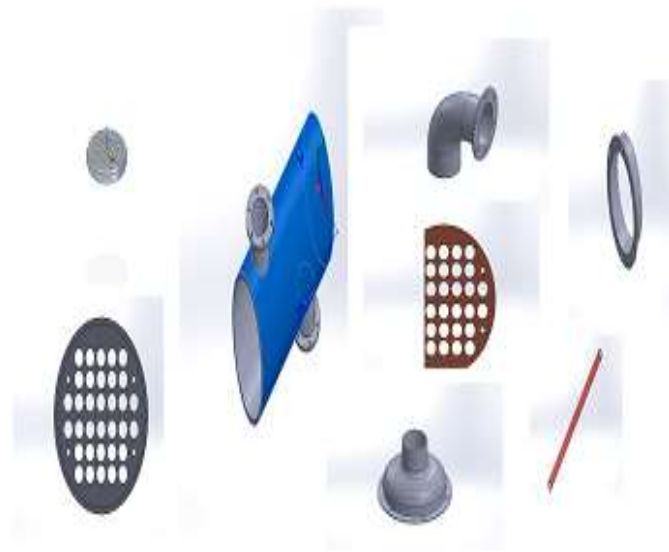
Fig. 7: Direction of flows.   **Fig. 8: Sustainability analysis of the shell and**

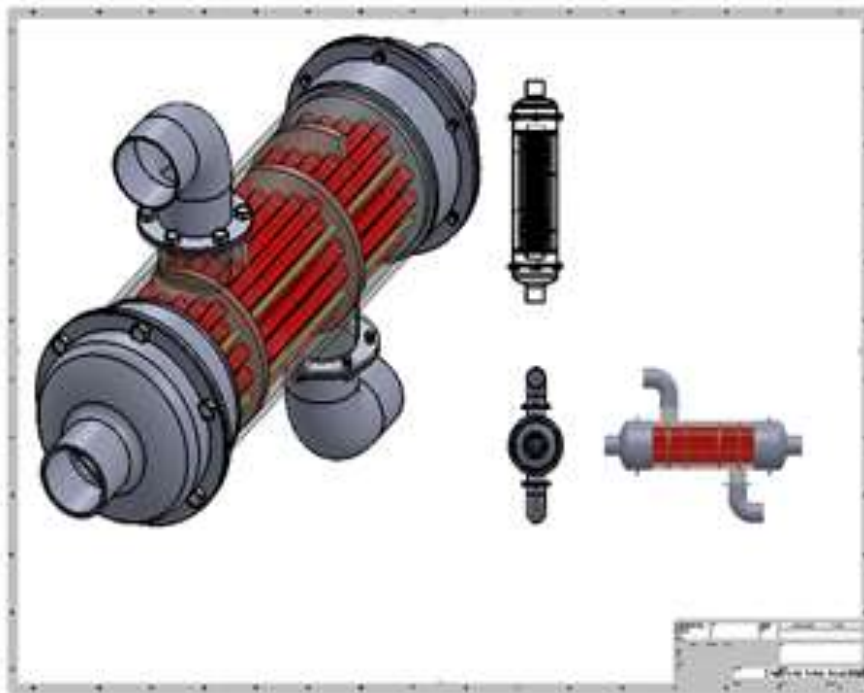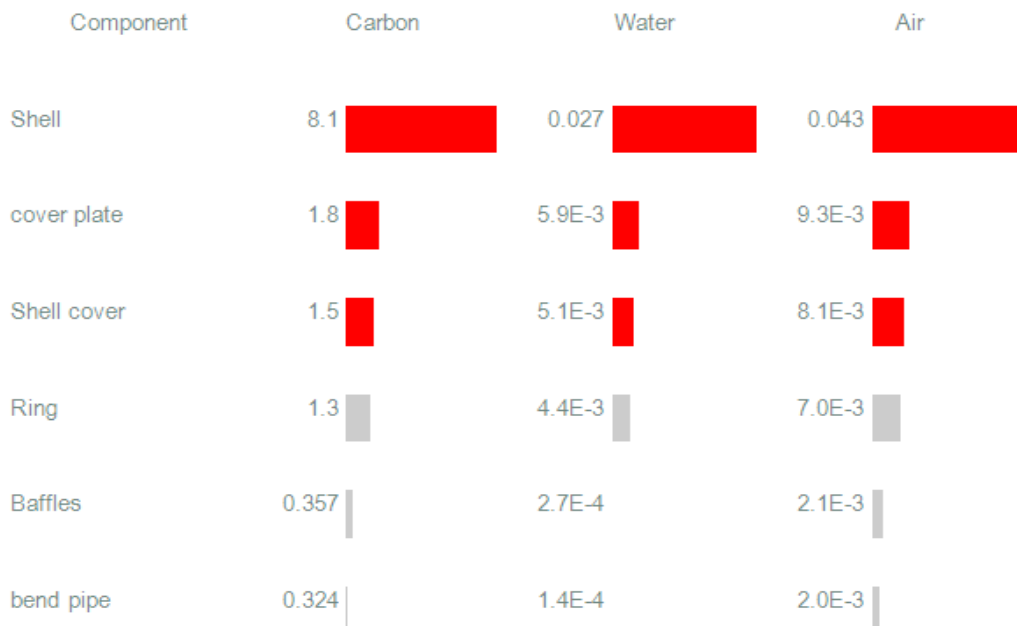**tube Component Environmental Impact.**

Fig. 9: Final Drawing and the Major Components of Shell and Tube Heat Exchanger.

Top Ten Components Contributing Most to the Four Areas of Environmental Impact

Component	Carbon	Water	Air
Shell	8.1	0.027	0.043
cover plate	1.8	5.9E-3	9.3E-3
Shell cover	1.5	5.1E-3	8.1E-3
Ring	1.3	4.4E-3	7.0E-3
Baffles	0.357	2.7E-4	2.1E-3
bend pipe	0.324	1.4E-4	2.0E-3

Environmental Impact (calculated using CML impact assessment methodology)

Carbon Footprint

Material:	180 kg CO_2e
Manufacturing:	31 kg CO_2e
Use:	0.00 kg CO_2e
Transportation:	2.7 kg CO_2e
End of Life:	22 kg CO_2e

240 kg CO_2e

Total Energy Consumed

Material:	2000 MJ
Manufacturing:	310 MJ
Use:	0.00 MJ
Transportation:	34 MJ
End of Life:	16 MJ

2300 MJ

Air Acidification

Material:	0.963 kg SO_2e
Manufacturing:	0.442 kg SO_2e
Use:	0.00 kg SO_2e
Transportation:	0.089 kg SO_2e
End of Life:	0.011 kg SO_2e

1.5 kg SO_2e

Water Eutrophication

Material:	0.571 kg PO_4e
Manufacturing:	0.017 kg PO_4e
Use:	0.00 kg PO_4e
Transportation:	8.4E-3 kg PO_4e
End of Life:	0.027 kg PO_4e

0.623 kg PO_4e

Material Financial Impact   75.40 USD

Comments

Design Process

The ability to create something out of nothing makes design one of the most exciting aspects of engineering. To be successful, design engineer require abroad set of talents include.

Knowledge creativity, people skill and planning ability Engineers use CAD to create two−and three−dimensional drawings, such as those for automobile and airplane parts, floor plans, and maps and machine assembly. While it may be faster for an engineer to create an initial drawing by hand, it is much more efficient to change and adjust drawings by computer. In the design stage, drafting and computer graphics techniques are combined to produce models of different machines. Using a computer to perform the six−step'art−to−part' process: The first two steps in this process are the use of sketching software to capture the initial design ideas and to produce accurate engineering drawings. The third step is rendering an accurate image of what the part will look like Next, engineers use analysis software to ensure that the part is strong enough shown in fig; 5 Step five is the production of a prototype, or model CAD began as an electronic drafting board, a replacement of the traditional paper and pencil drafting method. Over the years it has evolved into a sophisticated surface and solid modeling tool. Not only can products be represented precisely as solid models, factory shop floors can also be modeled and simulated in 3D. It is an indispensable tool to modern engineers illustrated in fig 6.

Wire Frame

The most basic functions of CAD are the 2D drafting functions. 2D geometry such as line, circles, and curves can be defined. A 2D profile can also be extruded into a 2 1⁄2 D object. The extruded object is a wireframe of the object CAD also allows a 3D wire-frame to be defined illustrated in fig; 3. To cover the wire-frame model, faces can be added to the model. This creates a shell of the object. Hidden line/surface algorithms can be applied to create realistic pictures. Many menu functions are used to help simplify the design process. Annotation and dimensioning are also supported. Text and dimension symbols can be placed anywhere on the drawing, at any angle, and at any size.

Explode Views

An exploded view drawing is a diagram, picture, schematic or technical drawing of an object, that shows the relationship or order of assembly of various parts. It shows the components of an object slightly separated by distance, or suspended in surrounding space in the case of a three-dimensional exploded diagram. An object is represented as if there had been a small

controlled explosion emanating from the middle of the object, causing the object's parts to be separated an equal distance away from their original locations. The exploded view drawing is used in parts catalogs, assembly and maintenance manuals and other instructional material. The projection of an exploded view is usually shown from above and slightly in diagonal from the left or right side of the drawing. An exploded view drawing is a type of drawing, that shows the intended assembly of mechanical or other parts. Shown in fig; 1.

Modelling

Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest as shown in fig 9. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. On the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software. Mathematical model classifications include deterministic (input and output variables are fixed values) or stochastic (at least one of the input or output variables is probabilistic); static (time is not taken into account) or dynamic (time-varying interactions among variables are taken into account). Typically, simulation models are stochastic and dynamic.

Simulation

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time. Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance. For instance,

simulation can be used to answer questions like: What is the best design for a new network? What are the associated resource requirements? How will a telecommunication network perform when the traffic load increases by 50%? How will new routing algorithm affect its performance? Which network protocol optimizes network performance? What will be the impact of a link failure? The subject of this tutorial is discrete event simulation in which the central assumption is that the system changes instantaneously in response to certain discrete events. For instance, in an M/M/1 queue - a single server queuing process in which time between arrivals and service time are exponential - an arrival causes the system to change instantaneously. On the other hand, continuous simulators, like flight simulators and weather simulators, attempt to quantify the changes in a system continuously over time in response to controls. Discrete event simulation is less detailed (coarser in its smallest time unit) than continuous simulation but it is much simpler to implement, and hence, is used in a wide variety of situations illustrated in fig 2-5.

Finite Element Analysis

Finite element analysis (FEA) is a computerized analysis method to envisage how a manufactured product will react to the physical world. The analysis includes bringing the product in contact with force, heat, vibration, fluid flow and other such physical conditions. The FEA can predict if the product is likely to break, tear, wear or behave the way it is manufactured to First developed in 1943 by R. Courant, finite element analysis is a part of the manufacturing process in order to help predict how an object would react to real-world conditions when used. FEA also helps solid-state scientists to improve the quality and function of an object. FEA essentially computes the individual component behavior and sums it up to predict the overall behavior of the manufactured product. FEA now commonly uses computers to model the object, which is then stressed and analyzed to obtain desired results. In the case of a faulty product or undesired result, FEA can help create a new design to meet the necessary conditions.

A typical finite element analysis on a software system requires the following information
Nodal point spatial locations (geometry) Elements connecting the nodal points, Mass properties, Boundary conditions or restraints, Loading or forcing function details, Analysis options.

Procedures

Divide structure into pieces (elements with nodes) (discretization/meshing) Connect (assemble) the elements at the nodes to form an approximate system of equations for the whole structure (forming element matrices) Solve the system of equations involving unknown quantities at the nodes (e.g., displacements).

Calculate desired quantities (e.g., strains and stresses) at selected elements Illustrated in fig 2.

Basic Theory

The way finite element analysis obtains the temperatures, stresses, flows, or other desired unknown parameters in the finite element model are by minimizing an energy functional. An energy functional consists of all the energies associated with the particular finite element model. Based on the law of conservation of energy, the finite element energy functional must equal zero. The finite element method obtains the correct solution for any finite element model by minimizing the energy functional. The minimum of the functional is found by setting the derivative of the with respect to the unknown grid point potential for zero.

Discretization

Meshing Coarse: Faster computation; not concerned about stress concentrations, singularities, or warping. Not near changes in geometry or displacement constraints or changes in material including thickness.

Meshing Fine: Best approximation but at the cost of the computation time. Look for disproportionate stress level changes from node to node or plate to plate and large adjacent node displacement differences to determine if need to refine the mesh. Nodes should be defined at locations where changes of geometry or loading occur. Changes in geometry relate to thickness, material and/or curvature. A simple check, if you can, is to decrease the mesh size by 50%, re-run analysis, and compare the change of magnitude of stresses and strains. If there is no significant change, then ok. In most companies, all of this knowledge of mesh size will be known and might be set a FEA control file illustrated in fig 2.

Sustainability

Simulation technology has been a significant tool for improving manufacturing operations in the past; but its focus has been on lowering costs, improving productivity and quality, and reducing time to market for new products. Sustainable manufacturing includes the integration

of processes, decision-making and the environmental concerns of an active industrial system to achieve economic growth, without destroying precious resources or the environment. Sustainability applies to the entire life cycle of a product shown in fig: 8 also detailed in component environment impact. It involves selection of materials, extraction of those materials, of parts, assembly methods, retailing, product use, recycling, recovery, and disposal will need to occur if simulation is to be applied successfully to sustainability. Manufacturers will need to focus on issues that they have not been concerned with before

Design for Environment (DFE)

Is systematic consideration of design performance with respect to environmental, health, safety, and sustainability objectives over the full product and process life cycle.

Environmentally Sustainable Design

Designers make decisions on the use of resources, modes of consumption and the lifecycles of products and services. Environmentally sustainable Design (also referred to as 'green design' Or 'eco-design') aims to ensure that products, services and systems are produced and provided in a way that reduces the use of non-renewable resources and minimizes environmental impact. It is increasingly important within the fields of architecture, urban design and planning, and design in general. Some common principles of environmentally sustainable design are as follows: Low-impact materials: designing for use of non-toxic, sustainably-produced or recycled materials which require little or no natural resources (such as energy and water) to transport and process, and whose use does not threaten bio-diversity; Resource efficiency: designing manufacturing processes, services and products which consume as little natural resources as possible; Quality and durability: creating longer-lasting and better-functioning products that last longer, or age in a manner that does not reduce the value of the product, reducing the impact of producing replacements Reuse, recycling and renewability: designing products that can composted be reused, recycled or after initial use.

CONCLUSION AND RECOMMENDATION

Heat exchangers find a variety of applications in various bioprocess industries in Food industry: for production of juices, hazel nut pastes yoghurts and other products, Ethanol production and Beverage Industry for production of wines, beer, ethanol and vinegar. Simulation technology has been a significant tool for improving manufacturing operations in the past; but its focus has been on lowering costs, improving productivity and quality, and reducing time to market. CAD Has allowed the designer to bypass much of the Manuel

drafting and analysis. Simulation tools enable us to be creative and to quickly test new ideas that would be much More difficult, time-consuming, and expensive to test in the lab. (Jeffrey D. Wilson Nasa Glenn Research Center) It also help us reduce cost and time -to-market by testing our designs on the computer rather than in the field. Many of the individual tasks within the overall design process can be performed using a computer. Base on this discuss the following policy are necessary, efforts should be made to adopt and popularize the design-, FEA, DFM, DFE ETC especially for the benefits of mankind who make up a great percentage of the Nation's population. If, the use of machine design adopted, the problem in agricultural processing Equipment will be minimized and hunger and poverty will be eradicated , detailed experiment of shell and tube Heat exchanger will be presented in the future work.

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