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Field Synergy Analysis of Thermal Storage Effect of Solar Energy Storage Tank

Heming Yun[a,b,c,d*], Fangfang MA[b], Xunhu Guo[b], Baoming Chen[c,d]

[a]*School of Energy and Power Engineering, Shandong University, Jinan 250113,China;*
[b]*School of Thermal Energy Engineering, Shandong Jianzhu University, Jinan 250101,China;*
[c]*Key Laboratory of Renewable Energy Utilization Technologies in Building , Ministry of Education , Jinan 250101, China;*
[d]*Shandong Key Laboratory of Renewable Energy Application Technology, Jinan 250101, China*

Abstract

The internal structure of solar energy storage water tank partition design was carried out in this paper. The energy storage tank with different internal structure had been simulated to analysis convective heat transfer mechanism in the water tank by using CFD method. The temperature stratification mechanism of water tank had been deeply analysed to improve the availability of storage tank as the goal based on the heat transfer and flow field synergy theory. The calculation results showed that the partition plate in the water tank could obviously improve the effect of hot and cold stratification of the water tank, so that a good effect of cold and hot stratification from left to right could be achieved; The influence of flow field on temperature field had been studied by analyzing the degree of synergy between velocity vector and temperature gradient vector, The flow resistance, drag reduction mechanism and influencing factors in the water tank were studied by analyzing the synergy between the velocity vector and the pressure gradient vector; Through the adjustment of internal structure and the change of water flow and heat transfer and pressure gradient direction, that was to change the angle between the velocity and the temperature gradient and the velocity and pressure gradient, and It could effectively improve the energy storage and delamination effect of the water tank; and provided a theoretical basis for the future design of efficient solar energy storage tank with low flow resistance.

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Keywords: Field synergy; Thermal storage; Solar energy storage tank; CFD(computational fluid dynamics)

1. Introduction

Solar energy is the fundamental source of all types of energy currently used by humans, including fossil fuels, hydraulic power,and wind power. Solar energy is almost unlimited in its supply, has minimal environmental impact, and is available free of charge. In fact, solar thermal energy has long been utilized to reduce the energy requirements for heating in both domestic and industrial settings[1,2].

A typical example of solar energy utilization is solar domestic hot water (SDHW) systems that collect and store solar thermal energy in the form of hot water for domestic use. Solar energy stratified water tank had been carried out to research on the basic laws of temperature stratified for solar energy water tank. In 1977, Lavan and Thompson[3]conducted an experimental study of the hot water temperature stratified storage system, which

* Corresponding author. Tel.: 152-6413-9511;
E-mail address: yunheming@163.com

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confirmed the phenomenon of temperature stratification in water storage, and proposed the factors affecting the temperature stratification. In 1978, Gretarsson S P et al[4] investigated the influence of dimensionless parameters on the development of thermocline, such as Rayleigh number and Prandtl number. In 1989, a one-dimensional model of temperature stratified thermal storage tank was established by Zurigat and Maloney et al[5], and an empirical based mixed parameter was introduced to simulate the three-dimensional model. In 1991, A., J., Ghajar[6] et al. Studied the influence of different inlet geometries on hot and cold water mixing during the turbulent flow of a heated water tank. In 1999, J, van, Berkel[7], et al. Established a stratified thermal storage model of two layers. The mixing phenomenon of hot and cold water was explained in detail by experiment and numerical simulation. The mixing mechanism of cold and hot water mixing surface was investigated. In 2001, R M Ramsayer[8], et al. Established a horizontal cylindrical heat storage tank model, and used numerical simulation to study the variation of temperature gradient in the water tank. In 2001, S, Knudsen[9], et al conducted a numerical simulation of solar hot water system, and tested the Danish domestic hot water system. In 2004, Gao Yuefen and Wei Bing[10] et al designed storage tank with regulator, the regulator reduced the disturbance of water flow with uniform flow uniform distribution of hot and cold water. In 2008, Han Yanmin[11] et al. Proposed a new type of horizontal storage tank, the water tank with the same volume of the same shape and different internal structures were analyzed through numerical simulation. partition plates were arranged to control turbulence and to inhibit the increase of cold and hot water mixing in the water tank, which could achieve good heat partition. In 2009, A, Aviv and Y, Blyakhman[12], et al. Studied the solar energy storage water tank by numerical simulation and experiment respectively. In 2009, Wang Dengjia and Liu Yanfeng[13] carried out the numerical simulation analysis on the heat storage tank of multi node model, compared various conditions that the entrance velocity was in the range of 0.01~0.05 m / s, the best effect of temperature stratification had been obtained in the water tank.

At present, the research of solar energy storage water tank is mainly based on the analysis of the causes of temperature stratification in the water tank, the influence of the dimensionless parameters on the stratification, the mixing mechanism of the cold and hot water mixing surface, etc. From the structure the impact of internal temperature stratification of measures such as the shape of the entrance, different diameter ratio and setting the diffuser has been investigated mainly for cylindrical tanks. There is little research on the large volume horizontal water tank, especially the influence mechanism of the flow inside the large horizontal water tank on the heat transfer, and the influence of the arrangement of the inner structure of the water tank on the temperature stratification.

The mechanism of the influence of large volume of horizontal tank temperature stratification had been simulated based on the CFD(Computational Fluid Dynamics) methods. To improve the energy availability of storage tank, the water temperature stratification mechanism has been deeply analyzed by using the field synergy theory for advanced flow and heat transfer theory and the irreversible thermodynamics theory.

2. Geometric model and mathematical description of solar energy storage water tank

The transient heat transfer characteristics of a solar energy storage tank are numerically simulated by means of CFD simulation. By analyzing the flow field and temperature field, the structure of heat transfer and fluid flow in the original design had been improved. On the premise that the basic structure size of the water tank remains unchanged, the influence of the inner structure of the tank on the temperature stratification effect of the water tank had been numerically simulated. The whole tank size was 6.5m× 6.0m× 4.2m, scheme 1 was the arrangement of 10 baffles from the left to right, each of the two partition form a fluid flow channel, makes the fluid flow along the upper and lower folding as shown in figure 1. Scheme 2 was divided into 18 separation spaces around the water tank, so that the fluid flowed from front to back, and then from left to right as shown in figure 2.