Design of LNG gasification and thermal energy comprehensive utilization system for vehicles

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Abstract: The development of new energy vehicles is one of the important measures for national energy conservation and emission reduction, and natural gas is an important part of new energy. At present, most natural gas vehicles on the market are CNG vehicles, and LNG has many advantages, mainly solving the problem of vehicle life. This work has designed a vehicle LNG gasification system, including the design of stable self-pressurization and new gasifier, so that LNG can be used instead of CNG in the car, and it can be combined with the designed thermal energy comprehensive utilization system, which can utilize LNG. Cold energy can further reduce energy consumption and achieve energy saving and emission reduction. We first carried out the theoretical check calculation, then completed the piping design of the system, and carried out the ANSYS simulation analysis of the key component gasifier, and verified the simulation results through experiments, and further simulated the system. Analyze, design and optimize the control mode of the system. On this basis, the system control is programmed based on the single-chip microcomputer. We also made the system model. It uses the single-chip microcomputer to control and can switch and display various working modes.

1. Introduction
As the country's economic development is growing faster, the demand for resources is also increasing. According to relevant statistics, 60\% of urban atmospheric pollution comes from exhaust emissions from motor vehicles. The use of natural gas as a fuel for vehicles instead of traditional gasoline and diesel is one of the important measures to reduce vehicle exhaust pollution. In the long run, the country has decided to set a timetable for the ban on fuel vehicles, which will promote the development of the natural gas automobile industry.

At present, most of the natural gas vehicles at home and abroad use compressed natural gas CNG, and LNG has many advantages. Its energy density is high (about 3 times that of CNG), the vehicle has long cruising range, low storage pressure and safer. All countries in the world are vigorously promoting LNG vehicles, of which the United States is in a leading position in LNG vehicle technology.

Compared with CNG, a gasification system is required to use LNG in a car. Since the combustion concentration range of LNG is small, the LNG engine has high requirements for gas supply, so the supply pressure control of the LNG gasification system for the vehicle is very important. In addition, the gasification of LNG at the gas station is mainly based on seawater gasification or air heating, and the cold energy of LNG is not well utilized [3]. Our project solves the problem of gasification control through the corresponding piping structure design and control design, and cooperates with the designed thermal energy comprehensive utilization system, which can utilize the cold energy of LNG to further reduce energy consumption and achieve energy saving and emission reduction. Effect.
2. Design plan

2.1. Piping design
The system consists of LNG bottles, gasifiers, natural gas engines, radiators, water air conditioners, surge tanks, cooling water tanks, air conditioning water tanks, cooling water pumps, air conditioning water pumps, and valve components and related control devices. The LNG bottle includes a filling port, a filter, a safety valve, a pressure gauge, a liquid level gauge, a discharge valve, an economic valve, a self-pressurizing port, etc., when the pressure in the bottle is high, the economic valve will automatically open, and the bottle will be automatically opened. The natural gas is used to avoid the excessive pressure from leaking from the safety valve and causing waste. The specific design is shown in Figure 1.

![Figure 1. System piping design](image)

2.2. Gasifier design
The gasifier uses a smaller, lighter plate-fin heat exchanger. In the gasifier, LNG flows in from the inlet, flows out from the outlet 2 after gasification, and is divided into two parts. One part is supplied to the engine after being stabilized by the surge tank, and the other part flows into the gasifier from the 3 inlet again, and is heated. After boosting, it flows back to the LNG bottle from the 4 outlet to complete self-pressurization. The engine cooling water or air conditioning water enters the gasifier from the inlets 5, 6 and flows out from the 7 and 8 outlets. In order to prevent the liquid from solidifying and blocking the flow path when the temperature is too low, the surface of the gasifier is also equipped with an electric heating layer, which can also assist the warm-up and improve the engine life. The gasifier is shown in Figure 2.

![Figure 2. Gasifier](image)

3. Gasifier numerical simulation
In since the LNG gasification process in the plate-fin heat exchanger belongs to the boiling heat transfer in the narrow flow channel, it has the characteristics of high heat transfer coefficient and complicated process, and its heat transfer efficiency is closely related to the size and shape of the flow channel. In
order to design the gasifier structural parameters suitable for LNG gasification, we use the FLUENT module in ANSYS software to analyze the LNG gasification process of a single narrow channel.

4. System and Control Simulink Simulation

In order to design a reasonable control method and verify the feasibility of the system, we established a feedback control function for the opening of each valve by establishing the Simulink model of the system, and stabilized and accelerated under the two modes of air conditioning not working and cooling. The four working conditions of step, step and sine were simulated. The established Simulink model is shown in Figure 3.

![System Simulink model](image)

In the various working conditions of our simulation, although the pressure and temperature fluctuate, they are all within the condition range, which can meet the requirements of the engine air supply. It can be seen that the opening control method and control function of the system and each valve are reasonable. The system can solve the problem of LNG gasification and cold energy utilization for vehicles.

5. Model making

We made the model of the system and placed the equipment on a self-made car chassis, and the layout of each device was also designed. The model uses transparent tubing and uses different colors of water to distinguish between different fluids. The model is controlled by a single-chip microcomputer and can switch and display various working modes. The model is shown in Figure 4.

![Model photo](image)

6. Application prospect

Inquiring about the Shanghai Stock Exchange stock code 601857 annual performance report, we can see that the gasoline sales in 2017 is 5173.39 kilolitres. The gasoline price is based on the 2018 easy car network data, taking the average of different cities and different types of gasoline in the country, which is 6.64 yuan / liter, the car The number is based on the statistical data of the 2017 National Statistical Report on National Economic and Social Development of the People's Republic of China, which is
21.992 million. It can be calculated that the average fuel consumption per vehicle per year is 2.35 kiloliters, and the annual fuel consumption is about 15620 yuan. The average selling price of natural gas is 3.60 yuan / m³, while driving the same mileage, the consumption of 1L of gasoline is equivalent to the consumption of 1.1 m³ of natural gas. The calculation shows that the average annual savings per vehicle is about 6,304 yuan, which is about 40%.

According to the information provided by BP China Carbon Emissions Calculator, each natural gas vehicle can reduce carbon dioxide emissions by 90% compared with gasoline vehicles, and reduce emissions by 80%. Each vehicle can reduce CO2 emissions by about 60 tons per year. Inquire about the 2017 annual reports of companies such as Poussin, Jetta and BYD. Currently, there are about 500,000 CNG vehicles on the market. If 10% of the current cars are replaced or converted into natural gas vehicles, the annual CO2 emissions will be reduced by 131.97 million tons. Due to our water-air conditioning technology, there is no need to use a compressor for air-conditioning in the summer. If the average air-conditioning is used for 3 hours every year from June to September, and the cooling power is calculated at 2kW, the engine efficiency is considered. It can further save 130.11 kg of natural gas per year, about 652.5 yuan, and further reduce emissions by 7.3%.

The natural gas vehicle itself has the advantages of economy and environmental protection, which makes it highly competitive in the market. With the support of national policies, as long as the technical problems of the CNG vehicle's battery life difference are solved, the penetration rate of natural gas vehicles will be greatly increased. Improvement, and our project has solved this problem and has broad market prospects.

### 7. Conclusion

LNG is one of the clean energy sources. It has broad application prospects in transportation facilities such as vehicles and ships. This project studies key issues such as regulation, stabilization and full utilization of energy in the gas phase of LNG from liquid phase to gas phase. The middle and frontier issues have important theoretical and applied research significance for related research.

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