Analysis of the social impact of heat engine and its future application

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Abstract. This paper aims to evaluate the social impact of the heat engine and analyze the application of heat engines in the future. This paper starts with some background information on heat engines and the challenges of gas pollution and gas shortage. The concepts of efficiency and environmental friendliness of the heat engine are widely discussed, which speeds up the development of several kinds of heat engines. We discuss the application of heat engines in different industries from three main aspects: agriculture, marine engine, and aviation. They improve our daily life and provide the required energy to the community. Thermoacoustic Heat Engine (TAHE), Liquid Air Cycle Engines (LACE), and a new class of Heat engine without the expulsion of reaction mass are introduced in this paper. Furthermore, the article will cover some futures. One is artificial intelligence, and another one is about biofuel, which helps heat engines to have higher efficiency and less pollution, and also how heat engines are involved in the next decade.

1. Introduction
Heat engines transfer thermal energy to mechanical work, which is common in our daily life. In 1629 the first steam turbine came out to the world, illustrating that the heat engine was implemented into functional devices. In the following decades, from the steam turbine to the gas turbine, and nowadays the jet engine and rocket, efficiency of the heat engine increased from 3% to 60%. Besides, since the Industrial Revolution, considered as a multiple field application technique, the heat engine has been widely used in agriculture [2], marine [3], and aviation [4]. Now, in the background of economic globalization, simple heat engines can no longer keep up with the development speed of various industries. Therefore, it is necessary to develop new technologies to improve engine performance to satisfy the increasing need.

However, following the requirements of the heat engine is increased, resource problems and environmental problems also follow one after another. In May of 2021, tens of thousands of gas stations in every state in the United States stopped working due to resource shortages. In addition, in China's Pearl River Delta port, the amount of pollution emitted by ships burning heavy oil every day is
comparable to that of 210,000 trucks. It brings more than a dozen chemical carcinogenic pollutants. This has brought great pressure to environmental protection and has seriously affected people's quality of life.

Therefore, more and more attention has to be paid to resource conservation and environmental protection. So, people have become interested in using industrial processes to treat exhaust gas waste heat in recent years.

In summary, this article analyzes the three aspects of agriculture, marine, and aviation of how to use new technologies to improve the performance of heat engines and how to alleviate environmental problems at present. In addition, it also analyzes how to improve performance connect with artificial intelligence in the future. And biofuel will become alternative fuel to solve the shortage of fuel near future.

2. Analysis of the Social Impact of Heat Engine in Three Different Industries

2.1. Agriculture

The development of agriculture is a foundation of a country. In recent years, the application of heat engines in agriculture have been developing rapidly. In this background, a novel type of heat engine continues to emerge and be applied.

The Thermoacoustic Heat Engine [5] is a motive power that converts heat energy into acoustic energy. It is an engine designed to treat and reuse the exhaust gas generated during the baking process of biscuits.

The principle [5] shown in Fig.1 is that the exhaust gas generated in the oven is used as a compressible fluid to transfer heat with the solid boundary (stack) when passing through the engine. In the process of heat energy transfer, the pressure and velocity in the compressed fluid will be locally changed, accompanied by temperature gradients. When the pressure-velocity phase is in the correct position, the acoustic wave oscillates to produce acoustic waves, and then the pressure generated by the acoustic wave produces mechanical work. The mechanical work can then be used again to generate electricity. Even at such a comparatively low temperature of 150 C, it is possible to recover waste heat to deliver an output of 1029.10W of acoustic power with a thermal engine efficiency of 5.42%. Through this whole process, the exhaust gas has been perfectly treated. This simple design and the absence of any moving mechanical parts make such devices suitable for various heat recovery applications in the industry.

![](image)

Figure 1. Design of a thermoacoustic heat engine
2.2. Navigation industry
In the context of economic globalization, the shipping industry is developing extremely rapidly, which requires its engines to have high better performance. Still, the performance is proportional to fuel consumption and pollutants emitted. Therefore, it is urgent to develop new technologies to solve these two problems.

2.2.1 Marine Engine with a Better Performance. Fuel injectors in marine diesel engines are an important factor affecting energy conversion and combustion performance. Good treatment of the spray and atomization process can improve the performance of the engine. Jinxia et al. [7] have designed a dual injector to optimize this process. They compare double spray with single spray from collision structure, axial diffusion characteristic, spatial distribution, periphery feature, and axial/radial diffusion ratio. And found that compared with single-injection, double-injection requires less gas mixing time, but it can form a larger distribution space and promote energy management which reduces unnecessary consumption. Therefore, the dual injector does improve the performance of the engine.

2.2.2 Marine Engine with a Good Waste Heat Recovery System. In the past, when waste heat recovery technology was used to reduce fuel consumption and store thermal energy, a simple energy cascade principle was usually used. However, with continuous development, the general waste heat cascade system cannot avoid the problem of energy consumption well.

On this basis, Tiancheng et al. [8] designed a new type of waste heat recovery system (WHS), which includes a two-stage evaporation Organic Rankine Cycle (ORC), an absorption refrigeration system (ARS), and a heat storage device (HSD). The technology first combines two-stage evaporative ORC and absorption refrigeration so that there will be two circulation subsystems. The reason for this is that the exhaust gas temperature at this time cannot be lower than 120 degrees Celsius to avoid corrosion of equipment pipes by a sulfuric acid vapor when the marine engine burns heavy oil. When there are two sub-cycles, one of them is used to recover the heat of the higher-temperature working fluid in the condenser, and the cycle gets rid of the limitation of outlet temperature. Then the heat storage device can store and reuse the heat energy. This binary fluid's output power, thermal, and energy efficiency are up to 2866 kw, 16.22%, and 48.25% at 80% engine load. From the economic point of view, the various evaluation indexes are improved notably with the support of heat storage devices. Therefore, this new type of WHS improves the performance of the engine and reduces fuel consumption.

Figure 2. Design of a thermoacoustic heat engine
2.3. Aviation Industry

Like the marine engine, the aviation engine also faces the problem of improving performance and gas emissions.

2.3.1. Liquid Air Cycle Engines (LACE). Compared with agricultural engines and marine engines, aviation engines require higher performance. The main challenges facing aviation engines are high mission costs, long transportation times, and the need for safer abort modes.[10] In this context, the pursuit of high-efficiency and low-pollution engines has become a mainstream trend. Therefore, the LACE [11] was proposed and widely used.

The main principle of this engine is to blow compressed air through a heat exchanger and quickly cool the air to rapidly liquefy its various components. The liquefied oxygen can be sent to the engine to be reused. The whole cycle process meets the requirements of high efficiency and environmental protection [11].

2.3.2. Heat engine without the expulsion of reaction mass. Brady J M [i] proposed a new class of heat engine based on the two prototypes Bootstrap V and Bootstrap VI, as shown in Fig. 3, and explored the relationship of impeller position within the duct to the accelerative force output. A new class of heat engines succeeds in directly converting thermal/kinetic energy to a sustained accelerative vector force without the expulsion of reaction mass. This technology in the small turbine engine field has kept pace with the growing requirements. Compact, efficient, low-cost turbofan engines in the under 1000 lb-thrust class have become available and can be considered for cruise missiles and low-cost, energy-efficient trainers [ii].

![Figure 3. Proof of concept prototypes Bootstrap V, Bootstrap VI with relocated impeller assembly, and Bootstrap VII with flow straightening vanes](image)

These engines rely on the properties of a gas in steady-state flow in a recirculating duct and the manipulation of the density and velocity of this gas by means of thermal management. The resulting propulsion system is a conventional heat engine in all respects except that it offers a self-referential method of accelerating itself and an attached mass given a source of energy and a means of cooling. The engine is simple in concept and design, scalable, and may contain only one moving part.

Besides, the Williams Research Corporation, Walled Lake, Michigan, covers a broad spectrum of applications in the 600 lb thrust area, particularly those requiring high specific thrust and low fuel consumption. The latest models of the engine have been specifically developed for cruise missiles. The
spectrum of flight vehicles thereby made practical is greatly expanded in the very small, high-performance areas.

3. Application
With the continuous development of technology, more and more fields are connected with artificial intelligence, which is true for heat engines. In addition, due to the increasing shortage of resources, finding alternative fuels is also a topic that must be studied.

3.1. Heat Engines combined with Artificial Intelligence

3.1.1. A 7-milligram Miniature Catalytic-combustion Engine. At present, autonomous microrobots at the subcentimeter scale have played a role in surveillance, drug transportation, and artificial pollination. In addition, microrobots at the subcentimeter scale can perform useful complex tasks if they were to become energy independent and could operate autonomously. So how to apply micro robots to heat engines is also a hot topic. Fares et al. have designed a micro heat engine, which is a 7-milligram miniature catalytic-combustion engine, mainly uses a cantilever shape-memory alloy (SMA) bending actuator.

Its working principle is divided into three steps, as shown in Figure 4.
(a) Apply platinum black powder on the SMA wires to form a catalytic surface. When no fuel is burning, the actuator remains in its relaxed position.
(b) When the fuel gas is introduced, a catalytic combustion reaction occurs on the Pt coating, increasing the Pt layer temperature. As a result, the SMA wire is heated and activates the shape memory effect, thereby shrinking its length. And, this change will cause the central carbon brazing to bend, reflecting the bending movement on the actuator.
(c) The gas source supplies an airflow to increase the cooling rate by convection. As a result, the actuator goes back to its relaxed position.

Through such a process, engine combustion can be catalyzed. However, due to the lack of support from the power system, these are still only at the laboratory stage.

![Figure 4. Design of the miniature catalytic-combustion engine](image)

3.1.2. Artificial Neural Network. Predicting the parameters of the engine is an important task, and the parameters of the engine can reflect its performance and failures. Therefore, the engine can be repaired and maintained in time. At present, thermodynamic modeling [13] is a commonly used prediction method, but it has the disadvantages of slow speed, inability to adapt to high-load engines, and long time-consuming. But using artificial neural network methods to make predictions can solve these problems well. The advantage of this tool is that it is very flexible and robust, adapting to different engine operation points with little error.
Figure 5. Neural Network Diagram

Joseba et al. [13] designed a test program, and Figure 5 shows the structure of its neural network. Its testing principle is that a neural network needs to be artificially established first, and a mature database is obtained after many pieces of trainings. Once the database is formed, it can be used to test new engines. So, this method requires very little time and can be expanded according to the engine's load, which solves the problem of difficult engine testing with excessive load.

3.2. Heat Engines used Biofuel
In recent years, biofuels are more popular, depending on their two advantages. Firstly, it solves the problem of increasing fuel demand and economic crisis. Secondly, it has good biodegradability, sustainability, wide availability, and low price [14].

3.2.1. Stoechospermum Marginatum Microalgae Biodiesel. Karthikeyan et al. [15] have studied the use of microalgae biodiesel instead of ordinary diesel to be applied to agricultural tractors' engines and conducted experiments in terms of torque, power, and specific fuel consumption. The results show that, compared with ordinary diesel, the microalgae biodiesel shows better performance, with the lowest torque value, the greatest power, and the least consumption. Figure 6. is Stoechospermum marginatum algae.

Figure 6. Stoechospermum marginatum algae

3.2.2. Bio-acetone-gasoline and Bioethanol-gasoline Blended Fuel. In addition to the biofuels mentioned above, Ashraf et al. [16] mixed with another biofuel: Bio-acetone-gasoline and bioethanol-gasoline blended fuels, the main purpose of which is to improve engine performance and reduce pollution emissions. The researchers selected the spark-ignition engine after considering the versatility and robustness of construction and the ability to accommodate different fuels to burn. By comparing mixed fuel and pure gasoline with octane number (ON) 95, they found that compared to pure gasoline, mixed fuel burns more fully and has lower emissions, and it is also a renewable energy source. Therefore, bio-acetone-gasoline and bioethanol-gasoline blended fuels are more valuable in use.
4. Conclusion

The heat engines help the human and create a convenient life for them. At present, with the advancement of science and technology, the heat engine has also improved. But the repeated use of heat engines will make the environment being polluted. In the third part of the future, there are many alternative ways to solve the problem, but most of them are still in the laboratory process. Based on the above findings, it can be known that the technology of heat engines will become more and more mature. In the future, heat engines will be combined with artificial intelligence to further improve engine performance. And to cope with the problems of resource shortage and environmental protection, biofuels are bound to become mainstream energy sources. The improvement of efficiency, the replacement of heat engine fuel, and the use of more ways of a heat engine are all directions that can be considered in the future.

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