DESIGN OF BUFFER TANK IN HEAT PUMP SYSTEM

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ABSTRACT

Buffer tank is a type of surge tank which is predominantly used to regulate pressure fluctuation in a heat pump system. In this system, the photovoltaic-thermal collector plays a major role in retaining heat of water inside the tank, since an insulating material completely encloses the buffer tank. The main objective of the study is to utilize a buffer tank to reduce the energy consumption of an electric heater of a heat pump system. In accordance with industrial design standards, the design of the buffer tank is made and examined using Finite Element Analysis (FEA) by varying the pressure and mesh density. The varying pressure has been calculated theoretically at different portions of the tank, such as the pressure inside cylindrical shells, dished ends, and flange tubes. The internal pressure of 1.6 bar and the external pressure of 2 bar were obtained according to the tank specifications. The post-run findings of stress, strain, displacement, and factor of safety are analysed and are significant to determine the efficiency of the heat pump system. The observed result from the analysis shows that the maximum Von-Mises values are below the maximum permitted working stress. The tank is experiencing a reversible deflection of maximum 1.813 mm at the dish end of the buffer tank. It is significantly less and has no impact on the buffer tank, the heat pump system operates more efficiently.

Keywords: Heat Pump System, Water Heating System, Buffer Tank, Finite Element Analysis.

I. INTRODUCTION

In a photovoltaic-thermal collector (PVT) assisted heat pump system, a buffer tank is employed as a water storage tank where it temporarily stores water while also maintaining heat. Initially, heat is captured and stored from a variety of sources. PVT panels only provide adequate heat during the summer season. Sometimes, when the sun doesn't shine as much, heat can be obtained through the heat pump and wind and infrared-sensitive solar collectors (WISC). The more predictable and consistent energy needs of families are met with the energy produced from unstable renewable sources, such as solar energy. PVT panels, which are typically employed in the system for their higher efficiency, are a combination of photo-voltaic panels and solar thermal collection panels (1). In solar heating systems, heat pumps can be employed as an additional source of heat due to their efficiency in converting electricity into heat. For purposes such as hot water demands, the heat pump must supply heat at a specific temperature. WISC, also known as energy absorbers, can be employed as heat exchangers between the system’s ambient air and the heat transfer fluid. When there isn’t much solar radiation available, it collects thermal energy from the surrounding environment. This makes it possible to extract low-temperature heat from the surrounding air (2). The buffer system saves solar energy and uses it on days with low temperatures, resulting in improved operational conditions for the heat pump with higher efficiency. Consequently, adding buffer storage may enhance a solar-assisted heat pump system's seasonal performance. It evaluates the interaction between the various system components and the dynamic performance of the thermal component of the system design. The analysis should provide in-sight into the conception of the system's dynamic behaviour as well as its numerous operational modes under various weather scenarios. Fig. 1. Clearly depicts the Explanation of the PVT system along with the control approach and the positions of sensors proposed in the research (3). The system's effectiveness and efficiency in harvesting solar radiation to generate electrical and thermal energy are evaluated. The results showed that the PVT system has the capability to provide both hot water and electricity for households, with a high level of energy conversion efficiency, particularly for electrical output. Additionally, the study analysed the system's performance in relation to various factors, such as fluid flow rate and ambient temperature (4). The nonlinear modelling and dynamic control of hydro turbines, in addition to the surge tank and sloped tail race tunnel system, are
considered working systems in this article. It also attempts to explain in brief what a surge tank is and the motion characteristics of a sloping ceiling tailrace tunnel. The author tries to give sufficient information about the interactions between the upstream surge tank and the sloping ceiling tunnel. The proposal of a nonlinear mathematical model, the dynamic characteristics, and the algebraic criterion of the hydro turbine help to make the system more stable. Various equations and formulas of the governing systems are provided in this research (5). The system, which consists of a centrifugal pump, surge tank, water tank, and pipelines, is constructed, and the volume of fluid (VOF) numerical model and geometric model for the system are completed along with simulation in the Fluent software. The surge tank in the system is primarily designed as a pressure tank to regulate the water flow at the output. Despite the surge tank’s many advantages, it also has several disadvantages, such as a low-pressure head, a lengthy construction period, a high price, and a difficult removal procedure. A geometrical model with specific dimensions and mesh characteristics is provided in order to analyse the effects of pulsation frequency, starting water level, and baffle architecture on flow stability. This also provides the best surge effect condition for the system to achieve better attenuation (6).

Figure 1: A depiction of the PVT system and its control approach along with the positions of sensors (3)

Despite playing a significant part in the functioning system, the buffer tank is challenging to manage. In such a circumstance, numerous natural disasters and human errors might cause it to fail. Steel storage buffer tanks that are susceptible to lateral loads and their bases have the propensity to bend and lift locally as a consequence of the hydrodynamic pressure of earthquakes. Due to the hydrodynamic pressure of earthquakes, steel storage buffer tanks that are susceptible to lateral loads and their bases have the propensity to bend and elevate locally. The storage tank base plate’s plastic rotation and the base plate’s variable contact with the foundation are examples of sources the author discovered for nonlinear behaviour processes. Other sources include big deflections, material yielding, large deflections, and material yielding. Both the rocking resistance of the liquid-loaded base plate and the stress distribution on the tank wall in contact with the foundation can be more accurately estimated thanks to the effective use of nonlinear quasi-static cyclic analysis and three-dimensional dynamic analysis (7). Storage tanks are crucial operating equipment at oilfield stations that serve a range of functions. According to the author, internal and external corrosion and perforation are the main causes of tank failures. They are sometimes supposed to explode as a result of this corrosion. He carried out a comprehensive investigation to pinpoint the precise reason for the storage tank explosion failure (8). The article (9) scrutinizes a buffer tank bursting accident that happened on a Liquefied Natural Gas (LNG) bus and derives lessons from the occurrence. The investigation looks into the causes of the disaster and provides insights on how to prevent future incidents. The study’s results are intended to advance the design, operation, and maintenance of LNG buses and vehicles of a similar nature.

In Article (10), the use of a thermal energy tank filled with paraffin is discussed as a viable way to heat a space. The paper apparently describes an experimental assessment of a full-scale prototype of such a tank, including its design, fabrication, and testing, in order to judge its efficacy and potential for use in space heating applications. The study may have focused on the tank’s capacity for thermal energy storage, efficiency of heat...
transmission, general performance in various conditions, and any challenges or limitations encountered during testing. The study may have also discussed the benefits of using this type of thermal energy storage technology from an economic and environmental perspective. The article authored by Wojciech Kreft examines a batch-fired straw boiler that is paired with a buffer tank for localized heating. The study delves into the system's design, construction, and testing, utilizing simulation and modelling to evaluate its performance. The research also explores how various factors like buffer tank size, straw type, and fuel moisture content can impact heat output. Additionally, the paper may have discussed the environmental advantages of using this type of heating system, such as the decrease in greenhouse gas emissions as compared to fossil fuel-based heating systems (11). Hot water tanks that have been integrated with phase change material-based storage units were investigated. Its aim was to evaluate the efficiency of these systems in terms of thermal energy storage and distribution. The study utilized numerical simulation techniques to model the system and validate the findings through experiments. The results may have shown the benefits of incorporating phase change materials into hot water tanks, including increased energy efficiency and storage capacity (12). It also establishes the ideal conditions for assessing the effectiveness and performance of a hybrid system. The system's performance was improved using numerical simulations that took into consideration variables including temperature and solar radiation. The study's findings could have demonstrated the benefits of employing a hybrid system, such as improved thermal energy distribution and storage capacities (13). In surge tanks, several design optimizations have been made since the very early years. In this study, the design computation and design parameters for the surge tank optimization are done using the graph-analytic method. The author also acknowledged that, in comparison to contemporary computing equipment, the outcomes of graph analysis indicate more inaccuracies. Despite having more inaccuracies, this method allows for the comparison of surge tank variations among multiple kinds (14). Article (15) discussed the pressure head or discharge reaction at any point along the pipeline system, including the effect of the tank, and created a novel method for designing a surge tank. Additionally, a transient simulation of the surge tank is provided. Future research on this article will concentrate on the experimental validation of the surge tank design employing the impulse response approach. The paper (16) outlines a distinctive design strategy for the hot water storage tank in a solar water heating system that incorporates artificial neural networks. This design takes into account factors like temperature and sunlight to enhance the performance of the system. The study's results may showcase the benefits of using this innovative design, such as improved thermal energy distribution and enhanced storage capacity. The effects of a static load on the structural integrity of a fuel tank were examined and the study aimed to evaluate the performance of the tank under a specific loading condition and determine its behaviour through computational analysis. The researchers utilized simulation techniques to model the loading scenario and measure the deformation and stress produced. The findings of the analysis were then used to make conclusions and suggestions for potential design improvements (17). The system of a single-tank thermal storage system for domestic hot water utilizes phase change material to store and release heat efficiently. The research encompasses the simulation and design of the system, as well as an investigation of its performance and efficiency. The findings are used to offer suggestions for improvement and potential real-world applications that the design and study of storage systems were depicted in very detail (18). The study (19) focuses on the use of computer models to analyse temperature changes in a buffer tank used with a greenhouse heating system. The temperature dynamics in the tank and its relationship with the heating system were examined. Simulation models were employed to evaluate the temperature fluctuations in the buffer tank and assess the performance of the system. The findings were then used to offer suggestions for improving the integration of the buffer tank with the greenhouse heating system and optimizing its operation. Thermal stratification in a solar hot water storage tank that features a mantle heat exchanger was detailly discussed. The temperature distribution and stratification in the tank and the assessment of the mantle heat exchanger's performance were investigated. The study employed computational models to simulate temperature changes in the tank and examine heat transfer and stratification in the system. The findings were utilized to offer recommendations for improving the design and operation of the solar hot water storage tank with mantle heat exchanger (20).

The process of modelling and verifying the thermal characteristics of seasonal storage tanks employed in solar district heating systems was examined. The temperature changes in the tanks and validate the accuracy of the models using experimental data were modelled. Analytical models were used to simulate the thermal...
behaviour of the storage tanks and evaluate their performance. The findings were then utilized to validate the models and suggest ways to improve the design and operation of the seasonal storage tanks for solar district heating systems (21). The performance of a roll-bond PVT heat pump system during the summer season was thoroughly evaluated in this research study. The system under examination was equipped with single stage compression and aimed to understand its ability to generate energy for heating and cooling a building, as well as its impact on energy consumption. The system operates efficiently and has the potential to significantly lower energy usage during the summer months. The system’s capacity for energy generation and its effects on energy consumption are accurately explored (22). The potential to increase energy efficiency and thermal comfort in district heating networks was discovered after examining a non-uniform temperature district heating system that combines decentralised heat pumps with independent storage tanks. When compared to traditional district heating systems that employ a central heating system, the usage of decentralised heat pumps and independent storage tanks can provide more effective heating and enhanced thermal comfort. This technology allows for more accurate temperature and energy regulation, resulting in a more effective and ecologically friendly heating solution for district heating networks (23).

The authors perform a thorough investigation of the elements that make up a hybrid PVT system for producing home hot water. Additionally, they concentrate on parts like the hot water storage tank, thermal collector, and solar panels. They evaluate the interaction between the system’s ideal operating circumstances and a number of important performance indicators, including energy production, hot water output, and thermal efficiency. The best design parameters for various operational circumstances are chosen by the authors using a multi-objective optimization technique. The study’s findings offer insightful information on whether hybrid PVT systems may be used to produce household hot water, which may have an impact on future design and study in this field (24). The authors of the paper conducted a comprehensive investigation into a heat pump water heating system that utilizes refrigerant. The system is meticulously modelled to understand its operations and performance, and the effects of variables like fluid flow rate and ambient temperature on energy conversion efficiency and heat production are analysed. The results demonstrate that the photovoltaic and thermal assisted heat pump water heating system is highly effective at converting energy into heat and distributing it effectively. The authors validate their findings through experimental tests, further affirming the efficiency of the system (25). Mesh density is critical for identifying structural flaws in the buffer tank using finite element analysis (FEA). Alireza Ghavidel et al. constructed four different mesh densities for the same structure in this research publication to examine FEA. Only one of the four situations has excellent accuracy and few errors, since it only contains FEA findings that are much closer to the theoretical value estimated. Therefore, this instance is employed to check the safety of the chosen structurally optimal solution and aid in design optimization (26).

Figure 2: A Schematic Diagram of Heat Pump System
From the literature study, it is observed that the water heaters run on electricity are commonly found in various settings such as houses, schools, and business centres, but they can be costly to operate due to the large amount of electricity they require to heat the water. Despite advances in energy efficiency, high power consumption remains a prevalent issue. Traditional methods to lower energy usage, such as insulating pipes or replacing worn parts, are no longer as effective. Most of the research publications depict the alternative solution of implementing a PVT and WISC assisted heat pump system separately, which uses electricity to gather heat from the outside air and transfer it to the home's water supply is greater efficient. Fig. 2 shows the schematic diagram of a heat pump system.

Combining PVT and WISC collector panels in the same heat pump system can lower energy expenses and reduce the amount of electrical energy used by the water heater. A heat pump system is a type of heating, ventilation, and air conditioning (HVAC) equipment that uses a refrigerant-based cycle to transfer heat from one location to another and is considered more energy-efficient than traditional HVAC systems. It can be used as a replacement for both furnaces and air conditioners in all types of climates. The system operates by extracting heat from the ground or the outside air in the winter to heat the facility and the opposite process in the summer to cool the facility. Photovoltaics (PV) is a technology that converts sunlight into electricity, however, their performance decreases as the temperature of the cells increases. Solar thermal collectors, on the other hand, convert solar energy into heat that can be used for space heating and hot water. A hybrid system, known as a hybrid PVT, combines these two technologies to remove excess heat from the PV cells, thereby increasing their efficiency and also utilizing the removed heat to meet other heating needs. This results in more efficient use of the available solar space for installation.

II. RESEARCH METHODOLOGY

The stability and durability of buffer tanks for the heating application of heat pump systems to achieve energy-efficient is categorised in the following order, which is depicted in the Fig. 3.
III. DESIGN OF BUFFER TANK

A Buffer tank is a vital component in the orchestration of heating and cooling systems. As a repository for hot or cold water, it stabilizes fluctuations in demand, thus optimizing system efficiency and conserving energy. In order to harness the full potential of a buffer tank, the design must be carefully considered, taking into account its size and capacity, heat exchange surface area, insulation, and material selection. The size and capacity of the buffer tank were meticulously calculated based on the heating or cooling load and the flow rate of the system. An inadequately sized tank will not effectively regulate demand changes, while an excessive tank may result in wasted space and elevated energy consumption. The heat exchange surface area plays a critical role in the tank’s performance, as a larger surface area enhances heat transfer, but may also increase the size and cost of the tank. To prevent energy loss, the stored energy in the buffer tank must be protected through effective insulation. The material of the buffer tank is selected as AISI A304L; it satisfies the demands of application, ensuring durability, corrosion resistance, and compatibility with the stored fluid. A well-designed buffer tank serves as a cornerstone in the efficient operation of heating and cooling systems, contributing to their seamless performance and energy conservation.

3.1 Drums and Cylinders under Pressure

The minimum thickness of the cylindrical shells and drums which are subjected to internal pressure is calculated using the formula,

\[ t = \frac{P r_i}{(a^* - 0.5^* p) + c} \]

Where, \( t \) is minimum thickness (mm), \( P \) is design pressure (Mpa), \( r_i \) is inside radius (mm) and \( j \) is the joint factor of the longitudinal joints. It has been established through calculations that, given the parameters of \( p \) equal to 1.6, \( r_i \) equal to 350, and \( j \) equal to 0.8, the minimum thickness tends to be 5.80549 millimeters.

3.2 Dished end under Pressure

The calculation of the minimum thickness of the dished end under internal pressure is performed using a formula,

\[ t = \frac{P D_o K}{2 Z i g^* J + C} \]

The minimum thickness has been established to be 4.85454 millimeters based on the calculations with the parameters of design pressure equal to 1.6 MPa, outside diameter equal to 712 mm, and joint factor equal to one.

3.3 Tubes under Pressure

The minimum thickness of tubes subjected to internal pressure is determined through the application of a formula.

\[ t = \frac{P D_o}{2 Z i g + P} \]

The minimum thickness (\( t \)) of tubes subjected to design pressure (\( p \)) is calculated based on the outside diameter (\( D_o \)). Given the specified values of \( p \) equal to 1.6 MPa and \( D_o \) equal to 712 millimeters, it has been established through calculations that the minimum thickness is 3.86256 millimeters.

IV. CAD MODELLING

4.1 Dished Top

The dished head, also known as a spherical head or hemi-spherical head, is an essential aspect in the design and construction of a buffer tank. Fig.4 shows the dished top of buffer tank. Its foremost purpose is to provide a rounded and closed terminus to the pressure vessel, performing multiple functions to secure the tank’s structural integrity and functionality. The dished head acts as a stress distributor, reinforcing the tank’s stability and strength by uniformly distributing the stress across its surface. Additionally, it acts as a leak-proof barrier, securing the contents of the pressure vessel and preventing any potential escape. It also serves as a structural support, fortifying the tank’s framework and reducing the possibility of deformation or collapse. Furthermore, the dished head contributes to the overall symmetry and balance of the tank, promoting its stability. In conclusion, the dished head is a critical component that plays a pivotal role in guaranteeing the security, reliability, and longevity of a buffer tank.
4.2 Dished Bottom

The dished bottom of the buffer tank, which has a rounded, concave centrepiece, represents the pressure vessel's foundation, see Fig. 5. This essential component performs a number of duties that together increase the tank's overall toughness and stability. Its flat, smooth surface is perfect for distributing stress, which reduces tank deformation and lengthens its useful life. Because of the dished bottom's symmetrical and balanced shape, the container is more stable overall, and the contents may drain more easily, lowering the danger of corrosion and contamination. The dishing strengthens the support system of the tank and the bottom of the tank, reducing the likelihood of damage or collapse. The buffer tank's dished bottom keeps the tank from bowing under pressure, which is crucial for safety, reliability, and longevity.

4.3 Shell Plate/Cylindrical Drum

A shell plate or cylindrical drum is a significant component of a buffer tank that comprises the primary body of the pressure vessel, see Fig. 6. This component might have a shell or a cylindric form. By establishing a chamber that is hermetically sealed from the outside, it creates a hermetic environment for the containment of the tank's contents. Additionally, it protects the structural integrity of the tank by withstanding internal pressure and outside stresses. When making shell plates, steel, stainless steel, and corrosion-resistant alloys are among the materials that are usually utilized. When choosing a material, corrosion resistance and durability are taken into consideration. The thickness of the shell plate must be taken into account when assessing the buffer tank's overall strength and dependability. The shell plate provides the required structural support, assuring the safety and dependability of the tank and its contents.

4.4 Support Clamp

Support clamps are essential parts in the field of tank engineering because they play a major role in the security and stability of buffer tanks. These feats of engineering are designed to keep the tank in place, releasing pressure from any one spot and avoiding distortion or collapse. Support clamps do this by guaranteeing the tank's safe and dependable functioning regardless of changes in pressure or temperature. In addition to enhancing the tank's safety, these clamps are crucial for reducing unintended movements and vibrations. These vibrations may cause damage to the tank or one of its components, prompting costly repairs or perhaps the tank's complete failure. Support clamps ensure the tank's stability and security, allowing for continued operation. The significance of support clamps in the field of buffer tanks cannot be emphasized. These sturdy, trustworthy components provide the foundation for a tank's safety and security, allowing it to function optimally and withstand the test of time. Therefore, the next time you encounter a buffer tank, take a moment to admire the support clamps, the unsung heroes of tank engineering.
4.5 Buffer Plates
A Buffer Tank’s stability and reliability are essential for maintaining consistent water temperatures and preventing structural damage. This is achieved through the use of metal plates such as the Doubling Plate, Square Plate, and Base Plate. The Doubling Plate supports the tank’s base and provides insulation during welding to maintain constant water temperatures and lower the risk of thermal stratification. The Square Plate serves as the tank’s base, providing stability, support, and evenly distributing the tank’s weight to reduce the risk of structural damage. The Base Plate, made from a sturdy material like steel, secures and levels the tank by connecting it to the ground or supporting structure while evenly distributing its weight to prevent structural damage. These metal plates play a critical role in preserving the stability and safety of the Buffer Tank.

4.6 Reinforcement Pad
The reinforcing pad, which is typically manufactured from a robust and long-lasting material such as stainless steel, plays a critical role in maintaining the integrity of the buffer tank. It is carefully fitted over the tube hole in the tank to provide extra support and to minimize the risk of breakage or degradation. The pad also helps to absorb and distribute any pressure or stress that may be applied to the tank, thereby ensuring its stability and longevity. The reinforcement pad serves to reinforce the surface of the buffer tank and effectively closes the tube hole, which helps to prevent leaks and spills, and to protect the tank from the wear and tear associated with repeated heating and cooling cycles. By performing these functions, the reinforcing pad helps to extend the lifespan of the buffer tank and to ensure its consistent and reliable operation.

4.7 pipes and Flanges
The utilization of pipes and flange connections are imperative for the proper functioning of a heat pump system. The pipes serve as a means of transporting water between the various components of the system, such as the heat pump, heat ex-changer, buffer tank, and others. Flange connections are utilized to securely connect pipes to the various components of the system. They provide a reliable and leak-proof seal, thereby increasing the efficiency and effectiveness of the system. The use of flanges reduces the likelihood of leaks, thus improving the overall performance of the system. In the event that maintenance or repairs are required, flanges can be easily removed and replaced, facilitating the maintenance process.

The above-listed parts are meticulously modelled and assembled together inside the design software and the assembled cad model of buffer tank is shown in Fig. 7 (A).
### V. FINITE ELEMENT ANALYSIS

The process of FEA consists of various processes that are used to evaluate and simulate the behaviour of a buffer tank structure or system. It is discussed in detail on the basis of three analytical methodologies, as seen in Fig. 8.

![Finite Element Analysis Diagram](image)

**Figure 8**: Steps involved in FEA.
5.1 Pre-Processing

The preliminary phase of FEA in the static structural analysis of a buffer tank is an indispensable component in the simulation process. Its aim is to transform the CAD model of the buffer tank into a simulation model that can predict its performance under a static pressure load. The procedure begins with loading the CAD model into the FEA software. Subsequently, the model undergoes meshing, which involves dividing it into several small elements. The use of a tetrahedral mesh in the finite element analysis (FEA) of the buffer tank is a well-considered decision. Tetrahedral meshing is preferred for FEA analysis of curved structures due to several advantages over other meshing techniques. It provides more constant element sizes, which reduces errors and inaccuracies in analysis. The findings become more accurate as a consequence. Second, the greater aspect ratio of tetrahedral components results in a more balanced design and lessens the possibility of element distortion.

As a result, the behaviour of the material is more accurately represented, and the stress and strain values are more precise. The meshed model is shown in the figure Fig. 7 (B). Additionally, since the components are more closely spaced out, tetrahedral meshing could be more computationally effective because fewer elements are required to represent a given area. With all of these advantages, tetrahedral meshing is the best option for FEA study of buffer tanks. Table 1 shows the complete information about the meshing pattern of the full buffer tank.

Each element is represented by a set of equations that define its load-bearing behaviour. The equations are dependent on the material properties of AISI A304L and geometric features. After meshing, a pressure load of 1.6 Bar is applied to the inner side of the total buffer tank to evaluate its structural stability and identify any areas of stress or potential points of failure that may need reinforcement. To obtain accurate results from a FEA, it is essential to define the boundary conditions and constraints of the model. These fixing parameters assist in defining these vital parameters. Firstly, a fixed geometry condition is established in regions where the size, shape, and location of a component are fixed. This condition is frequently employed in areas of the model that represent parts that are firmly attached to the ground or to another component. Secondly, a fixed bolt connection is established between two model components, such as a nut and a bolt. This constraint describes the manner in which the two components are connected and can be utilized to simulate the response of the connection to loads. A fully rigid connection is established between two model components, prohibiting any deformations of the two components. This type of constraint is utilized to depict the connections between parts that are intended to operate together as a single unit. The pre-processing step is essential to assure the correctness of the FEA results since the mesh quality and the accuracy of the load application directly affect the reliability of the findings.

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Table 1: Meshing Information of the Buffer Tank
5.2 Processing

The processing phase of a buffer tank is essential for maintaining its structural integrity. This phase starts with the development of a numerical model, which is a mathematical depiction of the physical structure of the tank. The model is built by converting the current CAD model of the tank into a sequence of linked components, each of which represents a distinct portion of the tank. To simplify the numerical model, the tank is divided into smaller components using a mesh. The mesh is a grid of points that divides the tank into several areas, facilitating analysis and comprehension. The numerical model and mesh serve as the basis for the numerical analysis, which determines the stress, strain, and deformation in the buffer tank as a result of the applied loads. Solving the mathematical equations that explain the behaviour of each mesh element is numerical analysis. This information is subsequently utilized to construct safety factors, which evaluate the buffer tank’s structural integrity. The computation of safety factors is regulated by technical rules and standards such as the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers (ASME). The safety parameters are a crucial indication of the tank’s capacity to sustain the pressure loads it will experience during its intended operation. A tank with a high safety factor is structurally robust and able to resist the stresses it will experience. A low safety factor, on the other hand, may suggest the existence of stress regions or vulnerabilities that need to be strengthened. In conclusion, the processing step of the buffer tank provides useful information on its structural stability and indicates possible areas of weakness. This information is necessary for assuring the buffer tank’s safety and dependability, as well as its capacity to execute its intended purpose successfully.

5.3 Post-Processing

The post-processing stage of the FEA of a buffer tank is a crucial step in evaluating the simulation results. This step involves thoroughly reviewing the findings of the analysis to gain a deeper understanding of the system’s behaviour. The post-run checks are standard procedures that are performed after the completion of a structural analysis to ensure that the results are reliable and valid for design purposes. The assessments are usually conducted using computer software and the results are presented in various forms.

VI. RESULT AND DISCUSSION

The post-run tests are essential components of the structural analysis technique and must be performed after each analysis to ensure that the results can be relied upon for design purposes. The results of the FEA analysis are visualized and interpreted to identify areas of the buffer tank that are subject to high levels of stress, strain, and displacement. This information can then be used to redesign reinforcement or modify the buffer tank design to improve its structural integrity. Thus, the post-processing stage of the FEA of a buffer tank is an important step in ensuring that the results are reliable and valid for design purposes. The post-run checks are standard procedures that are performed to verify the mechanical equilibrium, the continuous and smooth displacement form, and the accuracy of the stress contours. These tests play a crucial role in improving the structural integrity of the buffer tank design.

The following checks are typically performed during the post-processing stage:

A. Equilibrium between applied loads and support reactions:
   This check is performed to verify that the structure is in mechanical equilibrium. This means that the forces and moments acting on the structure are balanced, and the total of the loads applied to the structure equals the sum of the support reactions. In other words, the structure is in equilibrium if the sum of all forces and moments acting on it is zero.

B. Examination of the displacement form of the structure:
   This check is performed to confirm that the structure’s displacement form is continuous and smooth. Discontinuities in the displacement shape may indicate an error in the model, such as an incorrect boundary condition or material property. The examination consists of observing the shape of the structure’s displacement field and ensuring that there are no abrupt changes.

C. Examination of the stress contours:
   This verification is performed to ensure that the mesh used in the analysis accurately depicts the distribution of stresses in the structure. A flawed mesh may result in stress singularities and erroneous stress measurements.
The examination consists of observing the stress contours and ensuring that the mesh is developed enough to accurately reflect the stress distribution.

The findings of the FEA of the buffer tank under internal pressure of 1.6 bar and external pressure of 2 bar indicate that the aperture for the nozzle and the maintenance hole encounter the greatest stress. This data is required for preserving the structural integrity of the tank, since these locations of high stress have no chance to be prone to failure or deformation if exposed to pressure for an extended period of time. This procedure entails no making modifications to the design and rerunning the FEA until the stress levels reach an acceptable level. This method may be used to optimize the tank's design, guaranteeing that it can sustain the stresses.

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**Figure 9(A): Von Mises Stress Results of Buffer Tank**

### 6.1 Von Mises Stress Results

The Von Mises stress is a metric for the equivalent stress in a structure that accounts for the simultaneous action of several stress components. It can be employed to identify the areas of a structure that run the risk of yielding or experiencing plastic deformation under the loads being applied. It is a means of determining the total stress received by a structure. The findings of Von Mises stress in the tank instance are proportional to the cut-out in the shell. This indicates that the size and position of the cut-out on the shell are connected to the stresses seen in the tank. The shell around the maintenance access hole exhibits the highest strains, indicating that this is the area of the tank where the greatest stress is anticipated to occur. The simulation's highest recorded stress, 163.20 MPa, was recorded at the dish end section's bottom, see Fig. 9 (A). This result represents the tank’s maximum stress during the simulation, and it may be used to estimate the stress the tank would likely encounter under actual circumstances. When evaluating the structural integrity of the tank, the Von Mises stress measurements are important because they show which parts of the tank are susceptible to yielding or plastic deformation from the applied loads. Based on the findings, design modifications or additional reinforcement may be required in locations where the stress is anticipated to be significant, in order to guarantee that the tank can resist the forces it will be exposed to and keep its structural integrity.
6.2 Displacement Results

The results on displacement deal with the measurement of a given point or object's departure or movement from its starting position. It is the tank's under-pressure deformation or shape change in this case. The information reveals how the tank is affected by outside factors such as pressure and load. The findings indicate that a reversible, insignificant change of up to 1.813 mm will probably occur in the tank, see Fig. 9 (B). This suggests that once the pressure is removed, the tank will return to its original shape and the deviation won't seriously compromise the tank's structural integrity. The end of the dish shows the most deflection, which suggests that this is the portion of the tank where the most departure or deformation is predicted. The regions of the tank that may be susceptible to significant strain are revealed by these findings, which are significant when analysing the structural integrity of the tank. According on the findings, there is no necessary to change the design or add more reinforcement where the expected strain is severe. This will ensure the tank's ability to withstand stresses and maintain its structural integrity. Based on the results of the study of working displacement, it can be concluded that the factor of safety criterion has been satisfied. This is evidenced in Figure 10, which shows that the greatest working displacements observed are below the maximum allowable working displacement limit. Therefore, it can be inferred that the component or structure under consideration is able to withstand the applied loads and stresses with an acceptable level of safety and reliability.
VII. CONCLUSION

The integration of PVT and WISC into heat pump systems offers a solution to this energy consumption problem. The PVT system works by harnessing both the thermal and electrical energy of the sun to heat water, whereas the WISC system enhances this process by using wind and infrared energy. By combining these two techniques, the electric water heater can operate more efficiently, using less energy and reducing carbon emissions. In addition to the improving energy efficiency, this integration also helps reduce dependence on conventional energy sources for electricity. This can result in lower energy expenses and a more sustainable future.

The buffer tank was designed in accordance with industry standards. The integration of a buffer tank within a heating or cooling system can significantly enhance its overall efficiency. This is achieved through several key benefits that include: stability improvement, increased capacity, reduced stress on equipment, improved thermal comfort and improved control. The buffer tank works by stabilizing temperature fluctuations through the storage of excess energy, resulting in a more consistent temperature and improved thermal comfort for the users. The increased energy storage capacity also reduces the stress on the equipment, increasing its lifespan and allowing for higher demand accommodation. Moreover, the buffer tank enables more precise control over the heating or cooling system, thus reducing the number of on and off cycles required. This leads to an overall improvement in efficiency and energy savings.

A comprehensive FEA is carried out to assess the level of stability and reliability provided by the tank's design. A necessary iteration based on thickness and stress value calculations is carried out to derive the right scantlings for the shell and nozzles. The analysis shows that the highest Von Mises value observed, which is 163.20 MPa, does not exceed the maximum permissible working stress as determined by the factor of safety. Similarly, the results of the loaded pressure analysis also reveal that the highest displacement value observed, which is 1.813 mm, is below the maximum permissible working displacement that is established by the factor of safety criteria.

This work concludes that the system has the necessary stability and robustness to handle the anticipated loads and operate within safe operating limits. It demonstrates that the system is capable of functioning within safe stress limits and is not susceptible to material failure or structural damage. Therefore, there is no threat posed, the buffer tank is completely safe. Hence, the buffer tank in a heat pump works more efficiently and it can also serve as an additional source of heat for the house during the colder season, resulting in further cost savings.

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VIII. REFERENCES


