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Electric Locomotive Structure

电力机车构造

主　编　党建猛　张　嘉
副主编　李长留　高　伟

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主　编　党建猛　张　嘉

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PREFACE

“Electric locomotive structure” is the professional core course of railway locomotive major. It is the door stone for railway locomotive major students to learn professional knowledge and skills. It aims to enabling students to master the basic structure and function of electric locomotive machinery department.

This textbook is based on the Addis Ababa Djibouti railway electric locomotive driver training project. According to the operation and maintenance needs of Addis Ababa Djibouti railway drivers, AC drive HX_D1C electric locomotive is selected as the main learning object of the textbook. A large number of pictures are applied, which makes the contents easy to understand and to learn.

Based on the driver’s working environment and ability orientation, this textbook arranges typical tasks, focus on the practical application close to the locomotive production site, and highlight the cultivation of driver’s post ability, so that students can master the structural name and action principle of the mechanical part of electric locomotive.

This book is edited by Dang Jianmeng,Zhang Jia,Li Changliu and Gao Wei of Zhengzhou Railway Vocational and technical college. Dang Jianmeng edits Project 5,6 and 7 and is responsible for final compilation; Zhang Jia edits Project 2,3 and 4; Li Changliu edits Project 8; and Gao Wei edits Project 1.

However, limited by time and knowledge, there are inevitable omissions and inadequacies in the book. Please oblige us with your valuable comments.

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Project 1

Types of Locomotives

[Project Overview]

The project is divided into two parts: introduction of locomotives and main types of locomotives. This paper introduces the main functional characteristics of locomotive and the types of locomotive development process.

[Ability Aims]

(1) Be able to briefly describe the overall characteristics of the locomotive and summarize its main functions.

(2) Be able to tell the overall development process of locomotives and the main characteristics of each locomotive.

Task 1 Introduction to Locomotive

[Mission and Introduction]

Through the study of this project, understand the basic concept and main functional characteristics of locomotive, and use information means to learn the new trends of locomotive development and understand the new technology of locomotive development.

[Guidance Problem]

(1) What locomotive? What are the important applications of locomotives in life?

(2) What are the advantages and disadvantages of locomotive compared with other means of transportation?

[Lesson Preparation]

(1) Carefully read the contents about locomotive in the task knowledge material, and mark the important contents in the text. (10 minutes)

(2) According to their own understanding, summarize the main characteristics of steam locomotive, diesel locomotive and electric locomotive. (10 minutes)

[Text]

A locomotive is a railway vehicle that provides the motive power for a train, and has no payload capacity of its own; its sole purpose is to move the train along the tracks. Many trains feature self-propelled payload-carrying vehicles; these are not normally considered locomotives, and may be referred to as multiple units or railcars; the use of these self-propelled vehicles is increasingly common for passenger trains, but very rare for freight. Vehicles which provide the motive power to haul an unpowered train, but are not generally considered locomotives because they have payload space or are rarely detached from their trains, are known as power cars.

Traditionally, locomotives haul their trains. Increasingly common these days in passenger service is push-pull operation, where the locomotives push the trains in one direction, and are controlled from a control cab at the opposite end of the train in the other.

Benefits of Locomotives:

There are many reasons why the motive power for trains has been-traditionally isolated in-a-locomotive, rather than in self-propelled vehicles. These include:

(1) Ease of maintenance–it is easier to maintain one locomotive than many self-propelled cars.

(2) Safety–it is often safer to locate the train's power systems away from passengers. This was particularly the case for the steam locomotive, but still has some relevance.

(3) Easy replacement of motive power–should the locomotive break down, it is easy to-replace it with a new one. Failure of the motive power Unit does not require taking the whole train out of service.

(4) Efficiency–idle trains do not waste expensive motive power resources, Separate locomotives-mean that the costly motive power assets can be moved around as needed.

(5) Obsolescence cycles–separating the motive power from the payload-hauling cars-means-that-either can be replaced without affecting the other. At some times, locomotives have become obsolete when their cars are not, vice versa.

Task 2 Types of Locomotives

[Guidance Problem]

(1) Who invented the world's first steam locomotive? Can you try to describe the development of locomotives in the world?

(2) In addition to locomotive traction, what are the characteristics of rail transit transportation modes?

(3) What is the main line of locomotive technology development? What new technologies have emerged?

[Lesson Preparation]

(1) Carefully read all the contents about the development history of world locomotives in the knowledge material of this task, and mark the important contents in the text. (10 minutes)

(2) The development process of group production of locomotive manual newspaper requires novel layout and creative content. (15 minutes)

(3) According to their own understanding, summarize the main characteristics of steam locomotive, diesel locomotive and electric locomotive. (10 minutes)

[Text]

The three main categories of locomotives are often subdivided in their usage in rail transport operations. There are passenger locomotives, freight locomotives and switcher (or shunter) locomotives. These categories mainly depend on maneuverability, traction power and speed. Some locomotives are designed to work in mountain railways.

Locomotives may generate mechanical work from fuel, or they may take power from an outside source. It is common to classify locomotives by their-means of providing motive-work–the common ones include: steam locomotives, diesel-mechanical locomotives, diesel electric locomotives, diesel-hydraulic locomotives, gas turbine locomotives, electric locomotives, electro-diesel locomotives, magnetic levitation locomotives.

1. Steam Locomotives

The first railway locomotives (19th century) were powered by steam which is shown in Fig.1-1, first by burning-wood, later coal or oil. Because of the steam engine, some people took to calling the steam locomotives themselves “steam engines”. The steam locomotive remained by far the most-common type of locomotive until after World War Ⅱ. The age of steam correlates highly to the coal era.

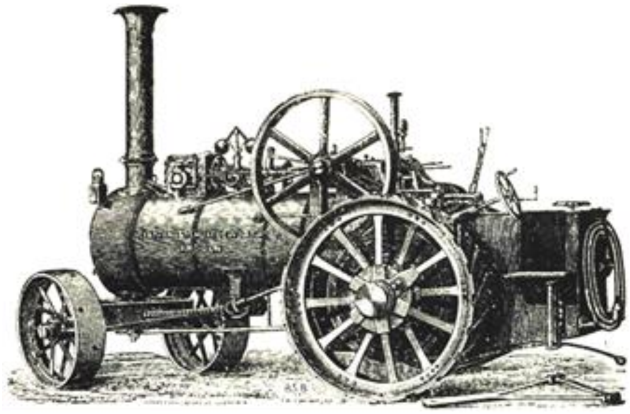

Fig.1-1 The earliest steam locomotive

The first steam locomotive was built by Richard Trevithick, and first ran on 21 February 1804, although it took some years before steam locomotive design became efficient and economically practical. Fairy Queen, built in 1855, plying between New Delhi and Alwar in India, is the longest running steam locomotive in regular service in the world, but John Ball, built in 1831, is currently the oldest operable steam locomotive. John Bull is preserved in mostly static display at the Smithsonian Institution in Washington, DC.

The all-time speed record for steam trains is held by an LNER Class A44-6-2 Pacific locomotive of the LNER in England, number 4,468 Mallard, which pulling six carriage (plus a dynamometer car) reached 203 km/h on a slight downhill gradient down-Stoke Bank. Aerodynamic passenger locomotives from other countries such as Germany and the United States attained speeds very close to this, and this is generally believed to be close to the practicable upper limit for the direct-coupled steam locomotive.

Before the middle of the 20th century, electric and diesel-electric locomotives began replacing steam locomotives. Steam locomotives are less efficient than their more modern diesel and electric counterparts and requite much greater manpower to operate and provide service. British Rail figures showed the cost of crewing and fueling a steam locomotive was some two and a half times that of diesel power, and the daily mileage achievable was far lower. As labour costs rose, particularly after the second world war, non-steam technologies became-much more cost efficient. By the end of the 1960s–1970s, most western countries had completely replaced steam locomotives in commercial service. Freight locomotives generally were replaced later. Other designs, such as locomotives powered by gas turbines, have been experimented with, but seen little use.

By the end of the 20th century, almost the only steam power still in regular use in North-America and Western European countries was on railroads specifically aimed at tourists and/or railroad enthusiasts, known as railfans or train spotters, although some narrow-gauge lines in Germany which form part of the public transport system, running to all-year-round timetables retain steam for all or part of their motive power. Steam locomotives remained in commercial use in parts of Mexico into the late 1970s.India has switched in the last decade from-seam-powered trains to electric and diesel-powered trains. In some mountainous and high-altitude rail lines, steam engines remain in use because they are less affected by reduced air pressure than diesel engines.

2. Diesel-Mechanical Locomotives

Diesel locomotives vary in the form of transmission used to convey the power from a diesel engine (or engines) to the wheels. The simplest form of transmission is by means of a gearbox, in the same way as on road vehicles. Diesel trains or locomotives that use this are called diesel-mechanical and began to appear (although limited in power) even before the first world war which saw a number of simplex diesel systems built for the war, a small number of which survive and are still operational today.

It has, however, been found impractical to build a gearbox which can cope with a power output of more than 300 kW without breaking, despite a number of attempts to do so. Therefore, this type of transmission is only suitable for low-powered shunting locomotives, or lightweight multiple Units or railcars.

For more powerful locomotives other types of transmission have to be used.

3. Diesel-Electric Locomotives

The most common form of transmission is electric; a locomotive using electric transmission is known as a diesel-electric locomotive. With this system, the diesel engine drives a generator or alternator; the electrical power produced then drives the wheels using electric motors. In fact, such a locomotive is an electric locomotive which carries its own generating station along with it.

Early diesel-electrics were switching engines used to move rail cars around in rail yanks: the first went into service in 1924.A decade later, the technology first began to be applied to regular rail service as streamliners went into service. Actually, a gasoline-electric system powered the first such train, but diesel-electric systems soon proved to be more cost-effective–because of higher efficiency and lower maintenance costs.

4. Diesel-Hydraulic Locomotives

In the US and Canada, they are now greatly outnumbered by diesel-electric locomotives, while they remain dominant alternatively, diesel-hydraulic locomotives use hydraulic transmission to convey the power from the diesel engine to the wheels. On this type of locomotive, the power is transmitted to the wheels by means of a device called a torque converter. A torque converter consists of three main parts, two of which rotate, and one which is fixed. All three main parts are sealed in a housing filled with oil. Many diesel-hydraulic multiple Units also have a “fluid flywheel” which acts as a “second gear” for running at higher speeds.

The inner rotating part of a torque converter is called a centrifugal pump (or impeller) the outer part is called a turbine wheel (or driven wheel), and between them is a fixed guide–wheel. All of these parts have specially shaped blades to control the flow of oil.

The centrifugal pump is connected directly to the diesel engine, and the turbine wheel is connected to an axle, which drives the wheels.

As the diesel engine rotates the centrifugal pump, oil is forced outwards at high pressure. The oil is forced through the blades of the fixed guide wheel and then through the blades of the turbine wheel, which causes it to rotate and thus turn the axle and the wheels. The oil is then pumped around the circuit again and again.

Diesel-hydraulic locomotives are slightly more efficient than diesel-electrics, but were found in many countries to be mechanically more complicated and more likely to break down. In Germany, however, diesel-hydraulic systems achieved extremely high reliability in operation.

5. Gas Turbine Locomotives

Locomotives powered by gas turbines were developed in many countries in the decades after World War Ⅱ. These used jot-type engines (similar to the turboshaft engines in a turbine helicopter) driving an output shaft. The normal method of transmitting power to the wheels involved an electrical transmission similar to a diesel-electric locomotive–the turbines running at constant speed driving a generator, feeding to large electric motors driving the wheels.

Gas turbine locomotives are very powerful, but also very noisy (they sounded rather like a jet aircraft). Union Pacific operated the largest feet of turbine locomotives and used them extensively, at one point claiming that the turbines hauled 10% of the railroad’s freight. Their efficiency was quite low, but this was initially not a problem; fuel was cheap, and Union Pacific’s gas turbines were fueled with cheap “Bunker C” heavy oil. This cheap fuel source vanished when improved refinery techniques allowed it to be “cracked” into lighter petroleum grades. After the oil crisis in the 1970s and the rise in fuel costs, gas turbine locomotives became uneconomic to run, and many were taken out of service.

6. Electric Locomotives

The electric locomotive is supplied externally with electric power, either through an overhead pickup or through a third-rail. While the cost of electrifying track is rather high, electric trains and locomotives are significantly cheaper to run than diesel ones, and are capable of superior acceleration as well as regenerative braking, making them ideal for passenger service in densely populated areas. Almost all high-speed train systems (e.g. ICE, TGV, ballet train) use electric power, because the power needed for such performance is not easily carried on board. For example, the most powerful electric locomotives that are used today on the channel tunnel freight services use 7MW of power.

The first known electric locomotive was built by a Scotsman, Robert Davidson of Aberdeen in 1837 and was powered by galvanic cells.

Modern electric locomotives range from small battery-powered machines for use in mines–to large main-line locomotives of 6,000 4.5 MW or more.

In reality most modern locomotives are electrically driven. Pure electric locomotives take their electrical supply from an external source while diesel-electric locomotives carry their own generating station.

Main line electric locomotives first appeared at the beginning of the 20th century. The reason for their introduction was the problem of smoke, especially in tunnels caused by steam locomotives. In the UK it was the London underground system, while in the USA it was under river tunnels, of which was required to eliminate smoke in built up areas.

Early electric locomotives all relied on external power sourcing. Once up and running they tend to be reliable and efficient, but the supply infrastructure is a large capital expense that does require ongoing maintenance. For this reason only heavily used lines could justify electrification. For suburban lines the reduction in pollution from steam locomotives was a benefit which all were aware of.

The world speed record for a wheeled train was set in 1990 by a French TGV which reached a speed of 515.3 km/h.

While recently designed electrified railway systems invariably operate on alternating current, many existing direct current systems are still in use–e.g. in South Africa, Spain and the United Kingdom (750 V and 1500 V); Netherlands (1500 V); Belgium, Italy, Poland (3,000 V), and the cites of Mumbai and Chicago（which will be switched to AC by 2025).

Early locomotives came in a variety of forms. Generally, they were designed to run of the supplied current, so locomotives with a direct current (DC) supply had DC motors while alternating current (AC) supplied locomotives with AC motors. AC can be either single or three phases. While the former requires two wire supply, one overhead the other being the track, three phases requires three supply wires. Three phases locomotives therefore had two overhead supplies, the track being the third.

DC supplies were either overhead or by means of a track level supply, commonly called the third rail.

AC traction motors tended to be larger than DC motors. This often meant electric locomotives with steam engine type cranks. DC motors could be smaller and set up to drive the axles, usually through a gear, but in some early examples by being part of the axle. Even so, some notable DC electric locomotives had large DC motors driving large driving wheels.

One possibility with electric locomotives is that the motor can be used as a generator during braking, feeding electricity back into the supply system; this is called regenerative braking. This is not a new idea, it was one reason for the adoption by some railways of 3-phase AC supplies. Especially in mountainous areas where the locomotive going down would generate much of the supply for a locomotive going up. The Swiss railway uses this system; three modern locomotives heading downwards generate enough power to power a single locomotive upward journey.

Today all electric locomotives tend to have driven motors close to the axles, although still have the motor in the body driving the wheels through internal drive shafts.

Modern solid state electrical control systems means the motor does not need to match the supply. This means multi-voltage cross border locomotives are now quite common. Drive motors are generally DC, but there are 3 phase drive motors on some locomotives.

A small number of electric locomotives can also operate off battery power to enable short journeys or shutting to occur on non-electrified lines or yards. Pure battery locomotives also found usage in mines and other underground workings where diesel fumes or smoke are not safe and where external electricity supplies could not be used. Battery locomotives are also used on many underground railways for maintenance operations as they are required to operate in areas where the electricity supply has been temporarily disconnected.

7. Electro-Diesel Locomotive

These are special locomotives that can either operate as an electric locomotive or a diesel locomotive. Dual-mode diesel-electric/third-rail locomotives are operated by the Long Island Rail Road and Metro-North Railroad between non-electrified territory and New

York City because of a local law banning diesel-powered locomotives in Manhattan tunnels. For the same reason Amtrak operates a fleet of dual-mode locomotives in the New York area. British Rail operated dual diesel-electric/electric locomotives designed to run primarily as electric locomotives. This allowed railway yards to remain un-electrified as the third-rail power system is extremely hazardous in a yard area.

8. Magnetic Levitation Locomotive

The newest technology in trains is magnetic levitation (maglev). These electrically powered trains have a special open motor which floats the train above the rail without the need for wheels. This greatly reduces friction. Very few systems are in service and the cost is very high. The experimental Japanese magnetic levitation train has reached 552 km/h.

The first commercial maglev trains ran in the 1980s in Birmingham, United Kingdom, or providing a low-speed shuttle service between the airport and its railway station. Despite the huge interest and excitement in the technology it was abandoned and replaced by a cable-hauled guideway a few years later.

[Questions]

1. What are the main types of locomotive development process?
2. In addition to locomotive traction, what are the characteristics of rail transit transportation modes?