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A Review of Numerical Simulation of Liquid Cryogenic Storage Tanks

Yongqun Hu, Xin Wang, Tingbo Zong

Xi'an Shiyou University, Xi'an 710065 China

*Corresponding author

Abstract

In this paper, a comprehensive study of cryogenic storage tanks is carried out, the application of carbon dioxide as a driving force for foam plugging, methane and water is analyzed, the structure of cryogenic storage tanks is analyzed and the operation research is carried out, and the thermal safety of storage tanks is analyzed. The research carried out a comprehensive analysis and research, and prospected the simulation research of cryogenic storage tanks.

Keywords

Cryogenic storage tanks; carbon dioxide; simulation research.

1. Introduction

At this stage, the prosperity and development of human economy and society is inseparable from our traditional natural fossil biofuels, but the large amount of carbon dioxide produced by its combustion has also caused a series of problems such as global warming. With the economic development in recent years and people's increasing attention and attention to environmental protection issues, how to effectively reduce the global CO2 emissions has gradually become a focus of attention of all countries,.

China is already the world's second largest CO2 emitter after the United States[1]. In 2002, my country's total CO2 emissions accounted for about 13.6% of the world's total CO2 emissions. It is estimated that by 2025, my country will further surpass the United States to become the world's largest CO2-emitting energy country,. Although CO2 has a wide range of economic uses in its production and life, such as the refrigeration and preservation of dry ice, the production of fire extinguishing equipment, etc., these consumptions account for a small proportion of the total CO2 emissions[2]. In recent years, with the development and deepening of CO2 research in countries around the world in recent years, the technology of CO2 capture and storage has also been developed rapidly, and EOR (Enhanced Underground Oil Recovery) technology has been widely studied and adopted in major countries,. By injecting a small amount of CO2 into the geological structure, not only a large amount of CO2 can be stored underground, but also the recovery rate of oil wells can be improved[3]. EOR technology not only reduces greenhouse gas emissions, but also helps mitigate global warming. How to reasonably transport and store CO2 is the key to this technology. In practical applications, CO2 is usually stored in low temperature liquefaction. Since the continuous storage temperature of CO2 in the storage tank is much lower than the temperature of the environment outside the storage tank, the storage tank will continuously absorb heat from the environment outside the storage tank[4]. Thereby, the temperature is increased, so that the temperature of CO2 in the storage tank increases, and the pressure increases. When the gas pressure in the storage tank is greater than the specified safety value, the safety valve will automatically open, and a small amount of gas is released from the storage tank, reducing the pressure value in the storage tank, but the carbon dioxide released from the storage tank While reducing the liquid storage capacity in the storage tank,

it also causes damage to the ecological environment,. Therefore, it is of great significance for CO2 flooding to study the dynamic change law of the storage characteristics of liquid CO2 storage tanks and ensure the safety of the liquid CO2 storage system[5].

2. Application of carbon dioxide flooding

2.1. Carbon dioxide flooding foam plugging

Due to the low critical pressure of carbon dioxide, it is very easy to reach the supercritical state, and carbon dioxide has the characteristics of low viscosity and easy to be compressed, and the injection capacity of carbon dioxide is significantly higher than that of water injection. However, due to the perennial water injection in the injected formation, the heterogeneity difference is very large, and the density of carbon dioxide gas is relatively small and the viscosity is much lower than that of water, so gas channeling is prone to occur in the formation, which affects the normal productivity of oil wells. PH is acidic, and research on acid-resistant foam plugging agent was carried out.

2.2. Carbon dioxide to drive methane

When the coalbed methane is extracted on the ground or underground, with the increase of the amount of methane extracted, the reservoir pressure of the coalbed will be greatly reduced, which will seriously affect the subsequent extraction of coalbed methane. In the field of oil and gas, injecting fluids such as water or carbon dioxide into reservoirs with long production time and large pressure attenuation can increase the pressure of the reservoir, improve gas production efficiency, and achieve secondary production increase in depleted oil and gas fields. This method of injecting fluids into the reservoir to increase production efficiency is called flooding. In the process of coalbed methane extraction, injecting carbon dioxide into the coalbed with lower methane pressure can increase the yield of coalbed methane. At the same time, since the adsorption of carbon dioxide in the coal is stronger than that of methane, injecting carbon dioxide into the coal seam can replace the adsorbed methane, which is more conducive to the output of coal seam methane.

2.3. Carbon dioxide drives water

The CO2 content in the produced water is one of the important factors affecting the changes of the pH value, salinity, corrosion rate and other characteristic parameters of the water; under the atmospheric pressure test condition of 40 ℃, the treatment effect of the CO2 flooding produced water by the aeration method is more obvious , which can effectively remove 70% of CO2 in water, thereby raising the pH value of water to 8, and effectively inhibiting the corrosion rate of produced water below 0.076 mm/a.

3. Research on Cryogenic Vessel Operation

Cryogenic storage tank is a special pressure vessel for storage and transportation of low-temperature liquefied gas under pressure. Due to its low operating pressure and high storage and transportation efficiency, it is gradually replacing traditional high-pressure gas cylinders, providing chemical, biological and medical industries. of industrial gases. Because the low-temperature liquefied gas stored and transported in the low-temperature storage tank has a very low boiling point (such as liquid nitrogen -196 °C, liquid oxygen -189.6 °C, liquid helium -268.9 °C), during transportation or non-sealed storage, the low-temperature liquefied gas absorbs heat and is extremely It is easy to vaporize and expand, which increases the pressure in the storage tank. At this time, excess gas must be discharged to ensure the safety of the storage tank. This is not conducive to the storage of low-temperature liquefied gas, but also caused a waste of resources. Therefore, accurate calculation of static heat transfer and rational

design of thermal insulation structure are crucial for improving the safety and economy of cryogenic storage tanks.

The purpose of low temperature insulation is to use various types and structures of insulation to reduce the heat transferred to the low temperature system as much as possible through various channels such as convection, conduction and radiation, so as to maintain the normal operation of the low temperature system. Common types of insulation are: high-bulk insulation, vacuum insulation, vacuum powder insulation, high-vacuum multi-layer insulation and high-vacuum multi-screen insulation. Among them, high vacuum multi-layer thermal insulation has the characteristics of compact structure and good thermal insulation performance, and is currently widely used in practical engineering. The high vacuum multi-layer thermal insulation layer is composed of surface materials and interlayer materials stacked layer by layer, covering the surface of the equipment that needs thermal insulation, and evacuating the thermal insulation space to a vacuum state (less than 0.01Pa). The surface material of the thermal insulation layer has high reflectivity and low absorption rate, which can greatly reduce the heat absorbed by the thermal insulation surface due to thermal radiation. The purpose of thermal insulation efficiency and reducing heat loss.

Full-capacity LNG cryogenic storage tanks are mainly composed of metal inner tanks, cold insulation between inner and outer tanks, prestressed reinforced concrete outer tank materials, and other process instruments and pipelines. The filling of the cold insulation material is divided into 3 parts according to the regional distribution, the tank top, the tank wall and the tank bottom.

The self-supporting storage tank adopts a composite structure inner tank, which is far superior to the general wall structure in terms of force, so it is no longer limited by the upper limit of 9% steel wall thickness specification of 50mm and the difficulty of welding thick plates. On the one hand, the composite finned siding can be prefabricated in advance, which can save more than 40% of the construction period; on the other hand, the siding is thin, the amount of high-altitude welding is small, and the construction period is shortened. The thickness of the wall plate is equal thickness plate, the rib and reinforcing ring structure are all small-sized plates, the material finished product requirements are not high, and the composite inner tank improves the material mechanical utilization rate, and the cost saving of the inner tank is expected to be more than 10%. It can be seen that it is self-supporting It is a very good idea for inner tank improvement in terms of storage tank.

4. Research on Thermal Safety of Storage Tanks

Xi Jiafu[6], of Lanzhou University of Technology took spherical liquid storage tanks as the research object to study the heat transfer and fatigue of storage batteries. By analyzing the heat transfer process of the insulating layer filled with storage tanks, he analyzed various heat leakage forms and their calculation methods.

And calculated the total heat leakage.

The research on the structure of cryogenic storage tanks mainly includes the following achievements:

Chen Weiwei[7], from Qingdao University of Science and Technology studied the distribution of the temperature field of the storage tank, and obtained the distribution law of the temperature field. And the distribution of temperature field is discussed in terms of air convection coefficient, air convection coefficient, ambient temperature, thermal conductivity of thermal insulation layer and other factors.

Lu Keke[8], from Tianjin University established a two-dimensional full-capacity storage tank finite element model. By changing the size and gradient of the ambient temperature of the outer tank of the storage tank, it was concluded that the temperature of the concrete outer tank was

little affected by the ambient temperature, and the thermal insulation material The temperature gradient between them is large. Low temperature effects that can be ignored when designing concrete outer tanks.

To sum up, the current research on storage tanks by domestic and foreign scholars mainly focuses on the thermophysical properties of low-temperature liquids, and there is less research on the outer wall of concrete tanks for full-capacity storage tanks.

By using heat transfer theory to theoretically analyze and calculate the whole process of heat leakage of the storage tank, so as to achieve the protection of the storage tank.

An accurate evaluation of temperature performance. The factors affecting the heat transfer performance of the storage tank are: gas heat transfer of the storage tank, solid heat conduction of the insulator and radiation heat transfer.

The following is a theoretical discussion of the heat transfer mechanism of three different heat transfer forms:

(1) Gas heat transfer

The mean free path of gas molecules and the distance between the walls (the size of the heat transfer characteristic) have a comparable order of magnitude, and the heat conduction of the gas becomes more complicated. When the state of the gas is closer to the low vacuum, the relationship between the heat conduction and the pressure is weaker; on the contrary, the closer the state of the gas is to the high vacuum, the more obvious the relationship between the heat conduction and the pressure, and is related to the thermal adaptation coefficient. Considering that the gas heat conduction path increases due to the sudden change of temperature near the vessel wall, and the heat conduction in this state mainly depends on factors such as Knudsen number.

(2) Heat conduction of insulators

Due to the discontinuity of granular and fibrous thermal insulation materials themselves, the heat exchange mechanism in their media becomes very complex, and their solid thermal conduction includes thermal conduction between the solid skeleton of individual particulate materials and between adjacent particles at the point of contact. contact heat conduction.

(3) Radiation heat transfer

When the vacuum degree is relatively high, the heat transfer mode of the thermal insulation material is mainly manifested as thermal radiation. When the heat radiation passes through the thermal insulation material, the radiation heat transfer will be greatly weakened because the heat flow is scattered in the incident direction due to the difference in the refractive index of the medium and the medium absorbs part of the radiation energy and converts it into its own heat energy. . Due to the properties of the thermal insulation material itself, the radiation heat transfer is greatly affected by the density and particle diameter.

5. Conclusion

In this paper, an in-depth study of low-temperature storage tanks is carried out, combined with the numerical simulation research of low-temperature storage tanks by many scholars before, which lays the foundation for the development of low-temperature storage tanks in the future, which is beneficial to the development and optimization of low-temperature storage tanks in the future. sexual opinion.

References

[1] S. T. Oliver,J. A. Gilbert,M. V. Bower. Deformation of a Composite Disk Having a Tapered Clamped Boundary[J]. Experimental Mechanics,2015,55(8):

[2] E. V. Onosovskii,L. M. Stolper,N. A. Kulik,V. Ya. Kostritskii. Selection of the optimum type and thickness of insulation for cryogenic tanks[J]. Chemical and Petroleum Engineering,1985,20(7):

[3] Nobuo Takeda,Tadahito Mizutani,Kentaro Hayashi,Yoji Okabe. Application of fiber Bragg grating sensors to real-time strain measurement of cryogenic tanks[P]. SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring,2003.

[4] Tao Wang,Limin Wang,Zhicheng Wang,Yubei Liu. The Liquid Nitrogen Level Measurement for Cryogenic Fuel Tank[P]. Proceedings of the 2015 International Conference on Test, Measurement and Computational Methods,2015.

[5] Experimental and numerical analysis of heat losses in a liquid nitrogen cryostat[J] . D. Boukeffa,M. Boumaza,M.-X. Francois,S. Pellerin. Applied Thermal Engineering . 2001 (9)

[6] Yu Shurong, Xi Jiafu, Chen Shuping, Liang Rui, Liu Fulu. Heat Transfer Calculation of Filling Insulation Layer of LNG Spherical Storage Tank with Evaporative Gas [J]. Journal of Lanzhou University of Technology, 2009, 35(01): 60-62.

[7] Chen Weiwei. Simulation research on static field and temperature field of large LNG storage tank based on ANSYS [D]. Qingdao University of Science and Technology, 2019.

[8] Lü Keke.Temperature-stress field analysis of LNG full-capacity storage tank[D].Tianjin University,2010.