Internal combustion engine alternative fuels

ABSTRACT

With the increasing concern for environmental protection and sustainable development, alternative fuels for internal combustion engines have become a topic of great concern. Traditional fuels such as oil not only have the problem of emission pollution, but also have the problem of limited quantity and easy to be influenced by political factors. Therefore, finding suitable alternative fuels is an important guarantee to ensure the sustainable development of people's lives and society. In recent years, some new fuels have been developed, such as biomass energy, hydrogen fuel, methanol, etc. The development and use of these alternative fuels can reduce the impact of traditional fuels on the environment and reduce dependence on fossil energy.

However, the research and use of alternative fuels also presents a series of problems, such as cost, energy density, sustainability, and so on. Therefore, the performance, feasibility, advantages and disadvantages of alternative fuels need to be fully studied and evaluated. On the basis of existing research, this paper will conduct an in-depth discussion from the aspects of combustion characteristics, emission characteristics, advantages and disadvantages of alternative fuels, so as to provide certain theoretical support and practical experience for the research and application of alternative fuels, and promote the development and application of alternative fuel technology.

Keywords: Alternative fuel; Pollutants; Clean energy

1.INTRODUCTION

As a common mechanical device, the internal combustion engine is an indispensable part of many vehicles and machine equipment. However, with the deterioration of the earth's environment, the research and application of alternative fuels has become an important problem that must be solved. Although traditional fuels, such as oil and natural gas, have the advantages of high energy density and easy storage, they also bring serious pollution problems, which makes the development of alternative fuels attract wide attention [1-4]. Therefore, in order to protect the environment and promote sustainable development, exploring new alternative fuels has become one of the current research hotspots [5-8]. Starting from the relationship between internal combustion engine and traditional fuels, this paper will discuss the application and development status of various alternative fuels, and analyze the advantages and disadvantages of various alternative fuels, so as to provide some references for the research in related fields[9-11].

2 THE IMPORTANCE OF ALTERNATIVE FUELS

2.1 DISADVANTAGES OF CONVENTIONAL FUELS

Traditional fuels, such as oil and natural gas, play an important role in the economy and development of human society. But at the same time, these traditional fuels also have many drawbacks and negative effects. The disadvantages and effects of traditional fuels will be analyzed in this paper.

1. Environmental pollution

The gases and particulate matter produced by the combustion of traditional fuels not only have a serious impact on air quality, but also cause oxidation and damage to the atmosphere and the ecological environment. For example, carbon dioxide emissions are one of the main causes of global warming and climate change; Emissions of sulfur oxides and nitrogen oxides can lead to problems such as acid rain and light pollution [12]. At the same time, studies have

shown that the toxic gases and particles emitted can have adverse health effects on humans and large animals.

2. Economic impact

The economic benefits of reliance on conventional fuels cannot be ignored, but at the same time the prices of these fuels are constrained by supply, demand and geography, and are subject to market and political fluctuations. For example, oil federation monopolies and sharp fluctuations in oil prices can have direct and indirect impacts on global markets and trade [13].

To sum up, the disadvantages and effects of traditional fuels are obvious. They destroy the environment, waste resources and have a negative impact on the economy. Therefore, it is essential to explore alternative fuels and develop relevant policies to mitigate the impact of traditional fuels and promote sustainable development.

2.2 THE IMPORTANCE OF ALTERNATIVE FUELS

With the development of the world economy, the increase of the global population and the acceleration of urbanization, the problems of energy demand and environmental pollution are becoming increasingly serious. The emphasis on environmental protection and sustainable development has become a global hot topic [14]. Finding alternative fuels to replace traditional fuels has become a strategic goal for many countries, and the importance of this initiative is mainly reflected in the following aspects.

The mining, processing and conversion of traditional fuels require a lot of energy and resources, while alternative fuels mainly use renewable energy such as biomass, solar energy, water flow, ocean energy, geothermal energy and so on. Renewable energy can be more sustainable, while also promoting sustainable development, ensuring future energy supplies and meeting human energy needs. With the continuous improvement of global renewable energy technology and the decline of costs, the use of new fuels will reduce production costs and business operating costs, improve the competitiveness and sustainable development of the industry, and create new opportunities and development space in the process of energy transformation.

By reducing dependence on conventional fuels, reducing geopolitical risks and

dependence on imported fuels in the energy sector, renewable energy can enhance a country's energy security and autonomy.

To sum up, the search for alternative fuels is essential to tackle environmental pollution and promote sustainable development. A truly global deployment of alternative fuels through innovative technologies and policy measures will create a more sustainable, clean and prosperous future for human society.

3 NATURAL GAS

3.1 PHYSICAL AND CHEMICAL PROPERTIES OF NATURAL GAS

Natural gas is a mixed gas that is primarily composed of methane (CH_4), but also contains small amounts of hydrocarbons such as ethane, propane, and butane, as well as some gaseous impurities such as nitrogen, carbon dioxide, and hydrogen sulfide[15]. Its physical and chemical properties include the following aspects: For air, the density of natural gas is low. Natural gas has a high calorific value, usually 35-50MJ/m^3. The boiling point of natural gas varies with the composition, generally between -165 ° C and -60 ° C. Natural gas is a flammable substance that burns easily in the air, and the carbon dioxide and water vapor produced during combustion are harmless to the environment. Natural gas may contain hydrogen sulfide (H_2S), which is a toxic gas that needs to be controlled and disposed of during handling and use to ensure safety. Natural gas is a volatile gas that is gaseous at room temperature but can be compressed into a liquid state for storage and transportation. In addition, natural gas also has the characteristics of clean, efficient, easy to use, colorless and odorless, and has become one of the important energy resources. As shown in Table 1, the physical properties of compressed natural gas are compared with those of other fuels.

Table 1 Comparison of physical properties between natural gas and other vehicle fuels

Physicochemical properties	Compressed natural gas	gasoline	Diesel oil	Liquefied petroleum gas	Ethyl alcohol
Molecular formula	The main component is CH_4	C_5~C_{12} hydrocarbon	C_{10}~C_{21} hydrocarbon	C_3H_8	C_2H_5OH
density /×10-3·kg·m-3	-	0.72~0.78	0.82~0.86	0.506	0.725
Boiling point /℃	-162	30~190	180~370	-	78
Spontaneous combustion temperature	650	500	350	504	420
Low calorific value of fuel /MJ·kg-1	50	44	42.5	46.42	27.2

3.2 COMBUSTION CHARACTERISTICS OF NATURAL GAS

The main component of natural gas is methane (CH_4). When burned, methane chemically reacts with oxygen to produce water vapor (H_2O) and carbon dioxide (CO_2) while releasing a large amount of heat. This combustion reaction is efficient because methane is a hydrocarbon with a simple molecular structure that is easy to burn and does not produce the large amounts of harmful gases and particles produced by traditional fuels such as coal or oil [16].

3.3 EMISSION CHARACTERISTICS OF NATURAL GAS

In the case of full combustion, the main emissions of natural gas are water vapor and carbon dioxide, which have relatively little impact on the atmospheric environment. In contrast, burning natural gas produces fewer carbon dioxide emissions than coal and oil and is therefore considered a cleaner fuel option. Although the main substances emitted by natural gas combustion are water vapor and carbon dioxide, a small amount of harmful gases such as nitrogen oxides (NO_x) and carbon monoxide (CO), as well as particulate matter [17], are also produced in the actual combustion process. The emissions of these

substances depend on factors such as combustion conditions, fuel quality and the efficiency of combustion equipment. Natural gas has a higher spontaneous combustion temperature than gasoline and diesel and is safer to use in transportation

3.4 THE ADVANTAGES AND DISADVANTAGES OF NATURAL GAS AS A VEHICLE FUEL

The boiling point and density of liquid natural gas are larger than kerosene, and the technical problems caused by low temperature and volume are easy to solve, so liquid natural gas can be used as a transitional vehicle fuel. The advantages of natural gas engine are: it can reduce the emission of nitrogen oxides; Can reduce particulate matter emissions; Can reduce the smoke; Abundant global reserves; The use cost is not high. Due to the limitations of the layout of the filling station network, it is difficult to popularize and can not be large-scale development in the short term.

4 HYDROGEN

4.1 HYDROGEN FUEL

Hydrogen is flammable, and when it mixes with oxygen and comes into contact with an ignition source, it burns violently, releasing a lot of energy. This property makes hydrogen an important fuel. Hydrogen has a melting point of -259.2°C and a boiling point of -252.9°C. These temperatures are much lower than those at normal temperature and pressure, so hydrogen usually exists as a gas at room temperature. Hydrogen can penetrate into many materials, including metals, plastics, and rubber [18]. This property needs to be considered in hydrogen storage and delivery to prevent hydrogen leakage and loss. Hydrogen in the production, transportation and storage are required to have a very high sealing, the use of the process will face great security challenges.

4.2 COMBUSTION CHARACTERISTICS OF HYDROGEN

Hydrogen is a widely used fuel in the energy and industrial fields, and its combustion characteristics are of great significance for understanding the application and safety of hydrogen. The combustion characteristics of hydrogen are discussed in detail below. Burning hydrogen in the presence of oxygen produces water, releasing

a lot of heat. The combustion of hydrogen is an exothermic reaction, releasing about 286 kJ of heat per gram of hydrogen combustion, more than twice that of many common fuels. Hydrogen burns at a higher rate than many other fuels, which means it can release energy faster under the same conditions. The main product of hydrogen combustion is water, which does not produce smoke or harmful gases, so it is considered a clean fuel. Hydrogen is flammable, and hydrogen mixed with air can be ignited very easily under the right conditions. Hydrogen can form explosive mixtures under the right conditions, so special care is needed when handling and storing hydrogen. In short, hydrogen as a fuel has unique combustion characteristics, its high combustion speed and smokeless combustion characteristics make it have important application prospects in energy and industrial fields. However, the flammable and explosive nature of hydrogen also requires us to maintain a high degree of vigilance when using and storing it to ensure safety.

There are two main combustion modes of hydrogen used in engines: one is hydrogen-doped combustion [19]; The other is pure hydrogen combustion [20]. Due to its physical and chemical characteristics, hydrogen has many abnormal combustion phenomena in internal combustion engine. The common abnormal combustion of hydrogen engine includes premature combustion, tempering, knocking and so on.

4.3 HYDROGEN EMISSION CHARACTERISTICS

Hydrogen emission characteristics are critical to issues such as environmental protection and climate change. Understanding the emission characteristics of hydrogen can help assess its sustainability as an energy source and take steps to reduce its adverse environmental impact.

The main product of hydrogen combustion is water. Water discharge is usually harmless to the environment. Compared to conventional fuels, hydrogen combustion does not produce greenhouse gases such as carbon dioxide, so it is considered a zero-emission energy option. This gives hydrogen potential in addressing the challenge of climate change.

Although hydrogen combustion does not produce carbon dioxide, it may generate

nitrogen oxides such as nitrogen oxide under high temperature combustion conditions, which have a certain impact on the atmospheric environment. By optimizing the combustion process and controlling the combustion temperature, the generation of harmful substances such as nitrogen oxide can be reduced.

To sum up, hydrogen as an energy source has unique emission characteristics, mainly discharging water, and no carbon emissions during combustion. Therefore, when promoting the development of hydrogen economy, it is necessary to comprehensively consider its life cycle emissions and take corresponding emission reduction measures.

4.4 ADVANTAGES AND DISADVANTAGES OF HYDROGEN AS A VEHICLE FUEL

(1) The advantages of using hydrogen energy

1. Reduce local pollution.

2. Reduce global CO_2 emissions.

3.Resolve the constraints of non-renewable energy such as oil and natural gas on human development.

(2) Technical problems and development status of hydrogen internal combustion engine

1. On-board hydrogen storage: The problem of hydrogen storage has always been a problem in the research of hydrogen energy-related technologies. The small size of hydrogen molecules makes it easy to penetrate into the storage tank materials and hydrogenate the materials, resulting in hydrogen embrittleness. At the same time, the flammable and explosive nature of hydrogen restricts the application scenarios of hydrogen energy. Especially in the vehicle engine, the need to store enough hydrogen energy fuel in a limited space to ensure the endurance is a huge challenge. At present, the research direction of hydrogen storage mainly includes high-pressure gaseous hydrogen storage, low-temperature liquid hydrogen storage and hydrogen storage materials.

2. Emissions: Hydrogen internal combustion engines theoretically have five emissions of H_2, HC, CO, CO_2 and NO, of which CO, CO_2 and HC are three pollutants produced by oil combustion, and the emission concentration is small. Nitrogen oxides

(NOx) are the main emissions of hydrogen internal combustion engines, which are formed by the reaction of nitrogen and oxygen in high-temperature cylinders, with emissions of up to 0.02g/kW·h. Exhaust emission control is the focus of controlling the exhaust emissions of hydrogen internal combustion engines.

5 METHANOL

5.1 ADVANTAGES AND DISADVANTAGES OF METHANOL AS A VEHICLE FUEL

Compared to traditional fossil fuels, methanol combustion produces lower CO_2 emissions and is extracted or produced from biomass, waste and renewable resources, making it highly renewable. Compared with some emerging clean energy technologies, the production and use of methanol as a fuel is more mature and can be produced and distributed using existing infrastructure and technologies. Methanol is compatible with existing internal combustion engine technology and does not require too many modifications and technical upgrades, so it can be rolled out to the existing vehicle market relatively quickly. Methanol has a competitive advantage over some other alternative fuels due to its high combustion efficiency and ability to provide a more stable and reliable power output.

The current cost of methanol production is high, especially when producing methanol from renewable resources or biomass, and the cost is likely to rise further. This makes the economics of methanol a large-scale alternative fuel challenging. Compared to conventional petroleum fuels, methanol has a lower energy density and requires more storage space or more frequent refills, which can have an impact on the vehicle's range and experience.Methanol is a flammable and explosive liquid, which requires strict control of temperature, pressure and leakage prevention during storage and use to ensure safety, which increases the cost of use and technical requirements.

6 GENERAL JUNCTION

The internal combustion engine is a common type of engine, but its use of fossil fuels also brings environmental and resource problems. Therefore, alternative fuels have become one of the important directions that the internal combustion engine can develop. At present, alternative fuels for internal combustion engines are mainly concentrated in hydrogen energy and liquid natural gas.

As an alternative fuel for internal combustion engine, hydrogen energy is widely used in hydrogen fuel cell vehicles and hydrogen-burning engines. The advantages are low pollution, high efficiency, and energy storage can be stored through renewable energy forms such as solar photovoltaic power generation, but there are also security risks and expensive development, storage and transportation costs. Liquefied natural gas (LNG) is an alternative fuel made from natural gas, which is widely used in public transportation, ships, trains and other fields. The advantage of liquefied natural gas is its environmental protection, renewable, low cost, so it is widely used in some fields, but it also contains some challenges, such as storage, transportation, equipment costs are higher. Hydrogen needs to be stored and transported at high pressures and low temperatures to maintain its liquid or high-pressure gaseous state. Transportation is usually carried out using high-pressure gas containers or liquefied hydrogen tanks. Strict safety measures are required during transportation, including the use of high-strength materials to manufacture containers to avoid leakage and prevent static build-up.

Conclusion

In general, the alternative fuel of internal combustion engine has a broad prospect, but the application of alternative fuel has certain limitations, involving the cost of each link, production scale. In addition, it is also necessary to strengthen policy support to accelerate the application and development of alternative fuels in the field of internal combustion engines, so as to better meet the needs of society for low-carbon development and environmental protection, and achieve sustainable development.

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REFERENCES

1. Alonso-Villar Albert,Davíðsdóttir Brynhildur,Stefánsson Hlynur,Ásgeirsson Eyjólfur Ingi,Kristjánsson Ragnar.Technical,economic, and environmental feasibility of alternative fuel heavy-duty vehicles in Iceland[J].Journal of Cleaner Production,2022,369.
2. Alagumalai A. Internal combustion engines: Progress and prospects. Renewable and Sustainable Energy Reviews. 2014 Oct 1;38:561-71.
3. Stone R. Introduction to internal combustion engines. London: Macmillan; 1999 Nov 11.

4. Ricardo HR. Recent research work on the internal-combustion engine. SAE Tra nsactions. 1922 Jan 1:1-93.
5. Cristian D ,Elisabetta C .Role of car segment and fuel type in the choice of a lternative fuel vehicles: A cross-nested logit model for the English market[J].Ap plied Energy,2024,357122451-.
6. Windecker A ,Ruder A .Fuel economy, cost, and greenhouse gas results for al ternative fuel vehicles in 2011[J].Transportation Research Part D,2013,2334-40.
7. Ferguson CR, Kirkpatrick AT. Internal combustion engines: applied thermoscienc es. John Wiley & Sons; 2015 Jul 1.
8. Abedin MJ, Masjuki HH, Kalam MA, Sanjid A, Rahman SA, Masum BM. Energ y balance of internal combustion engines using alternative fuels. Renewable an d Sustainable Energy Reviews. 2013 Oct 1;26:20-33.
9. Hossain AK, Davies PA. Pyrolysis liquids and gases as alternative fuels in inter nal combustion engines–A review. Renewable and Sustainable Energy Reviews. 2013 May 1;21:165-89.
10. Singh AP, Sharma YC, Mustafi NN, Agarwal AK, editors. Alternative fuels and t heir utilization strategies in internal combustion engines. Springer Singapore; 20 20.
11. Babu MG, Subramanian KA. Alternative transportation fuels: utilisation in combu stion engines. CRC Press; 2013 Jun 18.
12. Shukla PC, Belgiorno G, Di Blasio G, Agarwal AK, editors. Alcohol as an alter native fuel for internal combustion engines. Singapore: Springer; 2021 May 15.
13. Gupta HN. Fundamentals of internal combustion engines. PHI Learning Pvt. Lt d.; 2012 Dec 10.
14. Yuan Z ,Xianchun T ,Baihe G , et al.Cost-effectiveness analysis on improving fuel economy and promoting alternative fuel vehicles: A case study of Chongqi ng, China[J].Journal of Cleaner Production,2021,323
15. van Rossum Gerard J. 1st International congress of gas quality â€ specification and

measurement of physical and chemical properties of natural gas[J]. TrAC Trends in Analytical Chemistry,1986,5(10).

16. Liu J,Ma B ,Yu R ,et al.Optimization of the direct injection natural gas engine under different combustion modes[J].Fuel,2020, 272:117699.
17. Zhang Q ,Li Z,Wei Z,et al.Experiment investigation on the emission characteristics of a stoichiometric natural gas engine operating with different reference fuels[J].Fuel,2020,269(6):117449.
18. Aggarwal Aman,Yadav Suyash,Singh Kshitij,Singh Verma Ajay,Chhabra Sandeep. Study of utilization of hydrogen as fuel in internal combustion engine[J]. Materials Today: Proceedings,2022,64(P3).
19. Luo Jianbin,Liu Zhonghang,Wang Jie,Xu Hongxiang,Tie Yuanhao,Yang Dayong, Zhang Zhiqing,Zhang Chengtao,Wang Haijiao. Investigation of hydrogen addition on the combustion, performance, and emission characteristics of a heavy-duty engine fueled with diesel/natural gas[J]. Energy,2022,260.
20. Choi Jaehong,Ahn Myunggeun,Kwak Sanghyeok,Lee Jong Guen,Yoon Youngbin. Flame structure and NOx emission characteristics in a single hydrogen combustor[J]. International Journal of Hydrogen Energy,2022,47(68).