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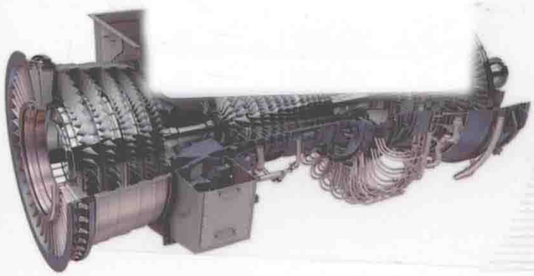

燃气轮机专业英语

主　编　杨家龙
副主编　赵宁波

哈尔滨工程大学出版社
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内容简介

本书以英文方式通俗地介绍了燃气轮机的专业入门知识，使读者能够学习和掌握燃气轮机知识的英文表达方式。本书面向大学燃气轮机专业方向的本科高年级学生和从业技术人员，使其通过对专业英语的阅读，培养提高燃气轮机专业英语阅读、理解能力和初级写作水平。因此，本书在内容上尽量通俗但不乏专业性地系统介绍燃气轮机的特点、原理、组成、结构、功能、应用和环保等方面的基本内容。

本书共13课，第1课至第5课依次着重介绍燃气轮机的工作原理、特点、结构组成、循环及布局方式，第6课至第13课介绍燃气轮机在各领域的应用、设计和对环境影响等方面的知识，目的是使读者阅读后对燃气轮机技术及应用有大致、全面的了解。

本书可作为燃气轮机专业学生在专业英语方面的教材，也可以作为相关专业技术人员的参考用书。

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前　言

能源、资源、环境和安全的挑战性时代的到来,对动力装置提出了更高的要求。燃气轮机以其单机功率大、体积小、质量轻、环境友好、操作维护简单、保养方便和工作可靠等优点受到了各国的重视。特别是在一些技术发达国家得到了广泛的应用,包括航空、船舶、发电、石油化工、天然气输送和区域供暖等。在此背景下,为了加强哈尔滨工程大学能源与动力工程专业领域燃气轮机专业方向本科生教材的建设,提高该专业方向学生专业英语能力,培养高素质的燃气轮机工程人才,弥补燃气轮机专业英语课程教材的匮乏(国内目前尚无此专业的英语阅读教材),体现我国燃气轮机事业大发展时代的特色,特编写本教材。

本教材编写以由浅入深、由通俗到专业的方式展开,突出重点,内容充实,符合教育者和阅读者的思维规律,体现了通过不同语言和表达方式理解、掌握专业知识的指导思想。

本书在内容上尽量系统地用英文原文,通俗但不乏专业性地介绍燃气轮机的特点、原理、组成、结构、功能、应用和环保等方面的基本内容,以增强学生的感性认识,提高教学效果。

本书由杨家龙副教授主编,第6课、第7课和第8课赵宁波副教授参编。

本书由哈尔滨工程大学郑群教授审阅,并提出了许多宝贵意见,在此表示感谢。同时感谢贾雄斌博士和郭宏伯博士在编写、校对过程中给与的大量帮助。因编者水平有限,不妥之处在所难免,欢迎提出宝贵意见。

编　者

2018年8月

目　　录

Lesson 1 How Does a Gas Turbine Work
燃气轮机是如何工作的

1.1 Text

Of the various means of producing mechanical power the turbine is in many respects the most satisfactory. The absence of reciprocating and rubbing members means that balancing problems are few, that the lubricating oil consumption is exceptionally low, and that reliability can be high. The inherent advantages of the turbine were first realized using water as the working fluid, and hydroelectric power is still a significant contributor to the world's energy resources. Around the turn or the twentieth century the steam turbine began its career and it has become the most important prime mover for electricity generation. Steam turbine plants producing well over 1,000 MW of shaft power with an efficiency of 40 percent are now being used. Steam turbines were widely used in marine applications, but could not compete with the thermal efficiency of the diesel engine when fuel costs became important in the mid 1970s; they are still used, however, in nuclear-powered aircraft carriers and submarines. In spite of its successful development, the steam turbine does have an inherent disadvantage. It is that the production of high-pressure high-temperature steam involves the installation of bulky and expensive steam generating equipment, whether it be a conventional boiler or nuclear reactor. The significant feature is that the hot gases produced in the boiler furnace or reactor core never reach the turbine; they are merely used indirectly to produce an intermediate fluid, namely steam. A much more compact power plant results when the water to steam step is eliminated and the hot gases themselves are used to drive the turbine. Serious development of the gas turbine began not long before the Second World War with shaft power in mind, but attention was soon transferred to the turbojet engine for aircraft propulsion. The gas turbine began to compete successfully in other fields only in the mid 1950s, but since then it has made a progressively greater impact in an increasing variety of applications.

In order to produce an expansion through a turbine a pressure ratio must be provided and the first necessary step in the cycle of a gas turbine plant must therefore be compression of the working fluid. If after compression the working fluid were to be expanded directly in the turbine, and there were no losses in either component, the power developed by the turbine would just equal that absorbed by the compressor. Thus if the two were coupled together the combination would do no more than turn itself round. But the power developed by the turbine can be increased by the addition of energy to raise the temperature of the working fluid prior to expansion. When the working fluid is air a very suitable means of doing this is by combustion of fuel in the air which has been compressed. Expansion or the hot working fluid then produces a greater power output from the turbine, so that it is able to provide a useful output in addition to driving the compressor. This represents the gas turbine or internal-combust ion turbine in its simplest form. The three main components are a compressor, combustion chamber and turbine, connected together as shown diagrammatically in Fig. 1-1.

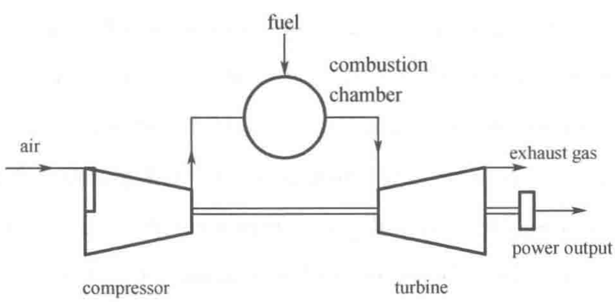

Fig. 1-1 Single gas turbine system

In practice, losses occur in both the compressor and turbine which increase the power absorbed by the compressor and decrease the power output of the turbine. A certain addition to the energy of the working fluid, and hence a certain fuel supply, will therefore be required before the one component can drive the other. This fuel produces no useful power, so that the component losses contribute to a lowering of the efficiency of the machine. Further addition of fuel will result in a useful power output, although for a given flow of air there is a limit to the rate at which fuel can be supplied and therefore to the net power output. The maximum fuel/air ratio that may be used is governed by the working temperature of the highly stressed turbine blades, which temperature must not be allowed to exceed a certain critical value. This value depends upon the creep strength of the materials used in the construction of the turbine and the working life required.

These then are the two main factors affecting the performance of gas turbines: component efficiencies and turbine working temperature. The higher they can be made, the better the all-round performance of the plant. It was, in fact, low efficiencies and poor turbine materials which brought about the failure of a number of early attempts to construct a gas turbine engine. For example, in 1904 two French engineers, Armengaud and Lemale, built a unit which did little more than turn itself over: the compressor efficiency was probably no more than 60 percent and the maximum gas temperature that could be used was about 740 K.

It will be shown in Lesson 2 that the overall efficiency of the gas turbine cycle depends primarily upon the pressure ratio of the compressor. The difficulty of obtaining a sufficiently high pressure ratio with an adequate compressor efficiency was not resolved until the science of aerodynamics could be applied to the problem. The development of the gas turbine has gone hand in hand with the development of this science, and that of metallurgy, with the result that it is now possible to find advanced engines using pressure ratios of up to 35 : 1, component efficiencies of 83 – 90 percent, and turbine inlet temperatures exceeding 1,650 K.

In the earliest days of the gas turbine, two possible systems of combustion were proposed: one at constant pressure, the other at constant volume. Theoretically, the thermal efficiency or the constant volume cycle is higher than that of the constant pressure cycle, but the mechanical difficulties are very much greater. With heat addition at constant volume, valves are necessary to isolate the combustion chamber from the compressor and turbine. Combustion is therefore intermittent, which impairs the smooth running of the machine. It is difficult to design a turbine to operate efficiently under such conditions, although several fairly successful attempts were made in Germany during the period 1908 – 1930 to construct gas turbines operating on this system, the development of the constant volume type has been discontinued. In the constant pressure gas turbine, combustion is a continuous process in which valves are unnecessary and it is soon accepted that the constant pressure cycle had the greater possibilities for future development. A key advantage of the constant pressure system was its ability to handle high mass flows, which in turn lead to high power.

It is important to realize that in the gas turbine the processes of compression, combustion and expansion do not occur in a single component as they do in a reciprocating engine. They occur in components which are separate in the sense that they can be designed, tested and developed individually, and these components can be linked together to form a gas turbine unit in a variety of ways. The possible number of components is not limited to the three already mentioned. Other compressors and turbines can be added, with intercoolers between the compressors, and reheat combustion chambers between the turbines. A heat-exchanger which uses some of the energy in the turbine exhaust gas to preheat the air entering the combustion chamber may also be introduced. These refinements may be used to increase the power output and efficiency of the plant at the expense of added complexity, weight and cost. The way in which these components are linked together not only affects the maximum overall thermal efficiency, but also the variation of efficiency with power output and of output torque with rotational speed. One arrangement may be suitable for driving an alternator under varying load at constant speed, while another may be more suitable for driving a ship's propeller where the power varies as the cube of the speed.

Apart from variations of the simple cycle obtained by the addition of these other components, consideration must be given to two systems distinguished by the use of open and closed cycles. In the almost universally used open-cycle gas turbine which has been considered up to this point, fresh atmospheric air is drawn into the circuit continuously and energy is added by the combustion of fuel in the working fluid itself. The products or combustion are expanded through the turbine and exhausted to the atmosphere. In the alternative, and rarely used, closed cycle shown in Fig. 1 – 2 the same working fluid, be it air or some other gas, is repeatedly circulated through the machine. Clearly in this type of plant the fuel cannot be burnt in the working fluid and the necessary energy must be added in a heater or "gas-boiler" wherein the fuel is burnt in a separate air stream supplied by an auxiliary fan. The closed cycle is more akin to that of steam turbine plant in that the combustion gases does not itself pass through the turbine. In the gas turbine the "condenser" takes the form of a pre-cooler for cooling of the gas before it re-enters the compressor. Although little used, numerous advantages are claimed for the closed cycle.

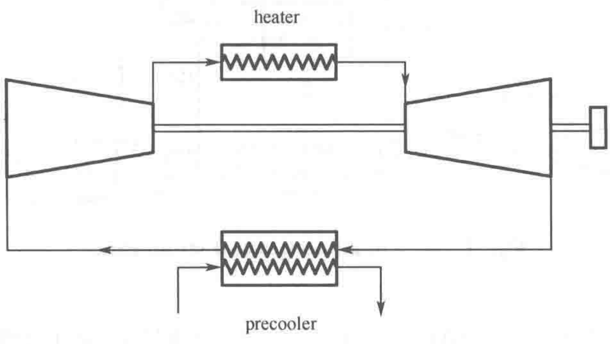

Fig. 1 – 2 Simple closed cycle

Finally, various combined gas and steam cycles are now widely used for electric power generation, with thermal efficiencies approaching 60 percent. The gas turbine exhaust, typically at a temperature of 500 – 600 ℃, is used to raise steam in a waste heat boiler (WHB) or heat recovery steam generator (HRSG); this steam is then used in a steam turbine which drives a generator. Fig. 1 – 3 shows such a system, using a dual-pressure steam cycle. With increasing cycle temperatures the exhaust gas entering the HRSG is hot enough to permit the use of a triple-pressure steam cycle incorporating a stage of reheat, and this is becoming common in large base-load power stations. It should be noted that the turbine exhaust has an unused oxygen content and it is possible to burn additional fuel in the boiler to raise steam output; this supplementary firing is most likely to be used with gas turbines operating at a relatively low exhaust gas temperature. The steam produced may be used in a process such as paper drying, brewing or building heating as well as producing electricity, and this is referred to as cogeneration or combined heat and power (CHP). Although the characteristic compactness of the gas turbine is sacrificed in binary cycle plant, the efficiency is so much higher than obtainable with the simple cycle that such turbines are now widely used for large-scale electricity generating stations.

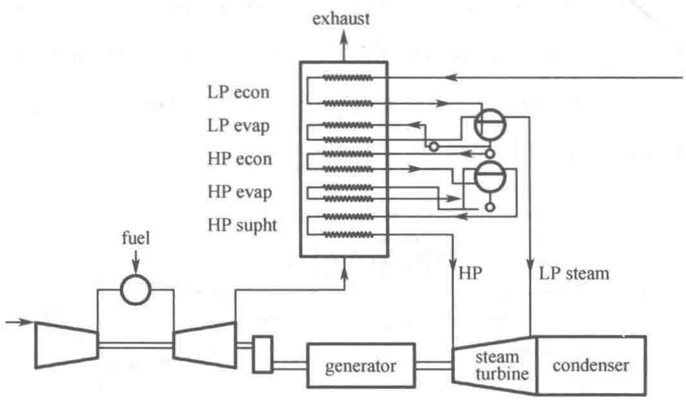

Fig. 1-3 Combined gas and steam cycle

The gas turbine has proved itself to be an extremely versatile prime mover, and has been used for a wide variety of functions, ranging from electric power generation, mechanical drive systems and jet propulsion to the supply of process heat and compressed air. The remainder of this introduction is intended to emphasize the wide range of applications. We commence, however, by discussing the various ways in which the components can be linked together to produce shaft power. Gas turbines for electric power generation pump drives for gas or liquid pipelines and land and sea transport will be considered before turning our attention to aircraft propulsion. The vast majority of land-based gas turbines are in use for the first two of these, and applications to land and sea transport are still in their infancy, although the gas turbine has been widely used in naval applications since the 1970s.

1.2 New words and expessions in text

reciprocating	往复的
installation	安装,安置
compact	小型的,紧凑的;把……压紧;契约,协议
eliminate	去除,排除,淘汰
pressure ratio	压比
component	组成,成分,组件,元件
prior to	优先于,比……重要
internal-combustion	内部燃烧的
combustion chamber	燃烧室
net power output	净输出功率
govern	管理,支配
turbine blade	涡轮叶片
exceed	超过
certain critical value	临界值
creep strength	疲劳强度
performance	表现,性能,状态
aerodynamic	空气动力学的
metallurgy	冶金学
reheat combustion chamber	再热燃烧室
exhaust	排气,耗尽,使精疲力竭
refinement	精炼,提炼,改进
variation	变化
alternator	交流发电机

1.3 Paraphrase of difficult sentences

1. Steam turbine plants producing well over 1,000 MW of shaft power with an efficiency of 40 percent are now being used. Steam turbines were widely used in marine applications, but could not compete with the thermal efficiency of the diesel engine when fuel costs became important in the mid 1970s; they are still used, however, in nuclear-powered aircraft carriers and submarines.

目前正在使用的由汽轮机厂生产的汽轮机发电效率达 40%，轴功率在 1 000 MW 以上。汽轮机广泛应用于船舶，但于 1970 年代中期燃料成本变得重要时，其无法与柴油发动机的热效率相媲美；然而，它们仍被用于核动力航空母舰和潜艇上。

2. It is that the production of high-pressure high-temperature steam involves the installation of bulky and expensive steam generating equipment, whether it be a conventional boiler or nuclear reactor.

无论是常规锅炉还是核反应堆，高压高温蒸汽的生产需要安装体积大、价格昂贵的蒸汽发生装置。

3. Serious development of the gas turbine began not long before the Second World War with shaft power in mind, but attention was soon transferred to the turbojet engine for aircraft propulsion.

燃气轮机的快速发展在第二次世界大战之前就开始了，当时人们还在考虑使用轴动力，但很快就把注意力转移到了用于飞机动力装置的涡轮喷气发动机上。

4. The maximum fuel/air ratio that may be used is governed by the working temperature of the highly stressed turbine blades, which temperature must not be allowed to exceed a certain critical value.

可使用的最大燃料/空气比取决于受最大应力的涡轮叶片的工作温度，其温度不得超过某一临界值。

5. In the earliest days of the gas turbine, two possible systems of combustion

were proposed: one at constant pressure, the other at constant volume. Theoretically, the thermal efficiency of the constant volume cycle is higher than that of the constant pressure cycle, but the mechanical difficulties are very much greater.

在燃气轮机发展早期,提出了两种可能的燃烧系统:恒压燃烧和恒容燃烧。理论上,恒容循环比恒压循环热效率高,但机械(制造)困难却大得多。

6. Combustion is therefore intermittent, which impairs the smooth running of the machine.

因此,燃烧是间歇性的,这会破坏机器的平稳运行。

7. They occur in components which are separate in the sense that they can be designed, tested and developed individually, and these components can be linked together to form a gas turbine unit in a variety of ways.

它们发生在分离的组件中,即它们可以单独设计、测试和开发,这些组件可以多种方式连接在一起,形成一个燃气轮机整体。

8. Other compressors and turbines can be added, with intercoolers between the compressors, and reheat combustion chambers between the turbines. A heat-exchanger which uses some of the energy in the turbine exhaust gas to preheat the air entering the combustion chamber may also be introduced.

还可以添加其他压气机和涡轮机,在压气机之间加上中间冷却器,在涡轮之间增加再热燃烧室。还可以引入一种热交换器,它利用涡轮废气中的一些能量来预热进入燃烧室的空气。

9. One arrangement may be suitable for driving an alternator under varying load at constant speed, while another may be more suitable for driving a ship's propeller where the power varies as the cube of the speed.

一种布置可能适合用于在恒速变负荷情况下驱动交流发电机,而另一种布置可能更适合用于在功率随速度的立方变化的情况下驱动船舶的螺旋桨。

10. It should be noted that the turbine exhaust has an unused oxygen content and it is possible to burn additional fuel in the boiler to raise steam output; this supplementary firing is most likely to be used with gas turbines operating at a relatively low exhaust gas temperature.

应该指出的是,涡轮机的废气中含有未燃烧的氧气,有可能在锅炉内燃烧额外的燃料提高蒸汽输出量;这种辅助燃烧最有可能用于在相对较低的废气温度下工作的燃气轮机。

Lesson 2 Components
组成部件

2.1 Text

2.1.1 Compressors

Compressors are either the axial design (with up to 19 stages) or the centrifugal design (with one or two impellers). In the axial compressor designs, beam and cantilever style stator vanes are utilized. Cantilever style stator vanes are used in compressors where stage loading is relatively light. Compressor pressure ratios have increased significantly over the past forty years with the aero-derivative consistently leading the way to higher levels. Pressure ratios, which were 5:1 at the start of World War II have increased to 12:1 for the newer industrial gas turbines. Through the use of increased stage loading (variable geometry and dual-spool techniques), compressor pressure ratios of most recent aero-derivatives have been increased to greater than 30:1. This advancement in the state of the art is a prime contributor in the overall increase in simple-cycle thermal efficiency to 35% for aero-derivative gas turbines. To achieve similar efficiencies the industrial gas turbines have had to use regenerators and other forms of waste heat recovery.

Courtesy of General Electric Company. Fig. 2-1 shows the LM2500 stationary gas turbine was derived from the CF6 "high bypass ratio" flight engine that powered the C5A, the largest military cargo aircraft built in the USA. The LM2500 is ISO base load rated at 23 megawatts. This cross section of the LM2500 includes the six stage power turbine. This power turbine was derived from the six stage fan-turbine used in a CF6 flight engine. Fig. 2 – 2 shows the sketch of a single spool gas twbine.

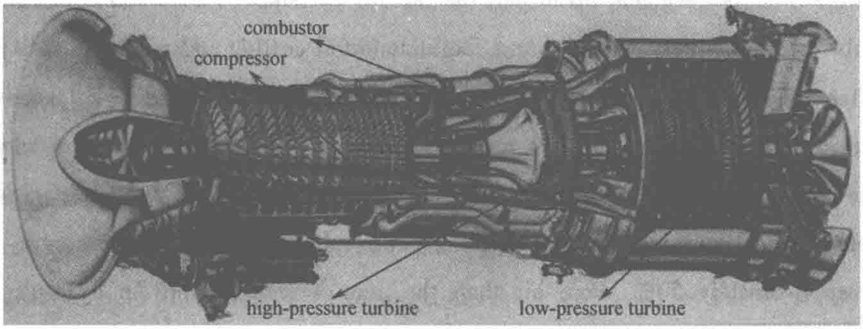

Fig. 2 – 1 The LM2500 stationary gas turbine

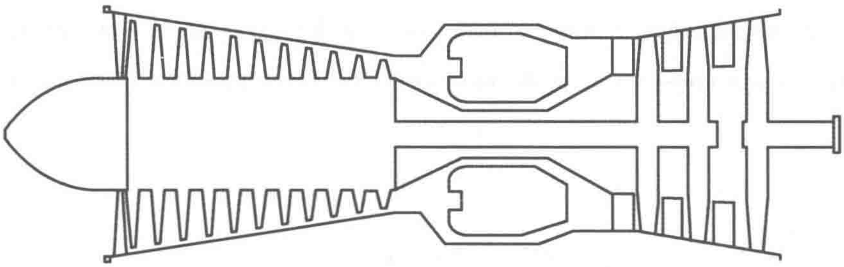

Fig. 2 – 2 Sketch of a single spool gas turbine

2.1.2 Turbines

Turbine nozzle and blade design was, and still is, a function of the performance match between the turbine and the compressor, and the strength and temperature resistance of available materials. Present production gas turbines (aero-derivative, heavy industrial, and hybrids) use an impulse-reaction turbine design. Turbine blade designs in the aero-derivative unit use high aspect ratio blades incorporating tip shrouds to dampen vibration and improve blade tip sealing characteristics. The heavy industrial machine incorporates a low aspect ratio (short, thick) blade with no shroud. Where long thin airfoils have been used, lacing wire has been removed.

Improvements in metallurgy and casting techniques have allowed designers to eliminate mid-span shrouds and lacing wires. On many units, aero-derivative, hybrid,