Research of Heavy-Duty Gas Turbines through Computer Mathematical Statistics and Big Data Analysis

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Abstract. Heavy duty gas turbine is the core power equipment of energy efficient conversion and clean utilization system in the 21st century and even longer. It is important for an efficient, clean and safe energy system. The heavy duty gas turbine is developed and manufactured at a level that represents a country's heavy industry and is by far the most efficient thermoelectric conversion equipment. This paper introduces the development status of the heavy duty gas turbine industry at home and abroad, summarizes the working principle and characteristics of heavy duty gas turbines, and prospects the development trend of heavy duty gas turbines.

Keywords: Heavy-duty gas turbines; turbines; heat engine.

1. Introduction

Since the 1980s, with the continuous innovation and development of metallurgy, cooling, thermal barrier coating, 3D printing and other technologies, the new generation of power units has developed rapidly since the beginning of the last century [1]. The gas turbine is a kind of high speed rotating thermal turbine-machine. Its thermal cycle consists of four processes: compression, heating, expansion and heat release of working medium [2]. The unit comprises a compressor, combustion chamber, turbine, control and auxiliary system [3]. At present, scientific research on the technology of heavy gas turbines has become an important direction to improve energy efficiency in the present and future [4]. Especially in the field of power generation, gas turbine power generation technology has been widely used for its high efficiency [5], less pollution, short construction period, quick effect and other characteristics. According to the current scientific and technological development rate, the gas turbine will still become the core power device with the highest energy conversion efficiency in the 21st century, and its r&d and manufacturing level represents the level of a country's heavy industry [6].

GE, Siemens, MHI and Alstom are the main suppliers of heavy duty gas turbines in the international market share [7]. Western countries have invested a lot in gas turbine research and development for a long time. At the same time, they have deep technical accumulation and master the core technology of heavy gas turbines [8]. Each big manufacturer of heavy-duty gas turbine continues to study the development and diversity of creation, in view of gas turbine diversity can show liu cranes of heavy duty gas turbine's future vision, developmental, proposed the secondary air system due to will produce greater pressure in the gas turbine, so the inlet temperature is relatively high [9]. Therefore, the cooling air channel is added to the cooling air system, which can deliver cold gas to the outer shaft and protect the parts in the main passage of the turbine and improve the role of the secondary cooling air system [10]. To improve the efficiency of the system. Jiang Hongde, Ren Jing and other scholars also put forward the idea of further improving the performance of compressor and turbine components. Cooling is the key to turbine design and one of modern heavy-duty gas turbines' most critical core technologies [11]. The difficulty is that the heat load of turbines is constantly increasing, while the cold air volume is extremely limited. At present, the widely used cooling methods include internal enhanced heat transfer and gas film cooling. The changes in their geometric structure and arrangement form will have

a significant impact on the cooling effect. At the same time, Woosett had a summary of how to improve the efficiency of gas turbines: continuous improvement of thermal parameters to improve performance and stand-alone power has been the main trend of gas turbine development [12]. Research and use of advanced materials, processing technology, advanced cooling technology can improve the inlet gas temperature of the turbine; The introduction of aviation gas turbine technology, multistage adjustable static blades, design superior performance of the blade profile, and improve the compressor compression ratio, flow rate and compression efficiency; Reheat cycle.;At the same time, the advanced dry combustor is used to reduce NOx emissions. It can be seen that most scholars believe that the future development direction of the heavy gas turbine is to increase the efficiency by changing the system, reducing the temperature and changing the working medium in various ways to create more utilization value [13]. Through data statistics, data sorting, big data analysis and other methods, we will put forward our own ideas on the diversity and development prospects of the future heavy gas turbine [14].

To sum up, we first carried out data statistics, collected and integrated the data and the heavy gas turbines obtained by the scientific research institute, and then classified them. Respectively according to involve different areas of science and the class information in the field of the selection and collection, selected in recent years, the most practical and feasibility of the sample, after distribution are discussed, and data analysis, finally the experimental conclusions, diversity and efficiency of heavy-duty gas turbine with positive views.

2. Development history of heavy duty gas turbine

Heavy-duty gas turbines began to be used in the power industry in the early 1950s. Due to their small capacity and low efficiency, they were only used as emergency backup power sources and peak-shaving units in the power system at that time; the large power grids in Europe and the United States were used in the 1960s [15]. The instantaneous cracking accident has prompted people to realize that a certain number of gas turbine generator sets should be equipped in the power grid; after the 1980s, due to the continuous advancement of related technologies [6, 7], gas turbines and their combined cycles have developed rapidly.

The development of gas turbine power generation technology in my country did not start too late. The design and manufacture of heavy-duty gas turbines began in the late 1950s. From the 1960s to the early 1970s, Shanghai Steam Turbine Factory, Harbin Steam Turbine Factory, Dongfang Turbine Factory and Nanjing Steam Turbine Motor Factory all designed and produced gas turbines on their own [8], which was not far behind the world's leading level. However, due to the adjustment of national energy and economic policies, the market for gas turbines in China shrank severely in the 1980s, and production basically stopped. Since then, the main domestic companies producing heavy-duty gas turbines have been Nanjing Steam Turbine Motor Plant. Figure 1 shows the future development trend of heavy-duty gas turbine technology. It can be seen from the figure that with the increase of time, heavy-duty gas turbine technology has been continuously improved and improved.

Although my country has made great efforts in the theoretical research and industrial practice of heavy-duty gas turbines, due to the influence of many factors such as industrial technology, economic capacity and energy policy, the speed of research and development has been relatively slow. It has not yet formed a strict sense [10].

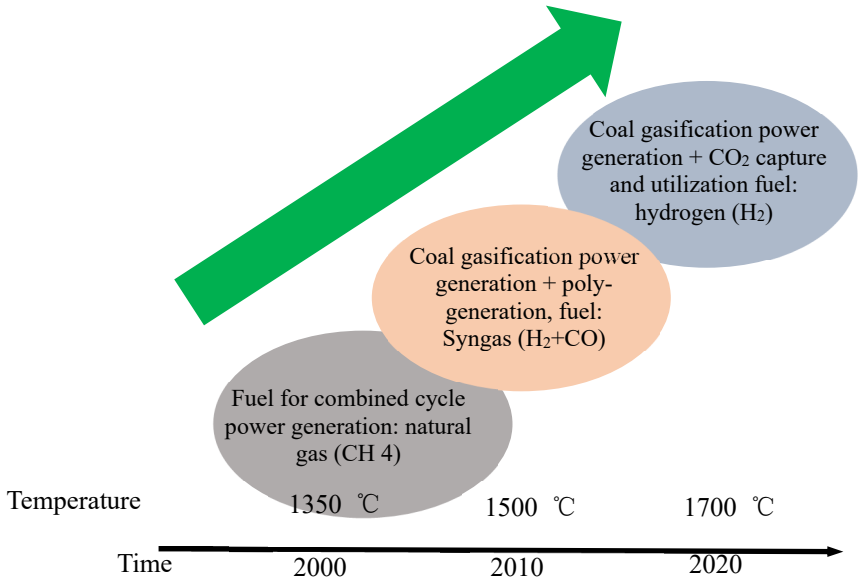

Figure 1. The development trend of heavy-duty gas turbine technology

3. Status and theoretical analysis of heavy duty gas turbine

3.1 Development status of foreign heavy gas turbines

Over the years, countries have never stopped pursuing technological innovation. As a functional heat engine technology, the gas turbine has been studied and applied by countries since its advent. From September 23 to October 23, 1985, Ding Zhenfang and others from the Ninth Design Institute of China Shipbuilding Corporation formed an investigation team to American Aviation Systems

TABLE 1. OVERVIEW OF THE G/H/J CLASS HEAVY DUTY GAS TURBINE PRODUCTS

company	Gas turbine model	Single cycle power/MW	Combined cycle power/MW	Single cycle efficiency/%	Combined cycle efficiency/%	Gas temperature/°C	Pressure ratio	Frequency/Hz
GE	9HA.02	470	701	41.5	61.4	-	21.8	50
Siemens	SGT5-8000H	340	530	40.0	60.0	1550	19.2	50
Mitsubishi	M501G	267	399	38.7	58.0	1500	19.2	60
	M701G	271	-	39.5	58.2	1500	19.0	50
	M701G2	334	498	-	59.3	1500	21.0	50
	M501H	225	330	-	60.0	1500	25.0	60
	M501J	327	470	-	61.5	1600	23.0	60

Engineering Corporation and other places and put forward opinions and improvement schemes on the problems existing in the design of its test bench [16]. The whole commissioning platform includes manufacturing, maintenance, testing and other parts. It can be seen that the United States has already entered the stage of improvement, testing and application in terms of gas turbines. The improvement suggestions put forward by the investigation team will also improve the function of the test platform to a certain extent and provide improvement schemes for its gas turbine test platform [17]. This behavior is undoubtedly helping the development of foreign gas turbines. On the one hand, it shows that countries attach importance to the technological development of gas turbines and are willing to invest funds and talents in this technology. On the other hand, it also shows that countries tend to cooperate with each other to promote the development of gas turbine technology, rather than doing it alone. Table 1 gives an overview of international heavy-duty gas turbine G/H/J-class products.

3.2 Development Status of Domestic Heavy-Duty Gas Turbines

Recently, China made a major breakthrough in researching and developing high-power heavy-duty gas turbines: the quality of the first stage stator blade castings of the 300MW Class F heavy-duty gas turbine kit has been certified and will soon be installed on the 300MW class F heavy-duty gas turbine. This news immediately caused the media at home and abroad. At the same time, the first f-class 50 mw heavy duty gas turbine was successfully fired and operated. These two achievements undoubtedly indicate that China has made a major breakthrough in the development and practical application of gas turbines, which enables China to further lead the technological update in the fields related to gas turbines.

KongJunWen, an expert from a gas-turbine research society，write in his essay that" Micro gas turbine for national defense land is mainly used for tank main and auxiliary power and mobile power supply." His recognition of micro gas-turbine and declaration of how micro gas turbine is used in military shows that gas turbine, in China, is recently used on the military area.

3.3 Theoretical Analysis of Heavy Duty Gas Turbine

3.3.1 Factors that promote its development.

As a technology, the gas turbine development is inseparable from its own powerful functions and incomparable advantages.

(1) Considerable heat efficiency

The gas turbine has been proving to have heat efficiency of 32% to40% in a single cycle and 52% to 60% in the combined cycle, depending on the temperature level of the turbo-machinery process. Comparing with a gasoline engine with 23% to 40% and a diesel engine with 40% to 50%, its heat efficiency is suitable for companies to invest and scientists to inquire.

(2) Great power density

Generally, the volume of a gas turbine with the same power is one third to one fifth of that of a diesel engine and one fifth to one tenth of that of the steam turbine. This is due to the exquisite continuous rotation thermodynamic cycle structure of the gas turbine itself. It has a small volume and large power. It is very suitable for the characteristics of small subdivisions and high speed requirements of warships.

(3) Fast start-up speed

Although the speed of the gas turbine is the highest among the three power systems, due to the lightness of the whole rotor, the maximum speed can be reached in 1-2 minutes with the help of the starter. Because the diesel engine's rotor motion originates from the piston's reciprocating, the acceleration is slow, and the steam turbine is "slow to respond". It may take up to one hour for the whole system to reach the maximum power output. The starting speed directly impacts the acceleration and deceleration performance of warships in wartime and anti submarine operations.

(4) Generate less low-frequency component noise

Because the gas turbine itself rotates at high speed and steadily, the more noise it generates is high-frequency whistling. The reciprocating piston of a diesel engine produces a large amount of low-frequency mechanical vibration noise, which just caters to the sea's easy propagation of low-frequency noise, which makes warships easy to be detected by enemy sonar [13]. Therefore, diesel power is not suitable for the power system of anti-submarine warships, while gas turbines are suitable for the power system of anti-submarine warships.

3.3.2 Factors that act against its development.

(1) large requirement on gas input

Because the gas turbine needs to inhale a lot of fresh air and emit a lot of waste gas at the same time, the use of gas turbines in military ships will cause the smoke exhaust system to occupy a lot of ship space. In short, it needs a larger chimney than a steam turbine, resulting in the spatial and structural limitations of other equipment [16].

(2) Environmental effect

As all fuel engines encounter, the development of dominated type, which burns carbon, of gas turbine takes a great risk on generating a large number of greenhouse gases, such as carbon dioxide, which, in hence, will worsen the greenhouse effect, increasing the global temperature, as several environmental scientists have stated. The development of this technology is and will always be hindered by environmental protectors unless clear energy is used appropriately.

(3) Surge

The surge occurred because the combustion was not carried out in the combustion chamber. If the gas flow rate in the gas turbine is too fast, fire on the burner will extinct, and the combustion will be carried out between the high-pressure turbine and the low-pressure turbine. As a result, the rotating speed of the gas turbine decreases, the combustion returns to normal, and the rotating speed returns to normal. In this way, the gas flow rate is too fast, so that the burner is de ignited and the combustion is carried out between the high-pressure turbine and the low-pressure turbine [7]. The speed of the gas turbine decreases, and the combustion returns to normal due to the decrease of the speed of the gas turbine. The repeated return of the speed to normal is called a surge.

3.3.3 Its roles in our life.

As the most conventional sorting, a gas turbine is sorted in both structures, the heavy and the light, and power, large, middle, small and micro. It is used as drives of planes and tanks. Even though the heavy type gas turbine is no longer used in planes in China due to its high weight, light type gas turbines are still used on planes and helicopters. A gas turbine currently drives several mechanics, either for military and or civilian [15].

4. Development trend and market change

4.1 The Development Trend

With the continuous development of gas turbine technology, the increasing change of energy structure and the continuous improvement of environmental protection requirements, the application of heavy gas turbines in the power industry will continue to accelerate. Heavy gas turbine power generation will also occupy a more important position in the power structure, and its development prospects are broad. It can be predicted that the heavy-duty gas turbine will continue to develop in the direction of large capacity and high parameters, which is embodied as follows: (1) The thermal efficiency of the cycle can be improved by further improving the gas turbine parameters; (2) To further reduce pollutant emission while enhancing fuel adaptability; ③ Research and development of a new generation of high temperature resistant materials; (4) Further improve the performance of the compressor and other main components; Experts predict that the maximum intake temperature of future gas turbines can reach 1700 °C and the combined cycle efficiency can reach about 65%.

From the law of the development of the whole human society and the existing social reality, clean energy will occupy an increasingly important proportion in the future society. Increased demand for natural gas power plants, increased demand for electricity, reduced carbon dioxide emissions, and the availability of efficient power technologies are driving the gas turbine market. The supply of natural gas is the main factor restricting the development of gas turbine power stations. To break this restrictive factor, countries around the world are introducing new policies. For example, China has taken a lot of measures -- the development of shale gas in the 12th Five-Year Plan. Therefore, the gas turbine power station has great development space with the wide application of clean energy. The economic applicability of gas turbines will affect the development of power stations in a large direction. At the same time, the national fuel supply policy and the diversification of energy demand will promote the development of gas turbine power stations in a small direction.

4.2 Market Change

The global Gas Turbines Market is expected to grow from an estimated $17.51 billion in 2017 to $20.66 billion by 2022, at a CAGR of 3.36%, from 2017 to 2022. The shale gas boom in North America and decommissioning of nuclear plants in Europe will likely boost the demand for gas turbines in these regions. The demand for gas turbines in the Middle East & Africa, Latin America, and the Asia Pacific is expected to be influenced by the new gas-fired power plants and the upgrade of old existing thermal power plants in the regions.

The increasing demand for natural gas-fired power plants, rising demand for electricity, reduction in carbon dioxide emissions, and availability of efficient power technology are driving the gas turbines market. Natural gas is the cleanliest source of fossil fuel used to support intermittent generation from renewable sources. Thus, an increase in the demand for natural gas power plants is expected as governments implement strict norms for the emission of carbon dioxide.

The power generation application segment is expected to be the fastest growing segment during the forecast period. The electricity demand is growing due to urbanization and industrialization. Gas turbines are used in the open cycle and combined cycle plants. Combined cycle power plants are more efficient than steam turbines as they generate more power. Gas turbines are used in utilities for base load standby power and peak load applications.

The Asia-Pacific region is currently the largest market for gas turbines, followed by Europe and North America. Japan accounted for a majority share in Asia-Pacific, while China is projected to grow at the highest CAGR from 2017 to 2022. The slowdown in the nuclear power industry due to the Fukushima incident and continuing replacement of nuclear & aging coal plants with gas-fired ones would continue to drive the Japanese gas turbines market. In developing countries such as China and India, factors such as strong growth in demand for electricity fuelled by high levels of urbanization, industrialization, and infrastructural developments and subsequent investments in developing new large-gas fired combined cycle power generation, apart from other power plants, would spur the demand for gas turbines.

5. Conclusion

Heavy duty gas turbine has broad market application prospect and development space due to its many advantages. It will continue to develop in the direction of large capacity and high parameter in the future. Gas turbine gathers the latest achievements in the field of human engineering technology and is an important symbol representing the level of science and technology and industry of a country. As a major power equipment integrating design, material, manufacturing, and other high-end technologies, the gas turbine has many applications. It is not only an extremely critical equipment in national defense equipment but also plays an irreplaceable strategic position and role in the fields of the national economy, such as power, energy exploitation and transmission, and distributed energy system. At the same time, it also plays an important role in national energy strategy, energy security and environmental protection. Therefore, it is very important to study the heavy duty gas turbine.

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