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Study on the Construction of an Urban Liquefied Natural Gas Bus and Its Cold Energy Recovery

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Abstract

As the green energy of urban bus, liquefied natural gas (LNG) is used more and more widely, which has played an important role in solving the urban pollution. An urban bus is chosen as the research object, the construction of its LNG fuel modification and the project design of its cold energy recovery are studied in the paper. The power and economy tests are carried out after the modification for the urban bus, and the referential results are obtained for the modification of in-used urban bus.

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Keywords: Urban bus; LNG; cold energy recovery; construction; engine bench test

1. Introduction

LNG is the cryogenic liquid mixture of natural gas with purification treatment, prolapse of heavy hydrocarbons, sulfide, carbon dioxide, water and sulfide impurities, and cryopreservation to -162 ℃. As a vehicle fuel, compared with other alternative fuel, LNG has great advantages in terms of reserves, economy, emissions and advanced technology [1].

Liquefied natural gas vehicle (LNGV) refers to the vehicle that takes natural gas stored in the thermal insulation gas tank as the fuel. At present, the in-used urban bus commonly take the gasoline or diesel as fuel. Most of these buses can be modified to use LNG as the fuel. In this paper, the in-used urban bus LCK-6180 is chosen as the research object, and the construction of its LNG fuel modification and the project design of its cold energy recovery are studied.

2. LNGV construction

LNGV gas supply system can work with the original diesel or gasoline engine fuel injection system. The main components include the LNG low temperature thermal insulation gas tank, the mixer, the gas

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track assembly and the LNG carburetor, etc. The following will describe the main constitution of the LNGV structure [2]. The modified urban bus is shown as Fig. 1 and the heat exchanger for cold recovery equipped in the bus can be seen in Fig.2.

Fig.1. Modified urban bus

Fig. 2. Heat exchanger for cold recovery in the bus

2.1. LNG gas tank

The vehicle LNG tank is an insulated, cryogenic pressure vessel. The LNG tank is a double-layer structure and the middle of which is vacuum. It mainly composed of liner, shell, insulation structure, internal support system and accessories. The liner tank, which directly contacts to the LNG and unders pressure, is used to fill LNG. Accordingly, the liner tank must be of good air tightness, corrosion resistance and low temperature resistance. The shell is to protect the liner tank, supporting the whole LNG tank. The main function of the shell is to withstand the external forces caused by LNG transportation and loading process.

LNG tank has many different functions of valves and gas-liquid pipes. The valves comprise the venting valve, the safety valve, the snifting valve, the liquid inlet and outlet valve, the vacuum valve and the pressure increasing valve etc.

2.2. Carburetor

The carburetor is mainly arranged between the LNG tank and the engine. The LNG carburetor is commonly the water bath type with a shell-tube structure. Based on the principle of convection heat transfer and the heat transfer of the engine, the amount of gasification is changed automatically by the carburetor. The convection heat transfer between low temperature LNG and high temperature water of the engine is held in the carburetor.

2.3. Mixer

The mixer of LNV is mounted between the middle cooler and the air inlet pipe of the engine. The main function of the mixer is that the natural gas and the air can be evenly mixed according to a certain proportion. By the high frequency solenoid valve, the injection quantity of natural gas can be adjusted in the LNGV gas supply system. The mixer determines the timing of the solenoid valve open according to the engine speed of various conditions and load changes. Thus the natural gas can be formed into a certain concentration of combustible gas mixture in the mixer to meet the needs of various working conditions.

In addition to the above parts, the gas supply system also includes the supply pipe, the pipeline pressure gauge, the buffer tank, the air track assembly and other parts.

3. Construction of the LNGV cold energy recovery

3.1. Cryonic Heat Exchanger

The cryonic heat exchanger, in which the air conditioning medium and the cryogenic LNG will exchange heat violently with large temperature difference, is the key equipment. The cryonic heat exchanger should not only have enough capacity of exchanging heat to recover enough cryonic energy for the refrigeration in the city bus but also have the ability to ensure the refrigerant medium (glycol aqueous solution) to be cold enough to obtain large temperature difference. Moreover, the refrigerant medium should realize the refrigerant effect in short time, or the air-conditioning system will not be of any utility value. Finally, the freezing points of the known refrigerant medium nowadays are higher than that of the LNG storage temperature, the refrigerant medium will ice up partially. Accordingly, the freezing rate of the refrigerant medium should also be considered to make sure the air-conditioning system works well in the project design.

3.2. Cold Storage System.

A set of cold storage apparatus should be installed in the air-conditioning system that works in complicated thermal conditions. When more LNG gas should be feed to the bus engine, the spare cryogenic energy will be stored. When the engine idles or the cryogenic energy is short, the spare cryogenic energy will release to the air heat exchanger [3].

3.3. Terminal System of Air-conditioning.

Terminal system of the air-conditioning is applied to release the cryogenic energy in the shape of cold wind to the bus cab. The main parts of the terminal system include air heat exchangers, the air blower and pipes.

3.4. Circulation System.

Circulation system is applied to drive the refrigerant medium to flow and to ensure the high pressure relief automatically in the system.

4. LNGV engine bench test

Firstly, the power performance of the modified LNG fuel vehicle is tested, and then compared with the vehicle dynamic data before the modification. The conclusion is drawn and the analysis is carried out according to the test results. Secondly, the power performance, economy and environmental performance of the modified vehicle are assessed to check out if the test can meet the technical requirements.

4.1. Power test

The comparison of the power performance between the original bus LCK-6180 and the modified bus can be shown in Table 1. From Table 1, the bus power has declined after the modification, which reflects in the decline of the top speed and the lowest speed of the bus. The bus will lack power obviously when the vehicle drive on the road with a large slope. Therefore, it is a key problem to improve the power performance of the modified LNG vehicle.

Table 1. Comparison of the power performance of the original and the modified bus LCK-6180

	Original (gasoline)	Modified (LNG)	Increase rate (%)
0~50 acceleration performance	21.7	33.74	55.5
20~50 acceleration performance	24.5	38.84	56.2
Top speed (*km/h*)	75.8	62.33	-14.5
Lowest steady speed (*km/h*)	16.1	18.76	16.5

4.2. Economy test

The economy test is to fill certain quantity of LNG to test the mileage by the amount of fuel when the bus is of heavy load. The weight of the LNG filled into the tank is 120 *kg* and the pressure in the tank is 0.47*MPa*. The test results is shown in Fig.3. The actual total mileage is 450 *km,* and the actual LNG consumption is 32.9 m^3/100*km*. The cost of applying LNG as the fuel can save about 40 percent than that of applying the gasoline as the fuel.

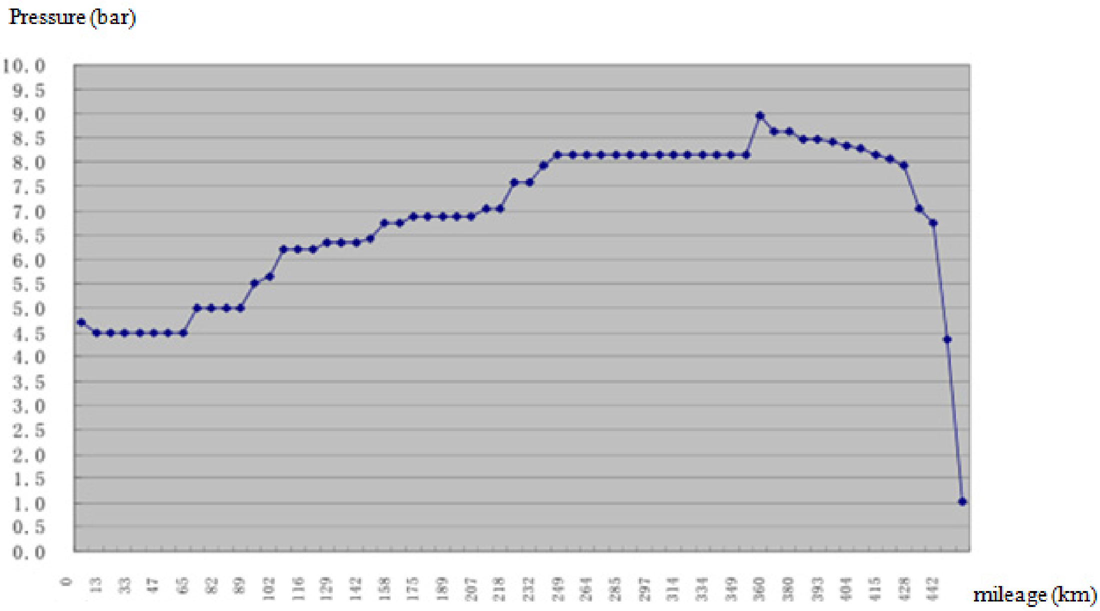

Fig. 3. Relationship between the mileage and the pressure with heavy load

To ensure that LNG flows into the outlet of the LNG tank is mostly liquid by adjusting the valve on the tank to set a relatively high pressure. The experimental results, which can be seen in Fig.4, show that the modified bus has an excellent refrigeration effect.

From Fig.4, the cooling effect of the refrigerant media is quite obvious. The experimental results show that the inlet temperature of the refrigerant media in the cryonic heat exchanger is 17 ℃ and the outlet temperature is 22 ℃. The cooling time is about 10 minutes, which can meet the requirement of the air conditioner in the urban bus.

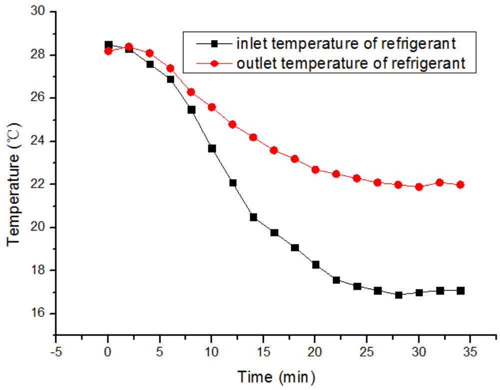

Fig.4. Temperature curve of the refrigerant media in the inlet and the outlet of the cryonic heat exchanger

5. Conclusions

The construction of the LNGV by modifying the gasoline urban bus is studied, and the cold energy recovery system of the modified LNGV is presented. After the modification of the bus, the engine bench test is performed to check the power performance and the energy performance. From the results of the test, the LNGV is of good economy performance, good cooling effect, and the power performance need to be improved especially in heavy load conditions.

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Biography

Yan Fayi, Doctor of Philosophy, majoring in mechanical engineering, whose main research area is new energy vehicle technology.