DESIGN & OPTIMIZATION OF THERMAL STRATIFICATION

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Abstract: *Thermal stratification in solar storage tanks has a major effect on the thermal performance of a solar water heating system. This experiment will be conducted to check thermal stratification in hot water storage tank such an important device of solar water heaters. A number of flat plates with different angled positions are integrated inside a vertical tank prototype. The reason of this investigation is to take a look at the effect of the flat plate positions within a vertical garage tank at the thermal stratification and to behavior the feasible performance improvements to achieve. CFD numerical comparison between two configurations was carried out and performance parameters such as temperature distribution. Experimental Investigation will be done using actual setup with help of storage tank, flat plate, water pumps etc. Validation will be done using thermal gauges mounted on setup and CFD results. Results and conclusions will be discussed in details and future scope will be suggested.*

Index Terms - Thermal Stratification, Solar, Storage tank, Flat plate, CFD, Temperature & Gauges, etc.

I. INTRODUCTION

The principle of thermal stratification in insulation of the storage tank – of very high importance to the efficiency of a solar heating system. The thermal stratification is based on a natural process: Since warm water is lighter than cold water, it will ascend until it reaches a layer of warmer water or the top of the tank. This process facilitates the efficient utilization of solar heat: the upper the temperature difference between Collector and Solar Storage and therefore the longer such a difference exists, the upper the Efficiency of solar heating. Therefore, the solar Heat Exchanger will be mounted near the bottom of the tank, where the water is relatively cold, so even small amounts of solar heat can be "harvested". And while the outlet will be near the top of the tank, where the temperatures are highest, the inlet feeding fresh cold water will be positioned near the bottom. The more stable the thermal stratification, the higher the efficiency of the solar heating system and the comfort for the user by providing reliably sufficient amounts of hot water.

While all state-of-the-art solar storage tanks make use of thermal stratification, there are significant discrepancies in design and efficiency. The most basic variant is represented by a so-called bivalent, upright-standing hot water tank for solar systems. Such a tank should be tall und have a relatively small diameter to allow significant stratification. The term "bivalent" refers to the number of heat exchangers integrated in the tank: The "solar" heat exchanger transfers the solar heat to the cold water at the bottom of the tank. A second heat exchanger, mounted at the top of the tank, serves as backup heater (electrical or connected to a central heating system), if e.g. in winter the energy provided by the sun is insufficient to produce as much hot water as needed. A thick insulation minimizes the cooling-down near the walls of the tank and thereby thermal turbulence in the tank caused by such local heat losses. More sophisticated design concepts include different additional measures to further the thermal stratification and to avoid thermal turbulence. Some systems add a third heat exchanger in the middle part of the tank ("trivalent tanks"); an electronic regulator then uses pre-programmed strategies to distribute the solar heat between the different heat exchangers. Other concepts try to achieve similar effects solitary by the design of the interior of the tank; a wide-spread implementation of this idea are the so-called Low Flow Systems.

Tanks with optimized thermal stratification boost not only the efficiency of the solar heating system, but also the comfort provided to the users: Starting with a totally cooled-down (unloaded) storage tank they will be able to supply solar heated water at significantly shorter notice than non-optimized systems.

Usually, the Collector is placed on the rooftop and the water tank in the basement. This means that circulating pumps have to transport the heat-transfer fluid from the tank up to the collector in order to keep the entire system working.

Thermosiphon systems work differently: the water tank is also mounted on or under the roof, but, most importantly, it is above the collector. This set-up makes it possible to use gravity for circulation.

The principle is simple: The Solar Radiation heats the heat-transfer fluid, whose density then decreases as its temperature increases. The fluid becomes lighter and rises – a phenomenon known as natural convection – inside the circulation pipes. An extra pump is not necessary. A Regulator, or Controller, is also not necessary because the sun controls the flow of the heat-transfer medium: When it shines, the heated heat-transfer fluid rises in the standpipes. The potable water is heated over a Heat Exchanger with a large surface area. The heat-transfer fluid which has cooled down then flows back to the collector – the process is back where it began.

II. OBJECTIVE

- To investigate the impact of the flat plate positions within a vertical storage tank on the thermal stratification and to conduct the possible performance enhancements to achieve.
- Validation using CFD and Experimental Methods.
- Plots of Temperature, velocity and pressure.
- Temperature measurement using Thermal gages.
- Manufacturing of flat plate titling mechanism

III. PROBLEM STATEMENT

- The principle of thermal stratification is insulation of the storage tank of very high importance to the efficiency of a solar heating system.
- In our project we study experimental investigate the impact of the flat plate positions within a vertical storage tank on the thermal stratification and to conduct the possible performance enhancements using CFD analysis.

IV. LITERATURE SURVEY

Effects of different thermal storage tank structures on temperature stratification and thermal efficiency during charging.

Authors: Angui Li, Feifei Cao, Wanqing Zhang, Bingjin Shi, Huang Li

In solar water heating systems, the structures of thermal storage devices have played essential roles within the improvement of thermal charging efficiency and system performance. This article was focused on the optimization of thermal storage tanks, also because the influences of thermal tank structures on the temperature stratification and warmth storage capacity. The thermal characteristics of three shapes of thermal storage tanks were investigated and analyzed through CFD simulation, which were Cylindrical tank, Circular frustum tank and Spherical tank. It has been observed that among the three thermal storage tanks, spherical tank has conceptional temperature stratification, while the truncated circular cone tank had the only temperature stratification and thermal charging efficiency. For the circular frustum tank, it had been found that when the radius ratio (n) of the cistern was 0.554, it could approach the superb characteristics of temperature stratification and thermal storage performance. This study could provide a theoretical basis for the structure optimization of the solar energy storage devices, also as proving to be beneficial to the enhancement of thermal charging efficiency.

V. EXPERIENTIAL PROCEDURE

The models representing the thermal stratification in hot water tanks treat in their majority the case of a vertical tank fed out with cold water from the bottom and providing hot water from the top according to load profiles. The stratification is modelled by dividing the tank into sufficiently fine horizontal layers for numerical stability reasons. For each layer, the energy and mass equations were established. The resolution of the total system provides the temperatures characterizing the tank layer's according to water loading profile, the required heating energy (electricity at night and solar supplement or gas during the day consumption).

Hot water production constitutes one of solar energy's privileged applications in the buildings. This is due to the nature of the need: hot water temperature (between 25 and 60 °C), weak variation needs during the year. In addition to the solar collectors, the essential component of a solar water heating system is the hot water storage tank. The energy stored inside the tank is increased, if the stratification is well improved.

Consequently, the aim of the current study is to understand the thermal behavior of the storage tank by conducting a CFD parametric study on a standard storage tank.

VI. Design

CATIA V5 Software has been used to create the model throughout the experimental project, CATIA (Computer aided three dimensional interactive element) is mainly used to design curves and figures in two-dimensional (2D) space or even curved surfaces, and solids in three-dimensional (3D) space model.

Procedure

1. Creating each model and sub parts as per the required dimensions using create solid part in CATIA soft.
2. Assembling each model to its proportion using assembly option with required constraints.
3. Finally Creating drafting of assembly by converting 3D model to the 2D snap with the help of convert to 2d sketch option in the software.

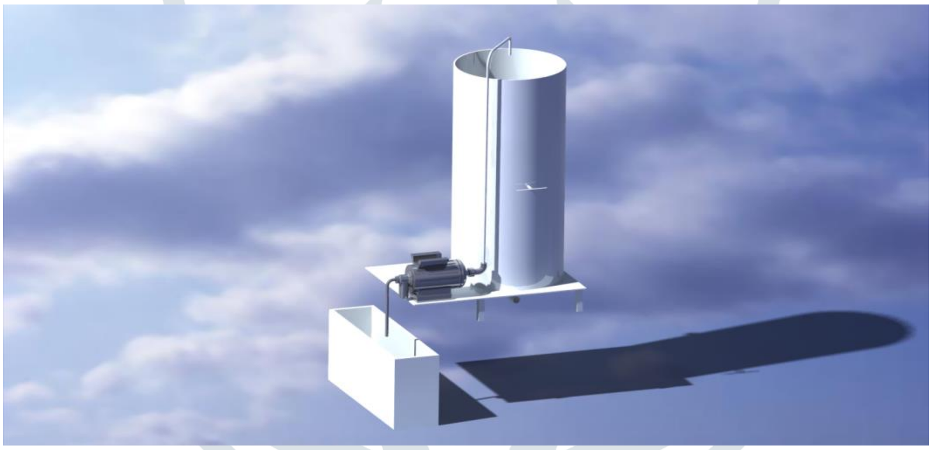

Fig. 6.1: CATIA 3D model

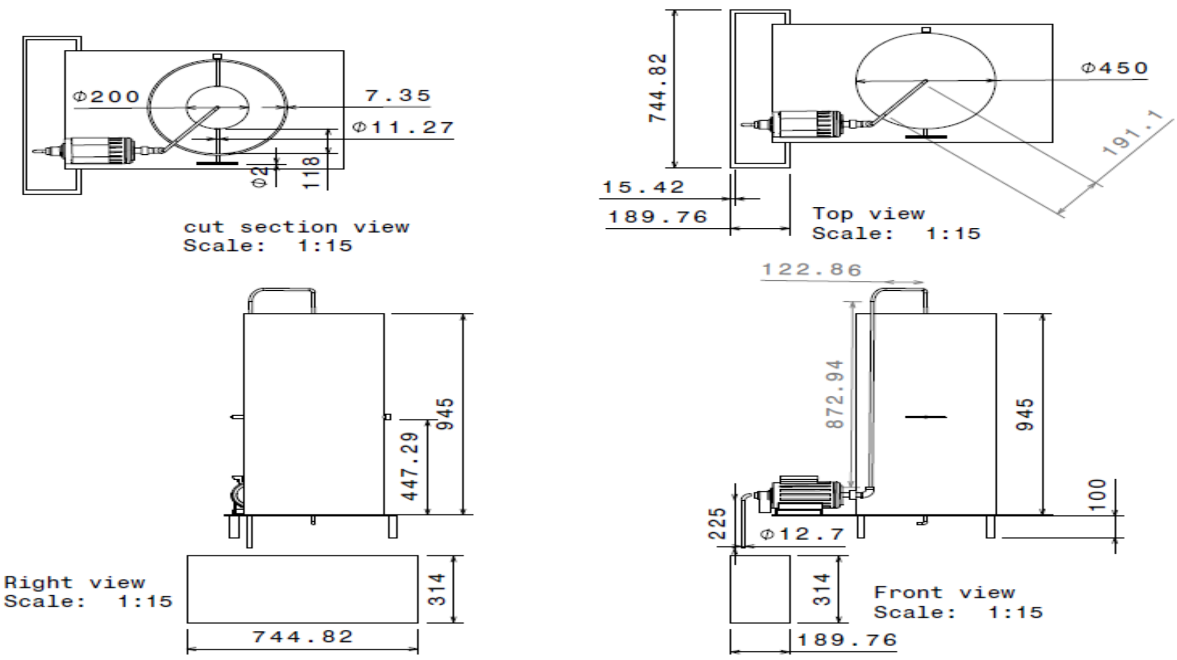

Fig. 6.2: 2D Drafting

VII. ANALYSIS & RESULTS

CFD analysis of a thermal stratification is done using ANSYS 2020 R2 software. ANSYS (Analysis of system) is a testing application which pre-posts & used to simulate computer models of structure or machine components for analysing strength, toughness, stress, Temperature distribution, fluid flow & other attributes.

Procedure

1. Taking CFD fluent into consideration.
2. Creating geometry in space claim model in ANSYS software as per required dimension.
3. Creating finest mesh for the model.
4. Applying boundary conditions like type of flow, initial temperature, fluid material, etc.
5. Setting up solution theory required.
6. Simulating the model by running pre calculation.
7. Obtaining results.

Fig. 7.1: Geometry

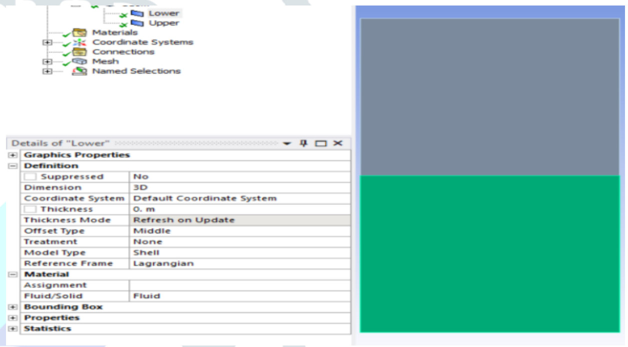

Fig. 7.2: Assigning Material

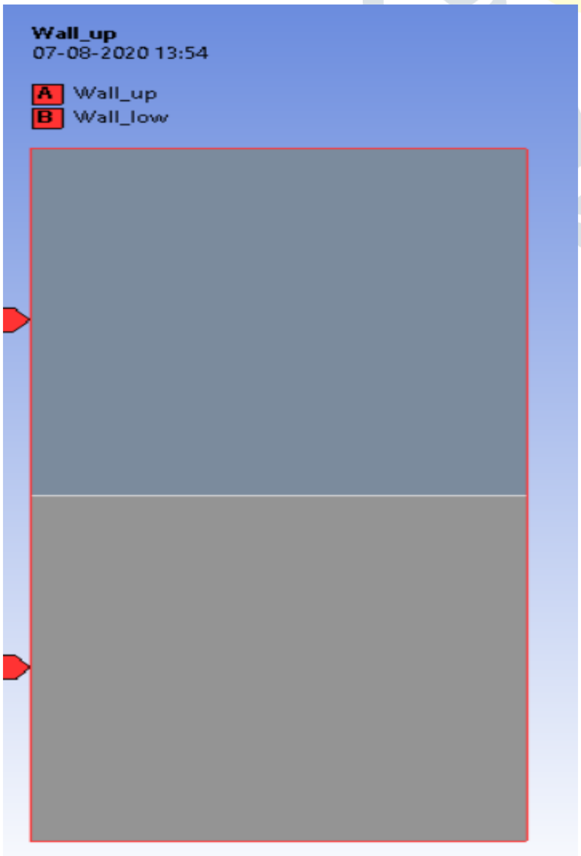

Fig. 7.3: Boundary conditions

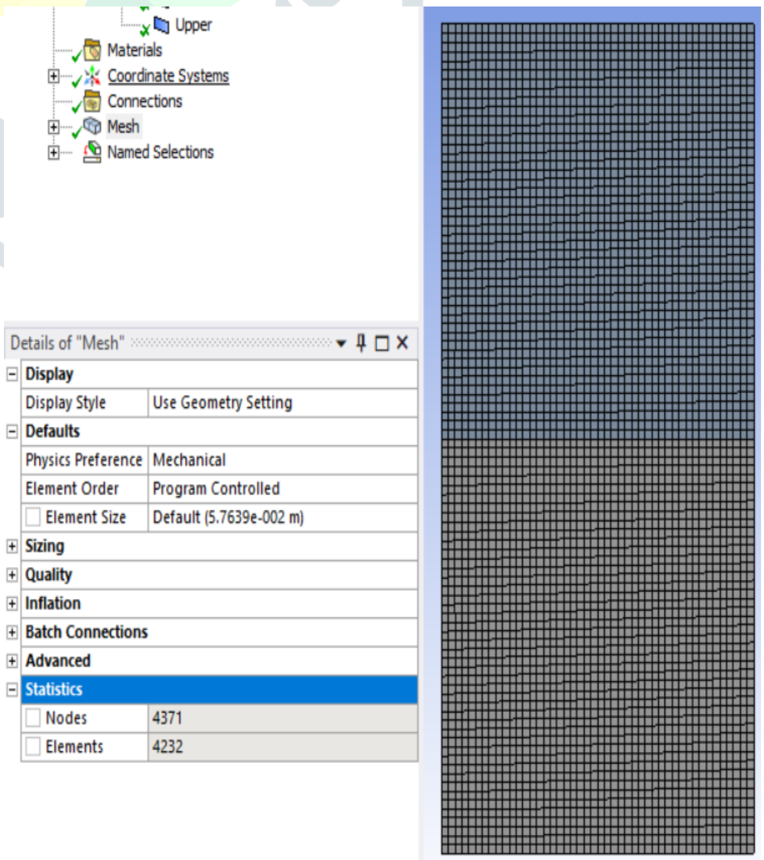

Fig. 7.4: Mesh

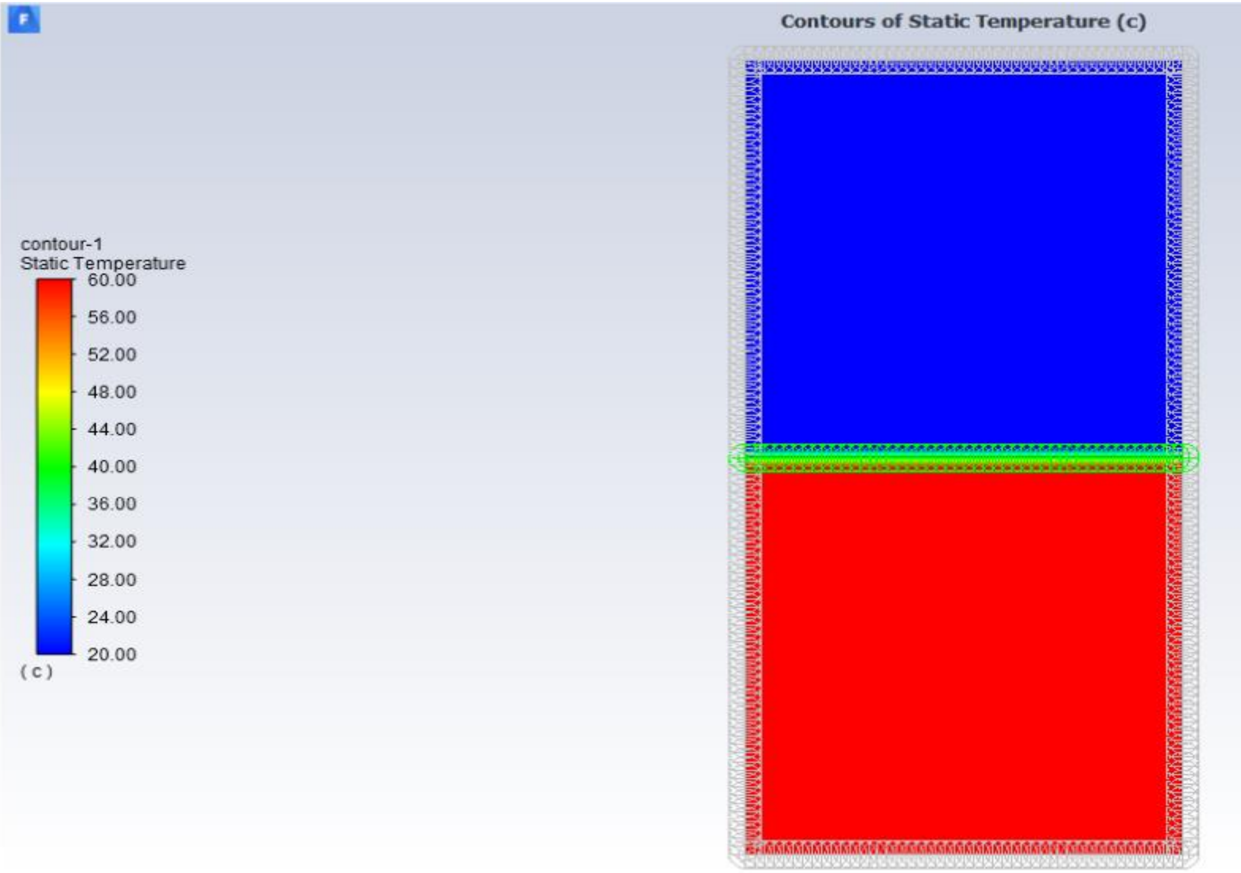

Fig. 7.5: Temperature contour before mixing of fluid in (ºC)

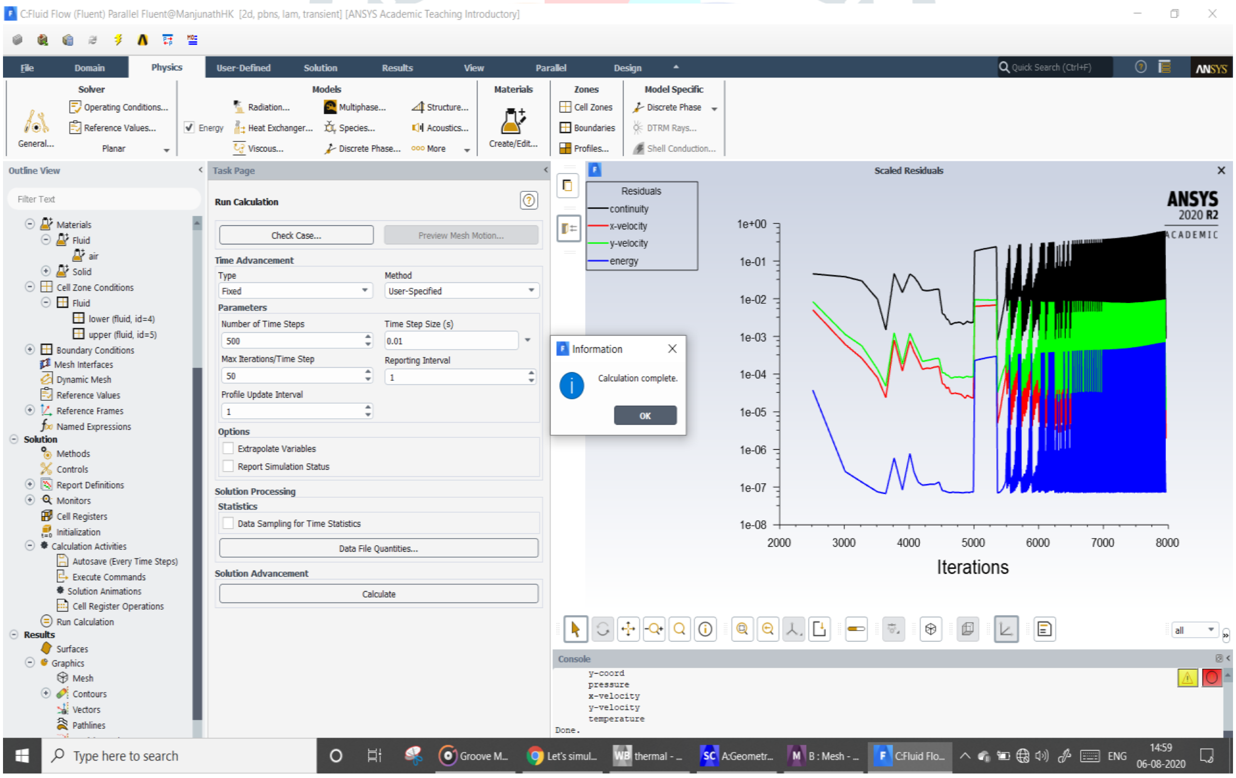

Fig. 7.6: Time Setup

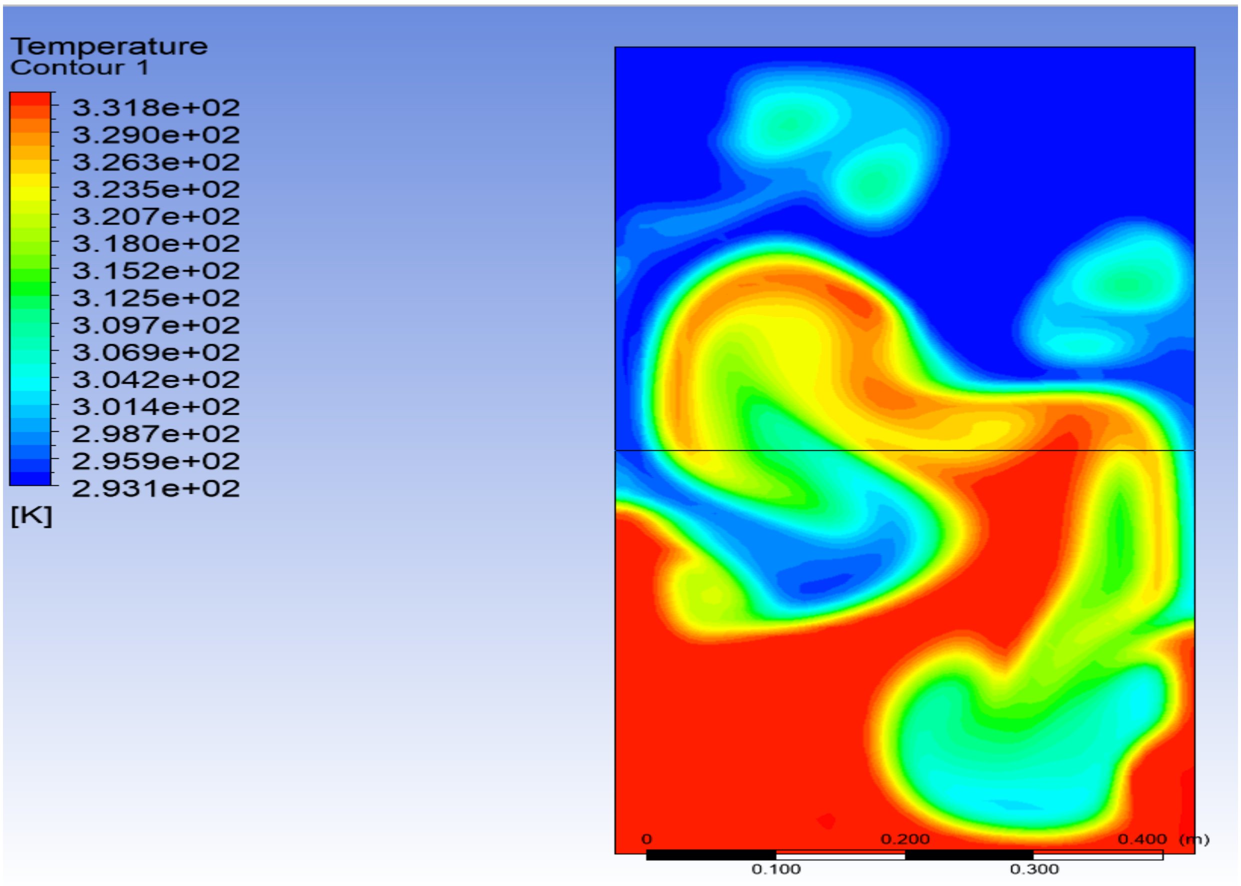

Fig. 7.7: Temperature after mixing of fluid in K

VIII. CONCLUSION

In this study of observation, thermal stratification of a domestic hot water storage tanks for the dynamic has been achieved or examined numerically. As the first objective, the development of thermal stratification during charging and discharging phases of heat transfer characteristics were studied inside a vertical cylinder storage tank. Those these findings were very helpful in defining the real behaviour of domestic water storage tank for the dynamic mode. CFD analysis for thermal stratification is still a topic for future scope in the improvement of predicative quality.

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