Study on improving fuel utilization by using automobile exhaust energy

Hu Yong

Hubei Three Gorges Polytecchnic, Yichang, Hubei, China

Keywords: waste gas energy; recycling; Integrated device

Abstract: The current situation of energy recovery and utilization technology of automobile exhaust gas is analyzed. It is proposed to use automobile exhaust gas to drive the turbine to rotate, so as to drive the coaxial compressor and rare earth permanent magnet generator to work. At the same time, it can provide compressed air to the engine cylinder to increase the effective power of the engine, provide power supply for automobile electrical equipment or charge the battery.

1. Introduction

Only 20% - 45% of the heat energy produced by the combustion of fuel in the engine cylinder is converted into effective mechanical work, and its waste heat energy is lost through exhaust, cooling medium and heat dissipation on the surface of parts, in which the energy taken away by exhaust gas accounts for 30% ~ 40% of the total energy. It can be seen that recycling the energy contained in waste gas is of great significance to realize automobile energy saving and improve energy utilization.

2. Current situation analysis

2.1 Exhaust gas Turbocharging Technology

Exhaust gas turbine augmentation is a widely used way for vehicle engines. The exhaust gas from the engine is used to drive the turbine to rotate at high speed and drive the compressor of the old shaft to compress the intake air to improve the intake pressure, so as to improve the air density and increase the intake air volume[1]. This technology can not only improve the fuel economy of internal combustion engine and reduce the emission of harmful emissions such as soot, CO and HC compounds, but also greatly improve the engine power without increasing the cylinder volume. However, after the engine adopts exhaust gas turbocharging technology, there are also some disadvantages[2]. It will improve the maximum explosion pressure and average temperature generated by the engine during operation, which will affect the mechanical performance and lubrication performance of the engine. At the same time, the amount of air flashed into the cylinder and the temperature of combustion smog will increase, so as to increase the emission of NO2.

2.2 Heating technology

The heating system, also known as the heating system, uses the waste heat of the engine exhaust pipe to provide heating for the cab and defrost and defog the windshield. The utility model has the advantages of no need to add other heat sources under the vehicle, low cost and simple structure. However, the heating process will increase the exhaust of the engine, and the heating amount is greatly affected by the working conditions of the engine. In addition, for vehicles running in urban areas, the engine often works under low working conditions and idle speed, and the exhaust temperature is not high enough to heat the compartment[3]. The heating technology is used in winter, with obvious seasonal characteristics, and the waste gas energy is not fully utilized.

2.3 Exhaust gas recirculation technology

The exhaust gas recirculation system sends a small part of the exhaust gas produced by the engine back to the intake pipe and re enters the combustion chamber together with the fresh air mixture to reduce the oxygen content in the cylinder. In the process of fuel combustion, the exhaust

  DOI: 10.25236/icmmct.2022.009

gas contains a large amount of CO2 and cannot be burned. However, it absorbs some heat to reduce the combustion temperature and pressure of the mixture, so as to inhibit the formation of NO2[4]. The exhaust gas sent to narrow combustion increases with the increase of engine speed and load. Exhaust gas recirculation technology will reduce NO2 emission, but due to the reduction of oxygen proportion in the cylinder, it will increase the emission of particulate matter and other pollution components. However, exhaust gas recirculation technology is the main way to reduce the content of NO2 in exhaust gas, so it has been widely used.

2.4 Thermoelectric power generation technology

Thermoelectric power generation consists of two different thermoelectric conversion materials, n-type semiconductor and p-type semiconductor, one end of which is connected to the same conductor and placed in the high-temperature environment through which the waste gas flows, and the other end is open connected to different conductors and placed in the low-temperature environment of the atmosphere. Due to the temperature difference at both ends of the thermoelectric conversion material, the potential difference is formed in the low-temperature open circuit through its internal narrow hole and electron diffusion, that is, positive and negative voltages are formed at terminals a and B respectively to directly convert heat energy into electric energy[5]. Thermoelectric power generation does not require chemical reaction, and the power generation process has no noise and? It has the advantages of low dyeing, small volume, light weight, wide application range and reliable application. It is now mostly used in military industry. However, at present, the thermoelectric conversion efficiency is generally low, ranging from 6% to 11%, and the cost of thermoelectric conversion materials is high, which is still a long way from popularization and application.

2.5 Improved fuel technology

The improved fuel technology uses the waste heat of the exhaust gas discharged by the engine to heat the fuel. It can decompose combustible gases such as hydrogen and carbon monoxide under the action of catalyst, so as to improve the combustible calorific value of fuel and reduce pollution and carbon deposition. At present, the improvement of methanol has been realized. Among the existing waste heat hydrogen production engines in China, the hydrogen production chain of methanol can reach 72.3%, which has certain advantages in reducing automobile fuel and self Ying. However, the improved technology can only catalyze the conversion of fixed liquid fuel and has a single purpose.

2.6 Driven air conditioning refrigeration technology

At present, the vehicle air conditioner driven by the waste heat of automobile exhaust can realize refrigeration by using the characteristics that some substances can adsorb some gas at a certain temperature and pressure and release it at another temperature and pressure. This way can reduce energy consumption and air pollution, but its application and development are restricted by the factors of large volume, complex structure and high cost[6]. If the recovered waste gas can be converted into electric energy and used to drive the automobile compressor to realize refrigeration, the automobile refrigeration and air conditioning can have greater development potential.

2.7 Turbine steam engine

The "turbine steam engine" manufactured by German BMW is based on two cycle systems: high temperature cycle, that is, the waste gas energy discharged from the dry engine is the main energy source, which passes through the heat exchanger together with the liquid medium and heats it into steam. The generated steam is directly directed to the expansion unit connected to the crankshaft of the internal combustion engine to provide power to the engine. Most of the remaining heat is absorbed by the engine cooling cycle to form the second energy source of the turbine steam engine, which is used to heat the liquid and improve the efficiency of liquid steam conversion, that is, the low-temperature cycle. After adopting this auxiliary drive system combination, the efficiency of the engine will be greatly improved and has certain application value. However, the system has high cost, complex structure and large volume, so it can not be popularized and applied in automobile[7].

Through comprehensive analysis of the existing utilization methods of vehicle exhaust energy collars, although they can promote the improvement of engine performance to a certain extent, there are various disadvantages around them, which makes a considerable part of exhaust energy wasted. Therefore, in order to make full use of waste gas energy, we must seek a new and more effective way of utilization.

3. Design of controller for exhaust energy recovery system of hybrid electric vehicle

3.1 Fuzzy processing

The fuzzy domain of the input parameters of the fuzzy controller is determined as [3500045000], the fuzzy domain of the generator flow I is determined as [4,5.5], the fuzzy domain of the battery SOC is determined as [0.2,1], and the fuzzy domain of the exhaust back pressure P is determined as [- 0.5,0.5]. The fuzzy domain of the speed n is divided into seven fuzzy subsets {Nb, nm, NS, Z0, PS, PM, Pb}, The fuzzy universe of current I, battery SOC and exhaust back pressure P is divided into five fuzzy subsets {Nb, NS, Z0, PS, Pb}; Output variable α The universe is [14,40], and the output variable is β The fuzzy universe of is [0,1], α and β The fuzzy universe is divided into seven fuzzy subsets {Nb, nm, NS, Z0, PS, PM, Pb}.

3.2 Fuzzy control rules

According to the requirements of system fuzzy rule formulation, 5 and 7 fuzzy subsets are defined for generator current I and turbine speed n respectively, 5 fuzzy subsets are defined for battery SOC and exhaust back pressure P, and the inclination angle of guide vane is formulated α Fuzzy control rule 35, wastegate opening β There are 25 fuzzy control rules and 60 fuzzy control rules in the fuzzy control rule base. The specific fuzzy rule table is shown in Table 1. The membership function and reasoning rules are established by using the fuzzy tool in MATLAB and the fuzzy toolbox of MATLAB. The membership function of each input variable of the controller is shown in Figure 1. The fuzzy controller adopts Mamdani reasoning method and the center of gravity method to defuzzify.

Table 1 Fuzzy control rules[8]

n/I	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NB	NM	NS
NS	NB	NB	NB	NB	NM	NS	ZO
ZO	NB	NB	NB	NB	NM	NS	ZO
PS	NB	NB	NM	NS	ZO	PS	PM
PB	NB	NM	ZS	ZO	PS	PM	PB
SOC/P	NB	NS	ZO	PS	PB	-	-
NB	NB	NB	NM	NS	ZO		
NS	NB	NB	NM	NS	ZO		
ZO	NB	NB	NM	NS	ZO		
PS	NB	NM	NS	ZO	PS		
PB	NM	NS	ZO	PB	PB		

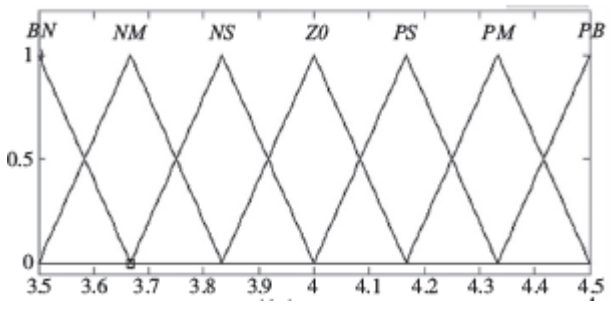

Fig. 1 Membership function of input variable speed n

4. Development prospect

By analyzing the existing waste gas energy utilization methods, it is concluded that the most effective utilization method is to convert the waste gas energy into mechanical energy and then into free electric energy. Based on the principle of making full use of waste gas energy alligator, taking the small volume, light weight and high efficiency of the device as the starting point, combined with turbocharging technology, a novel and efficient waste gas energy utilization scheme is proposed, that is, using waste gas turbocharging and power generation. The design idea of using exhaust gas turbocharging and power generation is as follows: firstly, the high-temperature and high-pressure exhaust gas discharged from the cylinder is used to directly drive the turbine placed at the engine exhaust port to rotate at high speed, so as to convert the exhaust gas energy into the mechanical energy of the turbine; The high-speed rotating turbine drives the coaxial compressor and permanent magnet generator rotor to rotate together. At this time, the turbine can drive the compressor to provide compressed air to the cylinder for full combustion, and drive the permanent magnet generator rotor to cut the magnetic line of force to generate electric energy to provide power for automotive electrical equipment or charge the battery. For engine exhaust negative pressure caused by new installation. The best matching can be achieved by optimizing the structure and length of the exhaust pipe. The device adopts thin permanent magnet generator, which has the advantages of simple structure, low failure rate, less copper consumption and high power generation efficiency. The new exhaust gas utilization device does not need to make major changes to the existing automobile equipment and its installation position. Therefore, it can be expected that it has good popularization prospect and high use value.

5. Conclusion

In order to improve the working efficiency and control accuracy of hybrid electric vehicle exhaust energy recovery system, a fuzzy controller for hybrid electric vehicle exhaust energy recovery system is designed, and the data acquisition system is designed according to the input and output parameter characteristics of the controller. The hardware circuit design of fuzzy controller is completed by Proteus, including control chip selection, power conversion circuit design, stepping motor drive circuit design, program debugging and circuit board production. The test shows that the change trend of the theoretical guide vane inclination is basically consistent with the actual inclination, and the change trend of the theoretical opening of the bypass valve is basically consistent with the actual opening. The error is very small, which can meet the working requirements.

References

[1] Liu Shujing, Li Yangyang, Liu Jingping, et al. (2021) Atkinson engine and vehicle performance analysis based on NSGA-II multi-objective optimization [J] Journal of Central South University (NATURAL SCIENCE EDITION), 52, 9, 3366-3380.

[2] Zhao Yufeng, Gao Hongliu. (2020) Analysis on Key Technologies of fault maintenance of new energy vehicles [J] Nanfang agricultural machinery, 51, 20, 91-92.

[3] Kang running, Wei Xiaolin, bin Feng, et al. (2020) Research Progress on Mechanism of CO catalytic combustion over Cu CE catalyst [J] Clean coal technology, 26, 5, 111-118.

[4] Hou Shengzhi, Zhu Di, Yin Jun, et al. (2019) Effect of ignition parameters on exhaust dilution combustion of direct injection gasoline engine [J] Small internal combustion engine and vehicle technology, 48, 4, 16-21.

[5] Liu Xi, Wang Qingchun, Long Ling, et al. (2019) Parametric research on exhaust heat generator based on diesel freight vehicle [J] Journal of Chongqing University of Technology (NATURAL SCIENCE EDITION), 33, 2, 145-154.

[6] Feng Hao, Qin Bo, Lin Sicong, et al. (2019) Experimental study on the effect of electronic supercharger on the performance of supercharged Miller Cycle Gasoline Engine [J] Automotive Engineering, 41, 7, 738-743.

[7] Li Mingli, Qiu bingtao, Jia Linpeng. (2019) Analysis and Research on SOC estimation method of residual power of lithium battery pack [J] Automation instrument, 40, 4, 56-59.

[8] Tian Shaojun, Liao Yi, Wang Yulei, et al. (2021) Study on several schemes to eliminate air flow pulsation and vibration noise of automobile fuel evaporation recovery system [J] Noise and vibration control, 41, 3, 197-203.